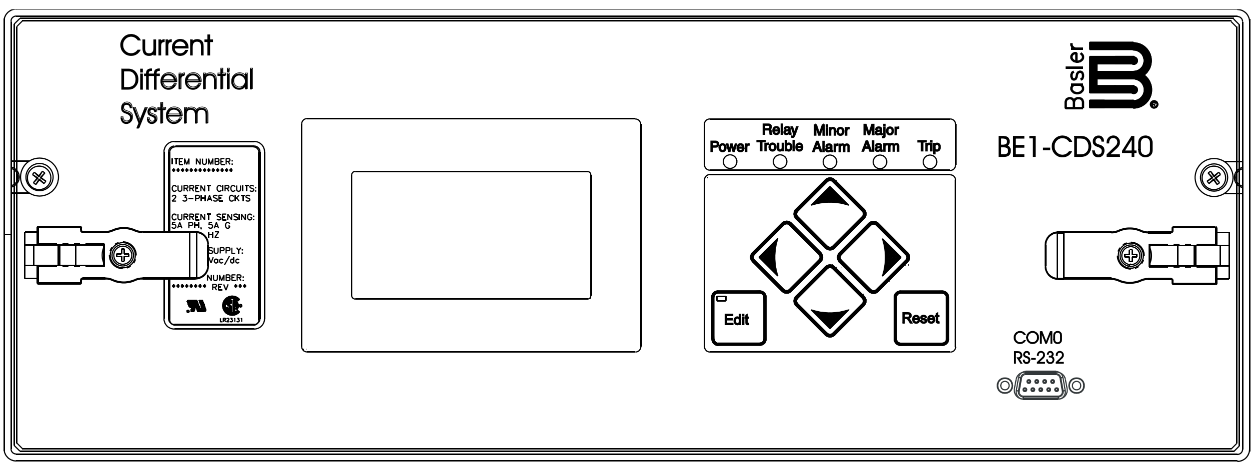
BE1-CDS240

Current Differential System

Instruction Manual



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Publication
9365200990, Rev P
January 2020

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INTRODUCTION

This instruction manual provides information about the operation and installation of the BE1-CDS240 Current Differential System. To accomplish this, the following information is provided:

- General information, specifications, and a *Quick Start* guide.
- Functional description and setting parameters for the input/output functions, protection and control functions, metering functions, and reporting and alarm functions.
- BESTlogic programmable logic design and programming.
- Documentation of the preprogrammed logic schemes and application tips.
- Description of security and user interface setup including ASCII communication and the human-machine interface (HMI).
- Installation procedures, dimension drawings, and connection diagrams.
- Description of the front panel HMI and the ASCII command interface with write access security procedures.
- A summary of setting, metering, reporting, control, and miscellaneous commands.
- Testing and maintenance procedures.
- Appendices contain time overcurrent characteristic curves, overexcitation (24) inverse time curves, terminal communication, and settings calculations assistance.

Optional instruction manuals for the BE1-CDS240 include:

- Distributed Network Protocol (DNP) (9365200991)
- Modbus® (9365200992).

WARNING!

To avoid personal injury or equipment damage, only qualified personnel should perform the procedures in this manual.

NOTE

Be sure that the relay is hard-wired to earth ground with no smaller than 12 AWG copper wire attached to the ground terminal on the rear of the unit case. When the relay is configured in a system with other devices, it is recommended to use a separate lead to the ground bus from each unit.

First Printing: March 2003

Printed in USA

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The English-language version of this manual serves as the only approved manual version.

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REVISION HISTORY

The following information provides a historical summary of the changes made to this instruction manual (9365200990), BESTCOMS™ software, application firmware, and hardware of the BE1-CDS240.

Manual Revision and Date	Change
P, 01/20	• Minor text edits throughout manual.
O	• This revision letter not used.
N2, 05/19	• Changed Prop 65 warning to generic version on back of cover page.
N1, 01/19	• Added Prop 65 warning on back of cover page.
N, 07/17	• Added caution box about nonvolatile memory in Section 7. • Removed GOST-R Certification from Section 1. • Minor text edits throughout manual.
M, 02/14	• Removed *Registration of Relay* from Section 12. • Added *Storage* statement in Section 14.
L, 07/12	• Clarified metering accuracy and temperature dependency values in Section 1. • Added Table 1-1, *Contact-Sensing Turn-On Voltages*. • Added Restraint Type setting for 87ND and 187ND in Section 4.
K, 07/11	• Changed all instances of SG-CTx ASCII command to SG-CTPx in Section 13. • Added Windows® 7 compatibility and removed Windows® 2000 compatibility in Section 14.
J, 01/11	• Added serial number to fault reports and sequence of events, replaced Figures 6-21 & 6-25 (*View/Download Relay Fault Files* screen), and updated Fault Summary Report Example in Section 6. • Added Figure 12-12 for horizontal case dimensions.
I	• This revision letter not used.
H, 10/09	• Added Harmonics and Ground 1 metering to Figure 5-1 and updated Figure 5-2. • Changed all instances of BESTWAVE to BESTWAVE*Plus*™.
G, 06/09	• Added Republic of Belarus Certification in Section 1. • Corrected 81 timing spec in Sections 1 and 13. • Added information about Date/Time Logging in Section 1. • Updated Figure 4-12, *87 Phase Tab,* and added information for new setting - % of Average / 2. • Updated Figure 6-2, *Clock Display Mode Tab,* and added information for new Date/Time Logging to SER Enable/Disable setting.
F, 12/08	• Added information to support Power Supply Option 3 (24 Vdc). • Added Power Flow Polarity setting for VTP Setup in Section 3. • Updated Contact Sensing Input ranges and burden data for re-designed contact sense circuit.
E, 03/08	• Added manual part number and revision to footers. • Added *Settings Compare* to the end of Section 6. • Added alternate DST (Daylight Saving Time) settings. • Updated terminal numbering in Figures 13-15, 13-16, 13-17, and 13-18.

Manual Revision and Date	Change
D, 10/06	• Added 59X (auxiliary) feature. • Added *IEC Transformer Setup* to Section 3. • Updated all BESTCOMS screen shots. • Updated Table 6-3, *Logic Variable Status Report Format,* with new logic bits for 59XPU and 59XT.
C, 03/04	• Enhanced the 24 feature. • Added virtual restraint. • Minor text edits.
B, 10/03	• Initial release

BESTCOMS™ Software Version and Date	Change
2.09.00, 03/15	• Added Windows 8 compatibility.
2.08.00, 06/12	• Added Restraint Type setting on 87ND/187ND settings screen.
2.07.02, 10/11	• Improved Settings Compare function. • Improved differential current metering.
2.07.01, 08/11	• Minor bug fixes.
2.07.00, 12/10	• Changed Nominal Frequency setting range from 50 or 60 Hz to 20-60 Hz on the *Power System / VT Setup* screen. • Added Windows 7 compatibility.
2.06.00, 07/09	• Added % of Average ÷ 2 setting on *Percentage Differential, 87 Phase* screen. • On *Reporting and Alarms, Clock Display Mode* screen, added Time/Date Logging to SER Enable/Disable setting for logging of time/date changes via Modbus™ or DNP. The default is disabled. • Added compensated current, second and fifth harmonic currents, to BESTCOMS metering. • Corrected Time Delay entry overflow errors. • Corrected 187ND Mode Labeling. • Improved routine for calculating the 87ND and 187ND taps with virtual circuits.
2.05.00, 12/08	• Added Power Supply Option 3 (24 Vdc) on *Style Number* screen on *General Info* tab. • Added Power Flow Polarity setting under *VTP Setup* on *Power System / VT Setup* tab.
2.04.07, 04/08	• Enhanced BESTCOMS error reporting.
2.04.06, 03/08	• Added the ability to turn off delta compensation for Yy0 connections. • Improved Settings Compare function.
2.04.05, 11/06	• Added 59X (auxiliary) function. • Added IEC transformer setup.
2.03.00, 03/04	• Enhanced overexcitation (24) function.
2.02.00, 09/03	• Initial release

Firmware Version and Date	Change
1.05.01, 03/15	• Improved settings upload.
1.05.00, 06/12	• Added Restraint Type setting for 87ND and 187ND elements.
1.04.06, 03/12	• Added Modbus register 41053 (Power Polarity).
1.04.05, 05/11	• Improved metering of phase angles.
1.04.04, 12/10	• Changed Nominal Frequency setting range from 50 or 60 Hz to 20-60. • Improved 2nd harmonic restraint pickup. • Added the serial number to the sequence of events and fault reports. • Improved 60FL alarm function. • Improved automatic scrolling on front panel. • Improved 87U target function. • Improved sequence of events in non-volatile memory.
1.04.02, 07/09	• Improved differential metering. • Improved DNP response time. • Added % of Average ÷ 2 setting for 87 function. • Added Time/Date Logging to SER Enable/Disable setting for logging of time/date changes via Modbus™ or DNP. The default is disabled. • Corrected ASCII command's metering label for CT CKT 3 when set to DAC. • Corrected metering labels for currents on the HMI. • Enhanced the 81 Inhibit so it responds to 3-wire mode. • DSP firmware file incorporated into the application HEX file.
App: 1.04.00, 12/08 DSP: 1.03.02, 12/08	• Added Power Flow Polarity setting for VTP Setup.
App: 1.03.02, 03/08 DSP: 1.03.01, 11/06	• Increased immunity to noise on IRIG input. • Improved breaker fail targeting. • Improved x62 timer when changing settings group.
App: 1.03.00, 09/06 DSP: 1.03.01, 11/06	• Added 59X (auxiliary) element. • Added 180° compensation parameter for the 87T function. • Enhanced 60FL functionality.
App: 1.02.01, 02/04 DSP: 1.02.01, 01/04	• Enhanced overexcitation (24) function. • Added virtual restraint feature. • Relocated logic bits for 62, 162, 262, and 362. • Added separate logic bits for 2nd Harmonic A, B, and C. • Added separate logic bits for 5th Harmonic A, B, and C.
App: 1.01.05, 09/03 DSP: 1.01.00, 06/03	• Initial release

Hardware Revision and Date	Change
AE, 12/16	• Updated engineering documents.
AD, 08/14	• Improved current transformers.
AC, 01/13	• Improved current transformers.
AB, 08/12	• Released firmware version 1.05.00 and BESTCOMS version 2.08.00.
AA, 05/11	• Released firmware version 1.04.05.

Hardware Revision and Date	Change
Z, 12/10	• Released firmware version 1.04.04 and BESTCOMS version 2.07.00.
Y, 03/10	• Updated engineering documents.
X, 12/09	• Basler color/font standardization.
W, 07/09	• Released firmware version 1.04.02 and BESTCOMS version 2.06.00.
V, 12/08	• Released firmware version 1.04.00 and BESTCOMS version 2.05.00.
U, 09/08	• EEPROM replacement.
T, 04/08	• Released BESTCOMS version 2.04.07.
S, 04/08	• Improved response time of contact sense inputs.
R, 03/08	• Released firmware version 1.03.02 and BESTCOMS version 2.04.06.
Q, 10/06	• Released firmware version 1.03.00 and BESTCOMS version 2.04.05.
N, 08/05	• Released firmware version 1.02.00.
M, 11/04	• Improved overlay to fit front panel.
L, 03/04	• Minor changes to enhance production efficiency.
K, 02/04	• Increased the size of the insertion/extraction lever in order to allow the relay to be inserted/removed from the case more easily.
J, 12/03	• Changed from surface mount to through hole connectors on I/O board.
H, 10/03	• Relocated slots on top cover.
G, 10/03	• Minor changes to enhance production efficiency.
F, 10/03	• Initial release

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SECTION 1 • GENERAL INFORMATION

Introduction

The BE1-CDS240 Current Differential System is an economical, microprocessor based, multifunction system that provides a four input, three-phase percentage differential with harmonic restraint protection. Also included is three-phase with voltage control, ground, and negative-sequence overcurrent protection, voltage and frequency protection, breaker failure for up to four breakers, breaker monitoring for four breakers, transformer monitoring, and metering functions, all in an integrated system with several communications options. The BE1-CDS240 Current Differential System is intended for use in any low impedance current differential protection application including transformer, generator, motor, and bus protection. Four setting groups are provided for adaptive relaying with automatic selection logic for cold load pickup and/or dynamic setting group changes.

The BE1-CDS240 can be ordered with 12 programmable contact sensing inputs, 10 programmable outputs, and one alarm output or eight programmable contact-sensing inputs, 14 programmable outputs and one alarm output. Outputs can be assigned various functions by logical programming to perform protection, control, or indicate operations. For example, protection functions can cause a protective trip operation. Control functions can cause a manual trip, manual close, or automatic reclose operation. Indicators could be relay alarm, setting group one enable, setting group two enable and others.

Protection scheme designers may select from an embedded pre-programmed logic scheme or from a number of logic library schemes found in BESTCOMS™ to perform the most common protection and control requirements or create a custom scheme using BESTlogic.

The BE1-CDS240 is available in a fully draw-out MX case with configurations for horizontal 19" rack mounting, horizontal panel mounting and vertical panel mounting. BE1-CDS240 features include:

- Up to four restraint inputs (four three-phase current circuits) and two virtual current circuits that can be used with any combination of two current inputs
- Independent ground input
- Three voltage inputs (Va, Vb, Vc, to Vn)
- Three-phase percentage differential protection with harmonic restraint
- Three-phase voltage, frequency and overcurrent protection
- Four setting groups
- One embedded preprogrammed logic scheme
- Fourteen or 10 programmable outputs
- Eight or 12 contact sensing inputs
- Breaker failure protection for four breakers
- Front panel HMI (human-machine interface)
- Communications ports: one front RS-232, one rear RS-232, one rear RS-485 and one rear IRIG port
- Communications protocols available: DNP3, Modbus® RTU, and ASCII
- Sequence of events recording
- Fault recording
- Oscillography
- Demand reporting
- Differential current monitoring
- Optional load profile reporting

Section 2, *Quick Start*, provides BE1-CDS240 Current Differential System users with a simplified, "How To Get Started" procedure.

Features

The BE1-CDS240 includes many features for the protection, monitoring, and control of power system equipment such as transformers, breakers, buses, generators, and motors. These features include protection and control functions, metering functions, reporting and alarm functions, and various communication options. A highly flexible programmable logic system called BESTlogic allows the user to apply the available functions with complete flexibility and customize the system to meet the requirements of the protected power system. Programmable I/O, extensive communications features, and an advanced HMI (human machine interface) provide easy access to the features provided. Through BESTCOMS software, BE1-CDS240 users with personal computers (PCs) have another easy-access means to communicate, program, control, and monitor relay/system performance. BESTCOMS is a Windows® (based software application that enhances communication between the PC user and the BE1-CDS240 relay. This software is provided free with every BE1-CDS240 relay. Another software application tool is BESTWAVE. BESTWAVE is a utility program to view standard COMTRADE (Common Format for Transient Data Exchange) files like those recorded by Basler Electric multifunction relays.

The following information summarizes the features included in this multifunction device. The organization of this information outlines the organization for the rest of the manual. Each feature, along with how to set it up and how to use the outputs is described in complete detail in the later sections of this manual.

I/O Functions

Power System Measurement Functions

- The BE1-CDS240 has four sets of three-phase currents that are digitally sampled and digitally filtered. The fundamental, second, and fifth harmonics are extracted using a Discrete Fourier Transform (DFT) algorithm for use by all of the current based functions.
- Neutral (residual) and negative-sequence current magnitudes are calculated from each set of three-phase currents.
- Each set of three-phase currents can be phase-shifted and tap compensated for use in transformer differential applications.
- Each three-phase current source can have its polarity reversed in the relay, which simplifies the commissioning process in the event polarity of a CT circuit is rolled.
- The digital sampling rate tracks the measured frequency to provide high accuracy at frequencies other than nominal frequency to make this relay ideally suited for applications such as generator, motor and generator step-up transformer differential protection.
- An independent ground current input (IG) measures the current in a transformer neutral, tertiary winding or a flux balancing CT and is used for providing ground differential protection.
- Each current circuit is low burden and isolated to allow for more effective zoning with fewer costly CTs.
- Three-phase voltage inputs are digitally sampled and the fundamental frequency is extracted using a Discrete Fourier Transform (DFT) algorithm. Voltage sensing circuits can be configured for single-phase, three wire or four wire voltage transformer circuits.
  Voltage sensing circuitry provides voltage protection, frequency protection, and watt/var metering. Neutral (residual), positive, negative, and zero sequence voltage magnitudes are calculated from the three-phase voltages.

Contact Sensing Inputs

- Eight (I/O option E) or 12 (I/O option A) programmable contact sensing inputs with programmable signal conditioning provide binary logic interface to the protection and control system.
- The function of each input is programmable using BESTlogic and can be given a user meaningful name for the variable and for each state (open and closed) for use in reporting functions.
- The threshold voltage is adjustable. See Section 12, *Installation, Contact Sensing Input Jumpers*.

Contact Outputs

- Fourteen (I/O option E) or 10 (I/O option A) programmable contact outputs provide a binary logic interface to the protection and control system (OUT1 through 14). OUTA is dedicated to critical alarms.
- OUT1 and 2 are dedicated form “c” contacts. The remainders are “a” contacts. Outputs 7, 8, 9, 10 are dedicated to trip coil monitoring for up to 4 breakers. However, board level jumpers are supplied so that the user can disable the TCM circuit and allocate the output contact to any virtual output. Refer to Section 12, *Installation, Trip Coil Monitor (TCM) Jumpers*.
- Each output is programmable using BESTlogic (assign any virtual output to any physical output relay) and can be given a user meaningful name for the variable and for each state (open and closed) for use in reporting functions.

- Output logic can be overridden to open, close or pulse each output contact for testing, or control purposes.

Protection and Control Functions

Setting Groups

- Four (4) settings groups allow adaptive relaying to be implemented to optimize the relay settings for various operating conditions.
- Automatic and external logic can be employed to select the active setting group.

Differential Protection

- Three-phase percentage restrained differential protection with harmonic restraint: 87. Protection can be set to monitor two, three, or four windings. Unused inputs can be used for overcurrent protection.
- Two restricted earth fault ground differential protection elements with independent ground (IG) input (and C-phase, IG2, of Current Circuit 4): 87ND and 187ND.
- Tap compensation for the differential protection can be automatically calculated by the relay based upon user settings of CT ratio, MVA and kV base values.
- Ground differential between calculated residual of any winding and the phase C current input of a fourth and unused winding (IG2).
- Each winding can be independently set for a phase relationship (relative to winding 1) of 0 to 360 degrees in steps of 30 degrees.
- Each winding can be set for IEC standard transformer connections.

Overcurrent Protection

- Instantaneous overcurrent with settable time delay for each operating quantity (A, B, C, N (using IN or IG) and Q. Eight (8) sets Phase, Five (5) sets Neutral, Four (4) sets Negative-Sequence. Each function is individually assignable to any of the current input circuits. Functions are: 50TP, 150TP, 250TP, 350TP, 450TP, 550TP, 650TP, 750TP, 50TN, 150TN, 250TN, 350TN, 450TN, 50TQ, 150TQ, 250TQ, and 350TQ.
- Inverse time overcurrent functions with integrating or instantaneous reset. Four (4) for Phase, five (5) for Neutral, and four (4) for Negative-Sequence. Each function is individually assignable to any of the current input circuits. Functions are 51TP, 151TP, 251TP, 351TP, 51TN, 151TN, 251TN, 351TN, 451TN, 51TQ, 151TQ, 251TQ, and 351TQ.
- Time overcurrent functions employ a dynamic integrating timing algorithm covering a range from pickup to 40 times pickup with selectable instantaneous or integrated reset characteristics.
- Time overcurrent curves conform to IEEE PC37.112 and include seven curves similar to Westinghouse/ABB CO curves, five curves similar to GE IAC curves, four IEC curves, a fixed time curve, and a user programmable curve.
- Digital signal processing filters out unwanted harmonic components while providing fast overcurrent response with limited transient overreach and overtravel.

Voltage Protection

- Voltage control or restraint for 51P (51V protection)
- One (1) volts per hertz protective element (24) provides overexcitation protection for a generator and/or transformer.
- Two phase (2) undervoltage elements, 27P and 127P, provide phase undervoltage protection.
- Two phase (2) overvoltage elements, 59 and 159, provide phase overvoltage protection.
- One (1) negative-sequence overvoltage element (47) provides protection for phase unbalance or a reverse system phase-sequence.
- One (1) zero sequence overvoltage element (59X) provides protection for ground faults on ungrounded systems using calculated 3VO.

Frequency Protection

- Six (6) over/underfrequency protection elements are provided: 81, 181, 281, 381, 481, and 581.

Fuse Loss Protection

- A fuse loss function, 60FL, protects against false tripping due to a loss of voltage sensing.

Breaker Failure Protection

- Four (4) breaker failure protection function blocks are assignable to any of the current input circuits: 50BF, 150BF, 250BF, and 350BF.
- The current circuit assigned to the breaker failure function block also determines which current circuit is used by the breaker monitoring functions described later.

General Purpose Logic Timers

- Four (4) general-purpose logic timers with six modes of operation: 62, 162, 262, and 362.

Virtual Control Switches

- Four (4) virtual breaker control switch, accessible locally from the HMI or remotely from the communications ports can be used to provide trip and close control of a selected breaker: 101, 101A, 101B, and 101C.
- The breaker label provided for the breaker monitoring function is used to label the virtual breaker control switch. This makes it easily discernible which breaker is being controlled as up to four (4) breakers can be controlled.
- Eight virtual switches with three modes of operation, accessible locally from the HMI or remotely from the communications ports. Switches can be used to provide additional control: for example, to trip and close additional switches or breakers, or to enable and disable certain functions: 43, 143, 243, 343, 443, 543, 643, and 743.

Metering Functions

- Metering, including magnitude and angle, is provided for all measured phase and neutral voltage and currents and all derived positive, neutral, and negative-sequence voltage and currents. Power factor, frequency, watts, vars, and demands are also provided.
- Metering, including magnitude and angle, is also provided for the phase and tap compensated restraint, second and fifth harmonic, and differential currents.

Reporting and Alarm Functions

Relay Identification

- The relay includes four 30-character, free-form fields for the user to enter information to identify the relay. Examples would be station name, circuit number, relay system, purchase order, etc. These fields are used by many of the reporting functions to identify which relay created the report.

Clock

- A real-time clock is included with a capacitor backup that will keep time upon loss of power for 8 to 24 hours depending upon conditions. Optional battery backup maintains time keeping for an extended period.
- A standard IRIG input (format B002 from IRIG Standard 200-98) is provided for receiving time synchronism signals from a master clock.
- The time and date reporting format is settable for 12 or 24-hour format and for mm/dd/yy or dd/mm/yy format.
- Automatic daylight savings time adjustment can be enabled.
- Recording of time or date changes made via Modbus or DNP to the sequence of events can be enabled.

General Status Reporting

- The relay has extensive capability to report its general status for monitoring, commissioning, and troubleshooting.
- Status reports are available from the HMI or the communications ports.

Demand Reporting

- Ampere demand registers are provided for monitoring A, B, C, N, and Q. These registers are assignable to any of the current input circuits.
- The demand interval and demand calculation method is separately settable for phase, neutral and negative-sequence measurements.

- The demand reporting function records today's peak, yesterday's peak, and peak since reset, with time stamps for each register.
- An optional 4,000-point data array can record over 40 days of 15-minute demand data.

Differential Current Monitoring

- A detailed current check record can be requested from the relay to aid in initial in-service readings to verify correct phase and tap compensation of the differential currents. This report can be stored with commissioning records to save time during initial check out.
- Once in service, the mismatch in the differential function is continuously monitored and can provide an alarm if the mismatch is approaching a trip condition due to loading current. A current check record is generated when this occurs and the diagnostic function will indicated the possible source of the mismatch: for example, incorrect or missing phase compensation.

Transformer Monitoring

- Transformer through-fault duty statistics are recorded including number of through faults, accumulated through-fault (It or I2t), and maximum through-fault (It or I2t). The through-fault current measurement is assignable to any of the current input circuits.
- Each of these conditions can be set to alarm.

Breaker Monitoring

- Breaker statistics are recorded for up to four breakers. They include the number of operations, fault current accumulation duty and breaker time to trip. This function is associated with the current input circuit assigned to the breaker failure function block.
- Each of these conditions can be set to alarm.

Trip Circuit Monitoring

- Four trip circuit monitor functions are provided to monitor the trip circuit of a breaker or lockout relay for loss of voltage (fuse blown) or loss of continuity (trip coil open).
- Each of the four TCMs can be disabled with a circuit board jumper allowing the associated output to operate the same as the other outputs.

Fault Reporting

- Fault reports consist of simple target information, fault summary reports, and detailed oscillography records to enable the user to retrieve information about disturbances in as much detail as is desired.
- Oscillography memory can be partitioned into 6 to 16 records and all data is stored in non-volatile memory.
- The relay records and reports oscillography data in industry standard IEEE, COMTRADE format to allow using any fault analysis software.

Sequence Of Events Recorder

- A 255-event sequence of events recorder (SER) is provided that records and time stamps all inputs and outputs to the relay as well as all alarm conditions monitored by the relay. Time stamps are to the nearest quarter cycle resolution. All records are stored in non-volatile memory.
- I/O and Alarm reports can be extracted from the records as well as reports of events recorded during the time span associated with a specific fault report.

Alarm Function

- The relay includes extensive self-diagnostics. Fatal relay trouble alarms are not programmable and are dedicated to the alarm output (OUTA) and the relay trouble LED on the front of the relay.
- Additional relay trouble alarms and all other alarm functions are programmable for major or minor priority. Programmed alarms are indicated by major and minor alarm LEDs on the front of the relay. The major and minor alarm points can also be programmed to any output contact including OUTA.
- The HMI provides local annunciation of programmed alarm conditions.
- Active alarms can be read and reset from the optional HMI or from the communications ports.
- Seventy (70) alarm conditions are available to be monitored including user definable logic conditions using BESTlogic.

Version Report

- The version of the embedded software (firmware) is available from the front panel interface HMI or the communications ports.
- The unit serial number and style number is also available from the communications ports.

BESTlogic Programmable Logic

- Each of the protection and control functions in the BE1-CDS240 is implemented in an independent function that is equivalent to its single function, discrete device counterpart so that it is immediately familiar to the protection engineer. Each independent function block has all of the inputs and outputs that the discrete component counterpart might have.
  Programming BESTlogic is equivalent to choosing the devices required by your protection and control scheme and drawing schematic diagrams to connect the inputs and outputs to obtain the desired operational logic.
- One preprogrammed embedded logic scheme (in the relay firmware) and a library of preprogrammed logic schemes in BESTCOMS are provided and thoroughly documented in Section 8, *Applications*. To set the relay to one of the BESTCOMS library applications, simply select the logic scheme and upload it to the relay.
- A set of custom logic settings is also available for you to optimize the functionality to the specific needs of your operation's practices and power system requirements.

Security

- Security can be defined for three distinct functional access areas: Settings, Reports, and Control. Each functional access area can be assigned a password. A global password provides access to all three functional areas. Each of these four passwords can be unique or multiple functional access areas can have the same password.
- Allowing the user to restrict access to any of the three functional access areas from only specific communication ports provides a second dimension of security. For example, you could set security to deny access to control commands from the rear RS-232 port that is connected through a modem to a telephone line.
- Security settings only affect write access. You have read access from any port to any area.

Human-Machine Interface

- Each BE1-CDS240 comes with a front panel display with LED (light emitting diode) indicators for power, relay trouble alarm, minor alarm, major alarm, and trip. Each BE1-CDS240 also comes with the software application program BESTCOMS for the CDS240. This program is a user friendly, Windows based program that makes relay setup and support very easy.
- The programmable graphical LCD (liquid crystal display) allows the relay to replace local indication and control functions such as panel metering, alarm annunciation, and control switches.
- The human-machine interface (HMI) is set up in a menu tree with four scrolling buttons for navigation. *Edit* and *Reset* pushbuttons provide access to change parameters and reset targets, alarms and other registers. Scrolling buttons are used for data entry when in edit mode. Edit mode is indicated by an LED on the *Edit* button.
- The LCD has automatic priority logic to govern what is being displayed on the screen so that when an operator approaches, the information of most interest is automatically displayed without having to navigate the menu structure. The priorities are targets, then alarms and then the programmable automatic scrolling list.
- Up to 16 screens can be defined in the programmable, automatic scroll list.

ASCII Command Interface

- Three (3) independent, isolated communications ports provide access to all functions in the relay. Com 0 is a 9-pin RS-232 port located on the front of the case. Com 1 is a 9-pin RS-232 port located on the back of the case. Com 2 is a three-terminal, RS-485 port located on the back of the case.
- Standard communications is an ASCII command interface to allow easy interaction with the relay using standard, off the shelf, communications software.
- The ASCII command interface is optimized to allow automating the procedure for setting the relay by allowing settings files to be captured from the relay and edited using any software that supports

*.txt file format. These ASCII *.txt files can then be used to set the relay using the send text file function of the communications software.

- Modbus and other common protocols are optionally available for the RS-485 communications port. A separate instruction manual appropriate for the protocol comes with each unit. Consult the product bulletin or the factory for availability of these options and instruction manuals.

Installation

- The BE1-CDS240 is available in two, fully draw-out, case styles; MX vertical can be mounted as an M1, M2, FT31, or an FT32. MX horizontal units can be panel mounted or 19" rack mounted.
- Relay terminals are clearly marked on the rear panel.

Testing and Maintenance

- Four (4) testing methods are covered in this manual: acceptance testing, commissioning testing, periodic testing, and functional testing.
- The relay also provides a virtual testing function that allows the user to isolate a portion of the logic program and test it by using a set of switches.

BESTCOMS™ Software

- BE1-CDS240 BESTCOMS is a 32-bit Windows based graphical user interface (GUI). It provides the user with point-and-click capability for applying settings to the relay. This facilitates setting the relay by eliminating the need for the user to be thoroughly knowledgeable of the ASCII commands associated with the relay settings.

Primary Applications

The BE1-CDS240 Current Differential System provides percentage restrained differential protection along with multiple overcurrent elements and is intended for use in any low impedance current differential protection application including transformer, generator, motor, reactor, and bus protection. Its unique capabilities make it ideally suited for applications with the following requirements.

- Applications that require low burden to extend the linear range of CTs.
- Applications where dedicated CTs for the differential are not available. Unlike traditional differential relays, dedicated CT circuits are not required because each CT input is isolated from the others and phase shift compensation can be accomplished internally.
- Applications that require high accuracy across a wide frequency range such as motor, generator, and generator step-up transformer protection or in co-generation facilities.
- Applications that require the flexibility provided by wide settings ranges, multiple setting groups and multiple coordination curves in one unit.
- Applications that require the economy and space savings provided by a multifunction, multi-phase unit. This one unit can provide all of the protection, as well as, the local and remote indication, metering and control required on a typical circuit.
- Applications that require harmonic restraint to aid security for the differential.
- Applications that require communication capability and protocol support.
- Applications where the optional case configurations facilitate modernizing protection and control systems in existing substations.
- Applications where the capabilities of a digital multifunction relay are required, yet draw-out construction is also desirable.
- Applications where bus protection is provided by a high-speed overcurrent-blocking scheme on the transformer bus mains instead of dedicated bus differential circuit.
- Applications where the capabilities of intelligent electronic devices (IEDs) are used to decrease relay and equipment maintenance costs.

Differential Protection Application Considerations

The principle of current differential relaying is simple in concept. Measure the current flowing into the protected zone and the current flowing out of the protected zone. These should match exactly (sum to zero). If they do not, there is a fault within the protected zone. The mismatch in current that results from the instantaneous summation of the currents into and out of the zone of protection is called the differential current or the operate current. While the concept is simple, several difficulties present challenges to the application of this type of protection. The BE1-CDS240 Current Differential System provides several features that allow it to easily address these complications and enable it to be used in all differential applications including transformer protection.

Problem 1: False Differential Current Due to Poor CT Performance

General

The principle of current differential relaying requires accurate measurement of the currents entering and exiting the zone of protection. During fault conditions where high current is flowing through the zone of protection, a CT may saturate and not faithfully reproduce the current flowing in the primary system. This will cause a false differential current to be seen by the differential relay.

BE1-CDS240 Solution

The percentage restrained differential characteristic, shown in Figure 1-1, is applied in this application. The differential current required to cause a trip is a percentage of the restraint current. The restraint current is a measure of the current flowing into or through the zone of protection. Thus for higher levels of restraint current, where the CTs may be subject to saturation, higher levels of differential current must be seen to cause a trip. The percentage restraint is often called the slope characteristic.

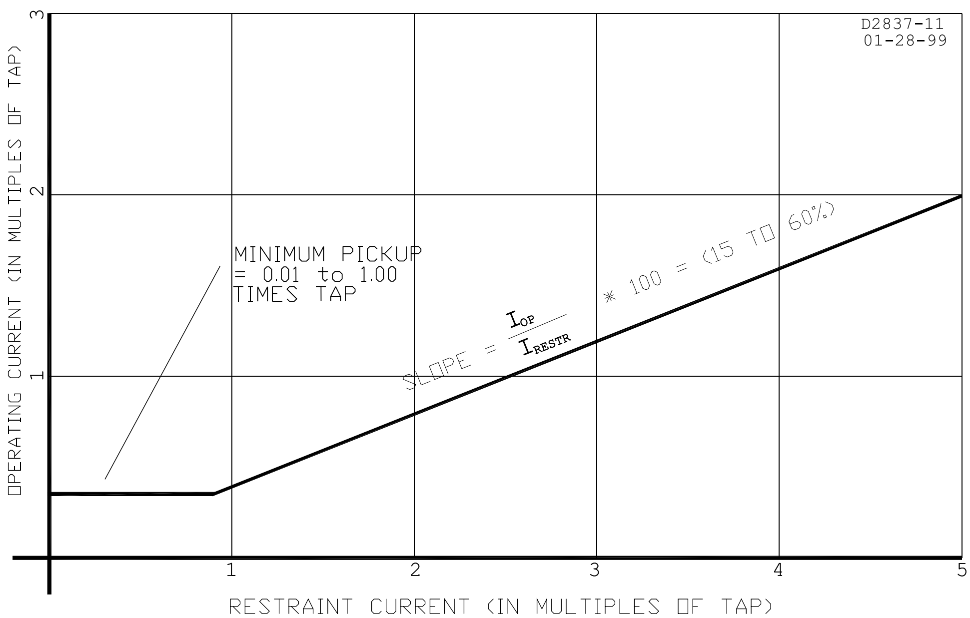


Figure 1-1. Restrained Differential Characteristic

The BE1-CDS240 relay has two settable restraint current calculation methods: average and maximum. Average restraint emulates the operating characteristics of common electromechanical relays. Maximum restraint is recommended because it uses the current from the best performing CT to determine the restraint to use during a fault condition. In addition, digital technology provides a transient monitor function that enables the BE1-CDS240 relay to detect the onset of CT saturation to ride through the condition to further enhance security from misoperation caused by poorly performing CTs.

Finally, Basler Electric addresses the source of false differential current at its roots. Active CT technology used on the current inputs provides low burden to extend the linear range of power system CTs and wide dynamic range to reduce measurement errors at high current levels. Sixteen bit ADC performance and digital anti-aliasing filters also contribute to minimizing magnitude and angle measurement errors.

Problem 2: Measured Current Magnitude Mismatch

General

The currents measured by each set of current inputs can be transformed from their primary values by different CT ratios. This is illustrated in Figure 1-2. When the zone of protection includes a transformer, there is another source of magnitude mismatch that must be accounted for. The primary currents that the differential relay must monitor will be on different voltage bases in most cases. This is due to the transformer action; the current on each side of the transformer is transformed by the inverse of the voltage transformation ratio. This is illustrated in Figure 1-3.

BE1-CDS240 Solution

The BE1-CDS240 relay applies a tap adjustment factor to the measured currents to cancel the effect of dissimilar CT ratio and voltage bases by converting the currents to per unit quantities on a common base. The tap-adjusted currents are used by the percentage restrained differential protection functions to determine the restraint and differential currents. Thus, the mismatch in magnitudes under normal balanced conditions is eliminated. The tap adjustment factor can be manually entered or automatically calculated by the relay using parameters entered for each CT input circuit and for the differential tap settings.

The setup parameters for each of the current input circuits are described in Section 3, *Input and Output Functions, Power System Inputs*. The CT ratio is included to allow the currents to be metered, displayed, and reported in primary values. The CT ratio is also used as a parameter for the automatic tap calculation feature.

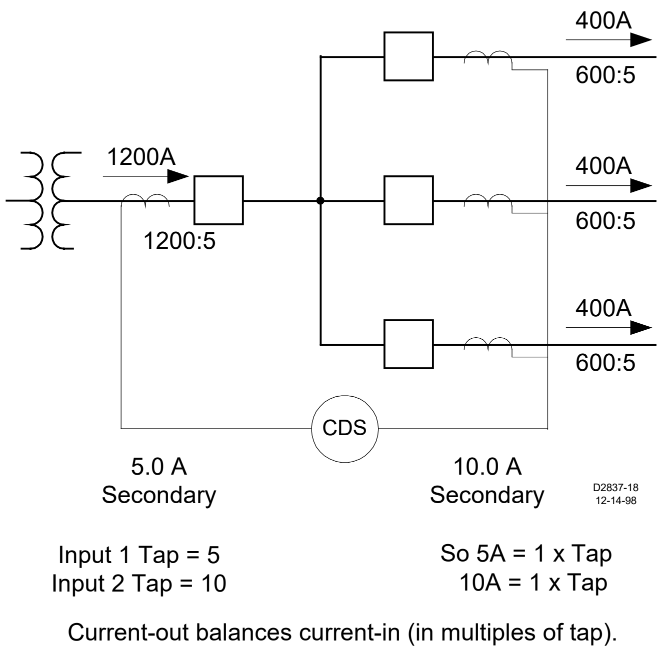


Figure 1-2. Tap Adjust for Mismatch

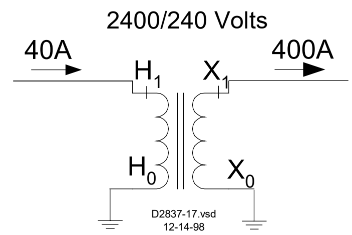


Figure 1-3. Currents on Different Voltage Bases

The setup parameters for the tap adjustment factor are described in Section 4, *Protection and Control, Differential Protection*. The user can enter the megavolt ampere (MVA) base for the application and the kilovolt (kV) base for each current input and the relay will automatically calculate the taps using these settings and the settings for each current input circuit. Alternatively, the user can enter the taps directly for each CT input.

Problem 3: Mismatch Caused by Load Tap Changers

General

The voltage transformation ratio (and thus the current transformation ratio) of a transformer within the zone of the differential can be adjusted in service by typically ±10% with the use of load tap changers. The tap adjustment factors can be used to eliminate the mismatch when the tap changer is at neutral. But, when the tap changer is off of neutral, differential current will be measured.

BE1-CDS240 Solution

The percentage restraint characteristic of the differential function mentioned previously allows the relay to accommodate a prescribed amount of mismatch. The differential current must exceed a percentage of the through current as described by the slope characteristic setting of the differential protection function. Also, the relay has four setting groups to allow the tap settings and other parameters to be changed dynamically based upon operating conditions.

Problem 4: Phase Angle Shift

General

When differential protection is used in a transformer application, the transformer often introduces a phase shift between the various current inputs to the zone of protection. An example is a transformer with a delta-connected high side and a wye-connected low side as shown in Figure 1-4, Illustration A. The currents in the phases connected to the delta side of the transformer are each made up of the combination of the current flowing in two legs of the delta winding. On the other hand, the currents in the phases connected to the wye side of the transformer are made up of the current in only one leg of the wye winding. It can be seen that the primary currents flowing into the zone of protection when tap is adjusted for magnitude mismatch still do not sum to zero as shown in Figure 1-4, Illustrations B and C.

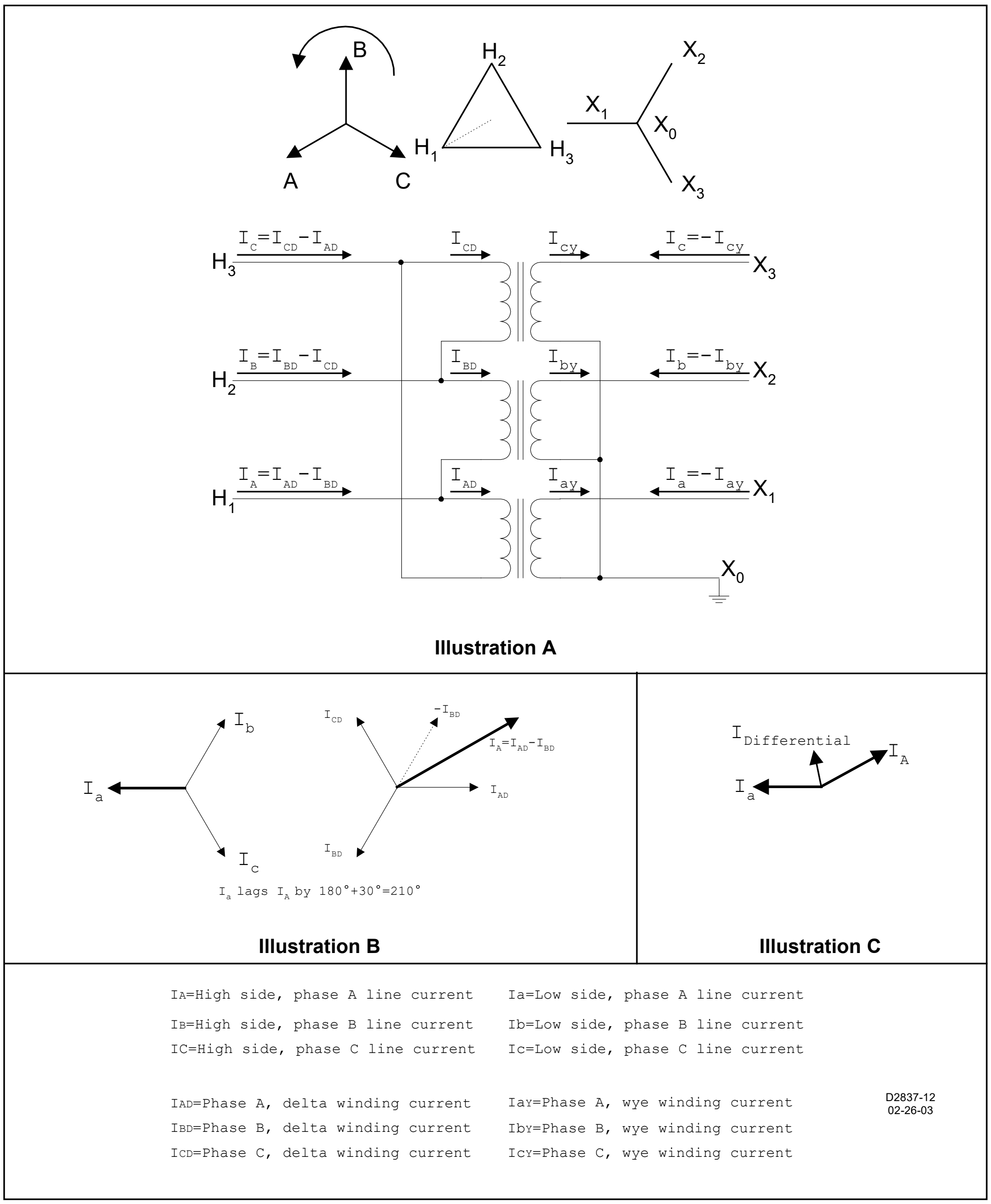


Figure 1-4. Delta/Wye Transformer Circuits

BE1-CDS240 Solution

The input currents must be combined to mimic the way they are combined in the protected power transformer so that the currents presented to the differential protection are made up of the same components. Traditionally, this has been done by special connection of the CTs. Figure 1-5 shows the transformer from Figure 1-4 with the CTs connected. The wye-side CTs can be connected in delta such that the differential protection is summing IA with Ia-Ib. The resulting two currents being seen by the differential relay are now made up of the same components but exactly 180 out of phase with each other. They will always sum to zero (after tap adjust for magnitude mismatch) under all conditions of balance or unbalance except when there is a fault inside the zone of protection.

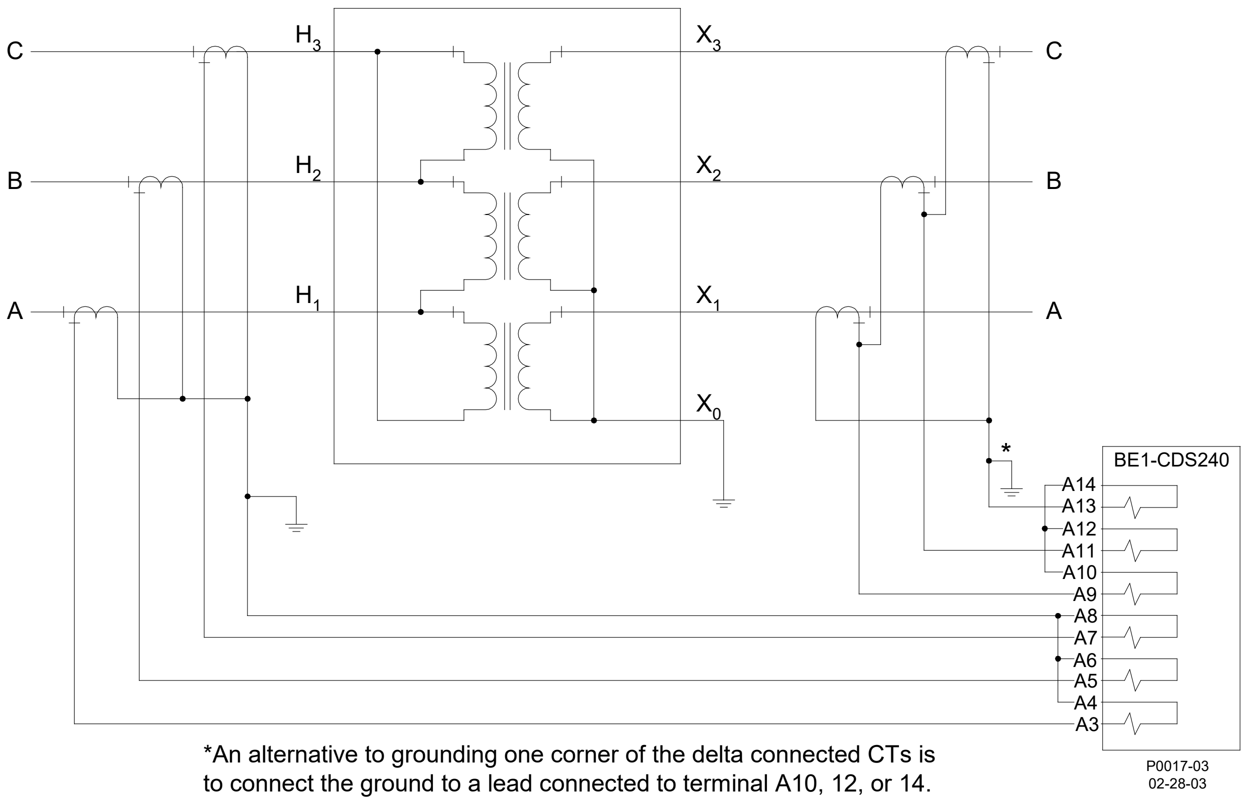


Figure 1-5. Three-Phase Connections, Delta-Wye Configuration, CT Compensation

There are several drawbacks to the traditional solution:

- The delta connection requires a dedicated set of CTs that generally cannot be used for other purposes.
- The delta connection is more difficult to test.
- The delta-connected CTs experience greater burden than wye-connected CTs because the lead burden must be multiplied by a factor of three in the CT performance calculation.

The BE1-CDS240 relays support the traditional solution so that they may be used in retrofit/modernization projects. However, in a numerical relay, it is possible to connect all of the CTs in wye as shown in Figure 1-6 so that the drawbacks mentioned above are not a consideration. The BE1-CDS240 relay can numerically combine currents internally to accomplish a numerical delta if required for phase angle compensation.

The setup parameters for each of the current input circuits are described in Section 3, *Input and Output Functions, Power System Inputs*. The CT connection and the transformer connection are included to allow the BE1-CDS240 relay to automatically determine the appropriate combination of currents to present to the differential protection function.

> **NOTE**
>
> The BE1-CDS240 relay uses transformer internal connection information to determine the correct phase compensation to use. It is not possible to reliably determine the phase compensation settings based simply upon phase angle shift information because the phase shift from high to low side is dependent upon the phase-sequence of the power system phasors. That is, a power system with ABC phase-sequence will produce a different phase shift from high to low than a power system with ACB phase-sequence in the same transformer connection. By specifying the transformer connections from the three-line diagram, the correct phase compensation can be determined in all cases.

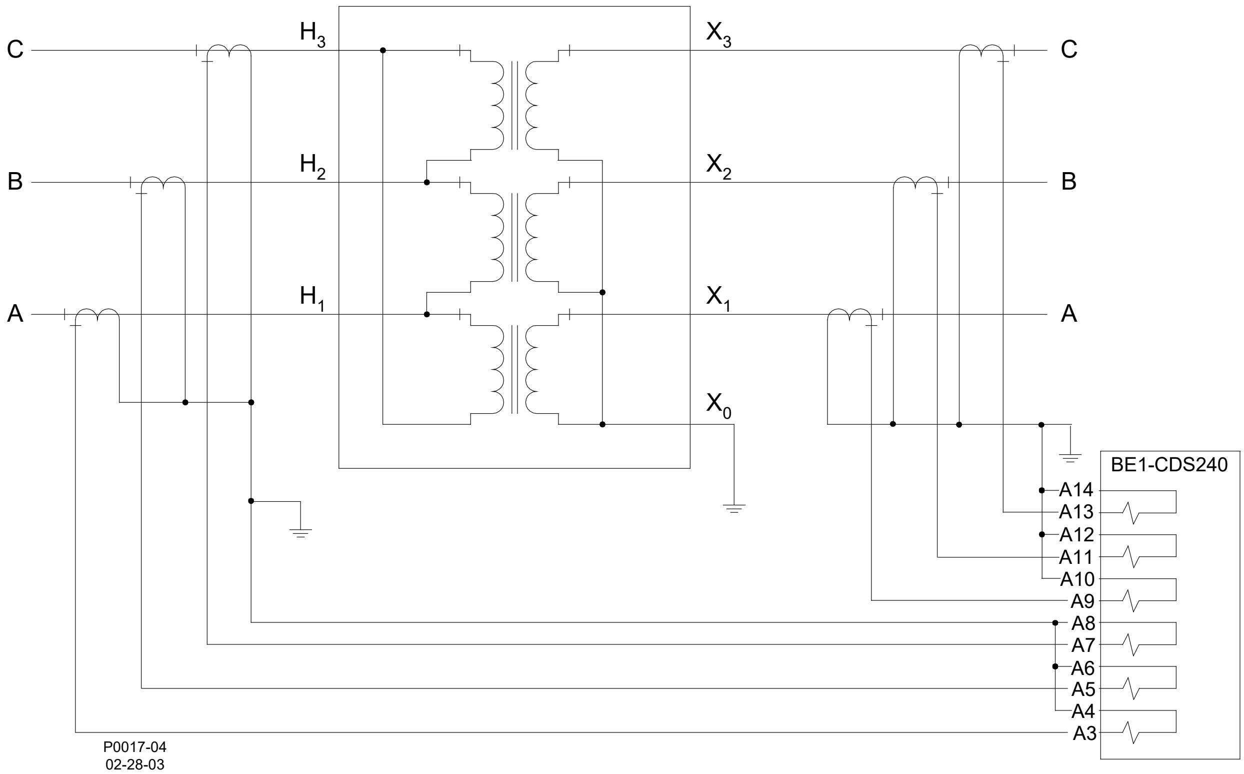


Figure 1-6. Three-Phase Connections, Delta-Wye Configuration, Internal Phase Compensation

Problem 5: Zero-Sequence Current Sources Within the Zone of Protection

General

A ground source (grounded transformer winding or zigzag grounding bank) within the zone of protection can result in differential current being measured during ground imbalances. The most common example of this is when the zone of protection is around a delta/grounded, wye transformer. If a ground fault or neutral imbalance occurs on the power system external to the wye side zone of protection, the zero-sequence components of the current flow through the grounded neutral and are a component of the current flowing out of the zone of protection. On the delta side, there is no path for the zero-sequence components to flow and they circulate inside the delta winding. The result is that this component of the current is not seen entering the zone of protection on the delta side resulting in a differential current that can cause the relay to operate.

BE1-CDS240 Solution

There are two traditional solutions to this problem. The first is using delta phase-shift compensation on the grounded side of the zone of protection to block the zero-sequence components from getting to the differential protection. The second is removing the zero-sequence components from the currents using a zero-sequence trap to prevent them from getting to the differential protection. The BE1-CDS240 provides both solutions.

In the previous discussion on compensating for the phase shift on the primary system, the solution is to combine the currents such that the currents seen by the differential are made up of the same components at all terminals of the zone of protection. This solution has the added benefit of causing the currents to match (after magnitude mismatch is eliminated by tap adjustment) under all situations of imbalance including ground faults. That is, by using delta compensation on the wye side of the power transformer to mimic the power transformer's delta connection, the zero-sequence currents are blocked from flowing to the differential protection and circulate in the CT delta just as they circulate in the delta of the power transformer on the delta side.

The BE1-CDS240 selects the proper phase shift compensation settings to not only provide the correct phase shift but also to block zero-sequence currents as appropriate.

The second solution of inserting a zero-sequence trap is used in applications where there is a grounding bank within the zone of protection that is not predicted by the transformer connection information contained in the CT circuit setup parameters. In the example shown in Figure 1-7, the compensation logic would require that the delta compensation be applied to the grounded wye winding. The grounding bank on the delta side will cause the differential protection to operate for external ground faults. Figure 1-7 shows how this would be done with traditional differential relays.

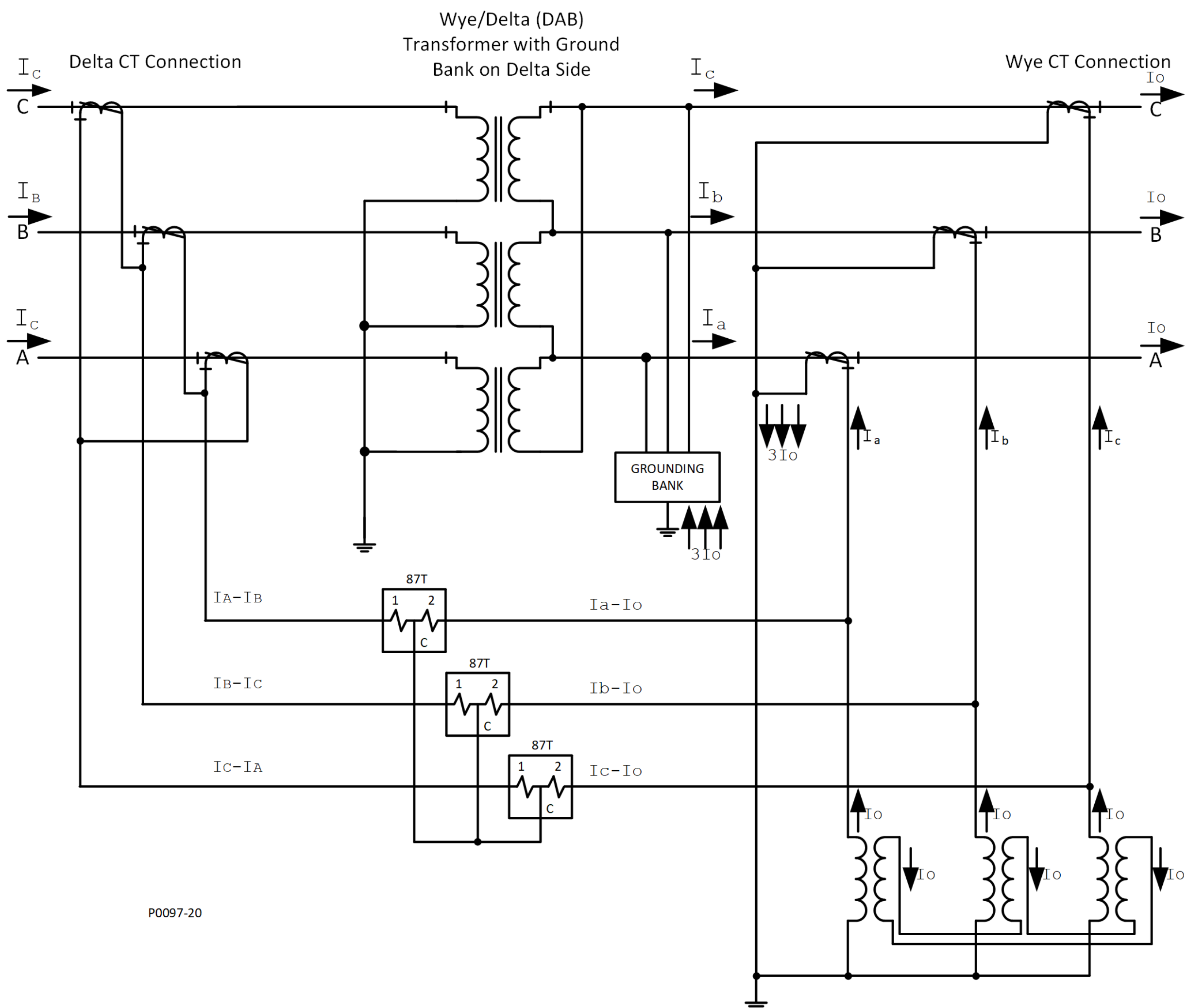


Figure 1-7. Traditional Zero-Sequence Trap for Application with Ground Banks

This application is greatly simplified with the BE1-CDS240. The user can connect all CTs in wye and specify that the delta transformer winding has a ground source. The BE1-CDS240 will apply delta compensation to the wye winding to obtain phase shift and zero-sequence compensation for that current input. For the delta winding with ground source, it will numerically remove the zero-sequence components from that current input just as would traditionally be done with a zero-sequence trap. The setup parameters for each of the current input circuits are described in Section 3, *Input and Output Functions, Power System Inputs*. The parameters specifying CT connection, transformer connection and ground source for each current circuit determines the angle and zero-sequence compensation used on each current input.

> **NOTE**
>
> The BE1-CDS240 relay does not automatically remove the zero-sequence components from all currents presented to the differential protection functions as that can unnecessarily reduce the relay's sensitivity to internal ground faults by 33%. Also, since the zero-sequence components are removed from all phases, it can result in confusion during single-phase testing by introducing differential current in phases not under test.

Problem 6: Transformer Energization Inrush and Overexcitation

General

When the zone of protection includes a transformer, excitation and energization inrush currents appear as differential current because they flow into the zone of protection and not back out again. Normally, transformer excitation losses are small. However, when the transformer is overexcited or upon initial energization or sympathetic inrush conditions, they can cause sensitive differential protection to operate.

BE1-CDS240 Solution

Overexcitation and inrush are nonlinear and the currents have high harmonic content. Inrush is characterized by high, even harmonics such as the second harmonic. Overexcitation is characterized by high, fifth harmonics. The BE1-CDS240 calculates the magnitude of the second and fifth harmonic components of the differential current. If the differential current is made up of a significant proportion of either of these two components, the user can select to inhibit the sensitive percentage restrained protection from operating.

Since CT saturation can also cause the currents seen by the relay to be rich in harmonics, an unrestrained instantaneous differential element is included to provide dependability for an internal fault with CT saturation.

During inrush, the second harmonic component may not be equally shared on all three phases. Because of this, misoperation can occur on a phase with low second harmonic content. Our unique method of second harmonic sharing improves security by allowing the harmonic restraint elements to respond to the ratio of operate current to the sum of harmonic current measured on all three phases. This is superior to other methods of cross blocking since each phase element operates independently in its comparison of operating current to harmonic current. Thus, security is enhanced without sacrificing dependability because a faulted phase will not be restrained by inrush on unfaulted phases.

To further enhance security from false tripping on inrush, the operating characteristic responds only to the fundamental component of this highly distorted current thus reducing sensitivity to inrush current yet allowing improved sensitivity to power system faults.

Problem 7: Digital Measurement Errors

General

Numerical relays sample the current and use digital signal processing algorithms to extract magnitude and angle information to develop their operating quantities. Most methods used are accurate only when the sampled power system quantity is operating at nominal frequency. Unless steps are taken to compensate, accuracy falls off very quickly with deviations in the power system frequency.

Another problem that must be overcome with digital technology is the need to use anti-aliasing filters prior to the sampling process to prevent harmonic components from affecting the measurement. Analog filters introduce phase shift errors and are subject to attenuation drift that can introduce magnitude and angle errors to the measurement.

These problems are more acute for differential protection since the operating quantity (differential current) is derived from the difference between the measured quantities. Any error in magnitude or angle measurement can result in large inaccuracies in the differential current measurement.

BE1-CDS240 Solution

Digital relay designers must decide on which of three solutions to use for this problem. They can allow misoperation at off-nominal frequencies. Alternatively, they can disable the protection at off-nominal frequency. Finally, they can compensate to maintain accuracy at off-nominal frequency. The BE1-CDS240 uses frequency tracking to adjust the sampling interval to maintain full accuracy across a wide frequency range so that it is both secure and dependable in all applications. For example, tripping of important transformers during a disturbance that causes the system to go unstable can have a catastrophic effect on an already over stressed power system. Generator and motor differential protection applications are another situation where accuracy across a wide frequency range is important.

To eliminate the errors introduced by analog low-pass filters, the BE1-CDS240 uses digital signal processing technology and 144 samples per cycle over-sampling to provide digital low-pass filtering.

Model and Style Number Description

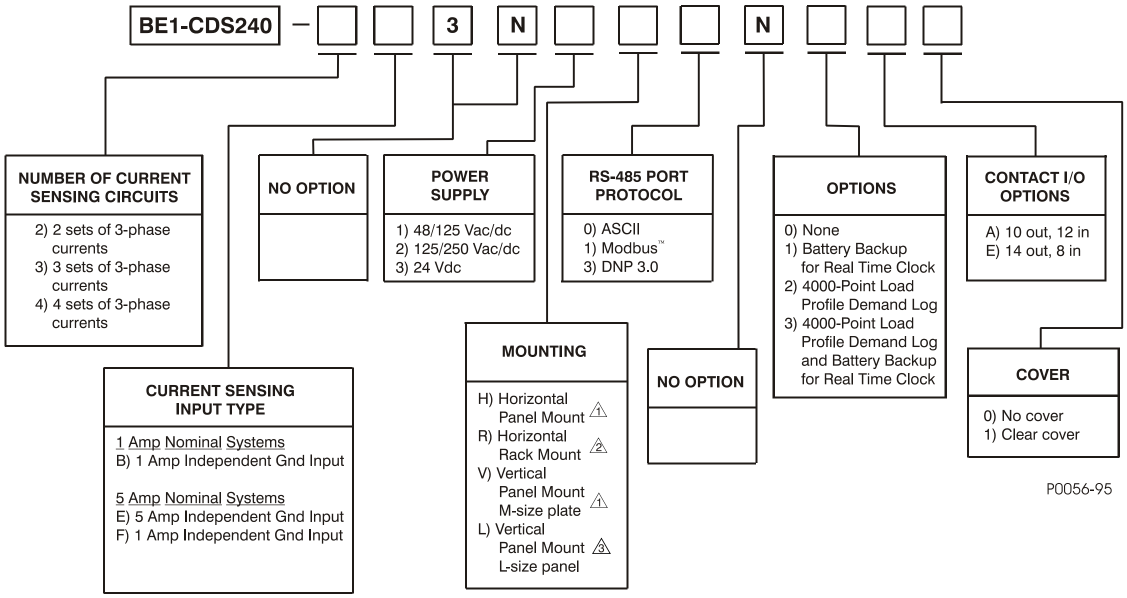
BE1-CDS240 electrical characteristics and operating features are defined by a combination of letters and numbers that make up the style number. The model number, together with the style number, describe the options included in a specific device and appear in the window on the front panel and on a label located inside the case. Upon receipt of a relay, be sure to check the style number against the requisition and the packing list to ensure that they agree.

Sample Style Number

The style number identification chart of Figure 1-8 defines the electrical characteristics and operational features included in BE1-CDS240 relays. For example, if the style number were **2B3N1H0N1A1**, the device would have the following features.

BE1-CDS240 —

(**2**) - Two sets of three-phase current sensing circuits
(**B**) - One ampere, independent ground current sensing
(**3**) - Three-phase voltage sensing input
(**N**) - Six button human-machine interface with liquid crystal display (LCD)
(**1**) - 48/125 Vac or Vdc power supply
(**H**) - Horizontal, panel-mount case
(**0**) - ASCII communication through the RS-485 port
(**N**) - Not equipped for Ethernet communication
(**1**) - Battery backup for real-time clock
(**A**) - Ten contact outputs and 12 contact inputs. Alarm output is normally closed contact.
(**1**) - Clear front panel cover



NOTES:

1. Medium size vertical escutcheon plate for retrofit of GE BDD15/BDD16 (M1/M2) relays and Westinghouse HU/HU1 (FT31) relays. This plate can also be used for horizontal panel mounting (included with "H" and "V" mounting options).
2. Rack mounting flanges for 19" EIA rack mounting (included with "R" mounting option).
3. Large size vertical escutcheon plate for retrofit of GE BDD17 (L2) and Westinghouse HU4 (FT42) relays (included with "L" mounting option).

Figure 1-8. Style Number Identification Chart

Operational Specifications

Metered Current Values and Accuracy

Current Range

5 Aac Nominal .... 0.5 to 15 Aac
1 Aac Nominal .... 0.1 to 3.0 Aac

Accuracy

IA, IB, IC, IG (Measured) .... ±1% of reading, ±1 least significant digit at 25°C
3I0, IQ (Calculated) .... ±4% of phase reading, ±1 least significant digit at 25°C

Temperature Dependence

IA, IB, IC, IG (Measured) .... ≤ ±0.02% per °C
3I0, IQ (Calculated) .... ≤ ±0.06% per °C

Phase Angle .... ±1° of reading, ±1 least significant digit at 25°C

Metered Voltage Values and Accuracy

Voltage Range

3 Wire Sensing .... 0 to 300 V_{L-L}
4 Wire Sensing .... 0 to 300 V_{L-L}

Accuracy (50 V to 300 V)

VA, VB, VC (Measured) .... ±0.5% of reading, ±1 least significant digit at 25°C
V1, V2, 3V0 (Calculated) .... ±4% of reading, ±1 least significant digit at 25°C

Temperature Dependence

VA, VB, VC (Measured) .... ≤ ±0.02% per °C
V1, V2, 3V0 (Calculated) .... ≤ ±0.06% per °C

Phase Angle .... ±1° of reading, ±1 least significant digit at 25°C

Metered Frequency Values and Accuracy

Frequency Range .... 10 to 75 hertz
Accuracy .... ±0.01 hertz, ±1 least significant digit at 25°C

Sensing Input

3 Wire Sensing .... Phase A - B
4 Wire Sensing .... Phase A - Neutral
Minimum Frequency Tracking Voltage .... 10 V rms

Calculated Values and Accuracy

Demand

Range .... 0.1 to 1.5 nominal
Type .... Exponential
Accuracy .... ±1% of reading, ±1 digit at 25°C
Temperature Dependence .... ≤ ±0.02% per °C
Interval .... 1 to 60 min

True Power

Range

5 Ampere CT .... –7,500 kW to +7,500 kW
1 Ampere CT .... –1,500 kW to +1,500 kW
Accuracy .... ±1% at unity power factor

Reactive Power

Range

5 Ampere CT .... –7,500 kvar to +7,500 kvar
1 Ampere CT .... –1,500 kvar to +1,500 kvar
Accuracy .... ±1% at zero power factor

Energy Data Reporting

Range

1 or 5 Ampere CT .... 100 MWh
Units of Measure .... kilo, mega, giga
Rollover Value of Registers 100,000
Accuracy .... ±1% at unity power factor

24 Overexcitation Protection

Pickup

Setting Range .... 0.5 to 6 V/Hz
Accuracy .... ±2%

Integrating Time Delay

Time Dial .... 0.0 to 9.9
Reset Dial .... 0.0 to 9.9
Accuracy .... 5% or 4 cycles, whichever is greater

$$T_T = \frac{DT}{\left(\frac{V/HZ_{MEASURED}}{V/HZ_{NOMINAL}} - 1 \right)^n}$$

Time to Trip

$$T_R = D_R * \frac{E_T}{FST} * 100$$

Time to Reset

where:

T_T = Time to trip

T_R = Time to reset
D_T = Time dial trip
D_R = Time dial, reset
E_T = Elapsed time
n = Curve exponent (0.5, 1, 2)
FST = Full scale trip time (TT)
ET/FST = Fraction of total travel toward trip that integration had progressed to. (After a trip, this value will be equal to one.)

Definite Time Delay

Time Delay..0.050 to 600 s
Accuracy ....5% or 4 cycles, whichever is greater

27P Phase Undervoltage Protection

Pickup

Setting Range ....10 to 300 V
Accuracy ....±2% or ±1 V, whichever is greater
Dropout/Pickup Ratio..102%

Time Delay

Setting Range ....0.050 to 600 s
Accuracy ....±0.5% or ±1 cycle, whichever is greater

47 Negative-Sequence Voltage Protection

Pickup

Setting Range ....1.0 to 300 V_{L-N}
Accuracy ....±2% or ±1 V, whichever is greater
Dropout/Pickup Ratio..98%

Time Delay

Setting Range ....0.050 to 600 s
Accuracy ....±0.5% or ±1 cycle, whichever is greater

50T Instantaneous Overcurrent Protection

Pickup

Setting Range

5 Ampere CT...0.5 to 150 A
1 Ampere CT...0.1 to 30 A

Accuracy (50TP, 50TN)

5 Ampere CT...±2% or ±50 mA, whichever is greater
1 Ampere CT ....±2% or ±10 mA, whichever is greater

Accuracy (50TQ)

5 Ampere CT ....±3% or ±75 mA, whichever is greater
1 Ampere CT...±3% or ±15 mA, whichever is greater
Dropout/Pickup Ratio..95%

Time Delay

Setting Range ....0 to 60 s

Accuracy

50TP, 50TN..±0.5% or ±¼ cycle, whichever is greater, *Plus* trip time for instantaneous response (0.0 setting)∗
50TQ ....±0.5% or ±1 cycle, whichever is greater, *Plus* trip time for instantaneous response (0.0 setting)∗

∗ Trip Time for 0.0 Delay Setting
50TP, 50TN..1¼ cycles maximum for currents ≥ 5 times the pickup setting. Three cycles maximum for a

current of 1.5 times pickup. Four maximum for a current of 1.05 times the pickup setting.

50TQ .... 2¼ cycles maximum for currents 5 times the pickup setting. Three maximum for a current of 1.5 times pickup. Five cycles maximum for a current of 1.05 times the pickup setting.

50BF Breaker Failure Protection

Pickup

Setting Range

5 Ampere CT .... 0.25 to 10 A
1 Ampere CT .... 0.05 to 2 A
SEF .... 0.01 to 0.05 A

Accuracy

5 Ampere CT .... ±2% or 0.05 A, whichever is greater
1 Ampere CT .... ±2% or 0.01 A, whichever is greater
SEF .... ±2.5% or 0.0025 A, whichever is greater

Time Delay

Delay Timer

Setting Range .... 50 to 999 ms
Accuracy .... ±0.5% or ±½ cycles; whichever is greater plus 2¼ cycles maximum for currents ≥ 5 times pickup setting. Three cycles maximum for a current of 1.5 times pickup. Four cycles maximum for a current of 1.05 times the pickup setting.
Reset Time .... Within 1¼ cycles of the current being removed

Control Timer

Setting Range .... 50 to 999 ms
Accuracy .... ±0.5% or ±1½ cycles, whichever is greater

51 Time Overcurrent Protection

Pickup

Setting Range

5 Ampere CT .... 0.5 to 16 A
1 Ampere CT .... 0.1 to 3.2 A

Accuracy (51P, 51N)

5 Ampere CT .... ±2% or ±50 mA, whichever is greater
1 Ampere CT .... ±2% or ±10 mA, whichever is greater

Accuracy (51Q)

5 Ampere CT .... ±3% or ±75 mA, whichever is greater
1 Ampere CT .... ±3% or ±15 mA, whichever is greater

Dropout/Pickup Ratio 95%

Time Current Characteristic Curves

Timing Accuracy (All 51 Functions) .... Within ±5% or ±1½ cycles, whichever is greater, for time dial settings greater than 0.1 and multiples of 2 to 40 times the pickup setting but not over 150 A for 5 A CT units or 30 A for 1 A CT units.

See Appendix A, *Time Overcurrent Characteristic Curves,* for information on available timing curves.

59P Phase Overvoltage Protection

Pickup

Setting Range .... 10 to 300 V
Accuracy .... ±2% or ±1 V, whichever is greater
Dropout/Pickup Ratio 98%

Time Delay

Setting Range .... 0.050 to 600 s
Accuracy .... ±0.5% or ±1 cycle, whichever is greater

59X Auxiliary Overvoltage Protection

Pickup

Setting Range .... 1 to 150 V
Accuracy .... ±2% or ±1 V, whichever is greater
Dropout/Pickup Ratio 98%

Time Delay

Setting Range .... 0.050 to 600 s
Accuracy .... ±0.5% or ±1 cycle, whichever is greater

60FL Fuse Loss

Nominal Voltage .... 50 to 250 V

Nominal Current

5 A Current Sensing .... 0.5 to 10 A
1 A Current Sensing .... 0.1 to 2 A

62 Logic Timers

Modes .... Pickup/Dropout, Integrating, Retriggerable, Non-Retriggerable, Oscillator, and Latch
Range .... 0 to 9,999 s
Accuracy .... ±0.5% or ±¾ cycles, whichever is greater

81 Frequency Protection

Pickup

Setting Range .... 40.00 to 70.00 Hz
Accuracy .... ±0.01 Hz

Time Delay

Setting Range: .... 0.000 to 600 s
Accuracy .... ±0.5% or ±1 cycle, whichever is greater, plus 3 cycle recognition time

87 Current Differential Protection

Restrained Differential (87RPU, 87RT)

Pickup Accuracy

5 Ampere CT .... ±4% or ±75 mA, whichever is greater
1 Ampere CT .... ±4% or ±25 mA, whichever is greater
Response Time (See Figure 1-9) .... <2 cycles at 5 times pickup
<3 cycles at 1.5 times pickup

Unrestrained Differential (87UT)

Pickup Accuracy

5 Ampere CT .... ±4% or ±75 mA, whichever is greater
1 Ampere CT .... ±4% or ±25 mA, whichever is greater
Response Time (See Figure 1-9) .... <1 cycle at 5 times pickup
<2 cycles at 1.5 times pickup

Harmonic Inhibit

Pickup Accuracy

5 Ampere CT .... ±2% of setting or 50 mA, whichever is greater
1 Ampere CT .... ±2% of setting or 50 mA, whichever is greater

TAP

Setting Range

5 Ampere CT .... 2 to 20 A
1 Ampere CT .... 0.4 to 4 A

Minimum Pickup

1 or 5 Ampere CT

Setting Range .... 0.1 to 1 per unit

Restraint Slope

1 or 5 Ampere CT

Setting Range .... 15 to 60%

Second and Fifth Harmonic

1 or 5 Ampere CT

Setting Range .... 5.0 to 75%

Unrestrained Pickup

1 or 5 Ampere CT

Setting Range .... 1 to 21 x TAP, up to 30 times I nominal, symmetrical

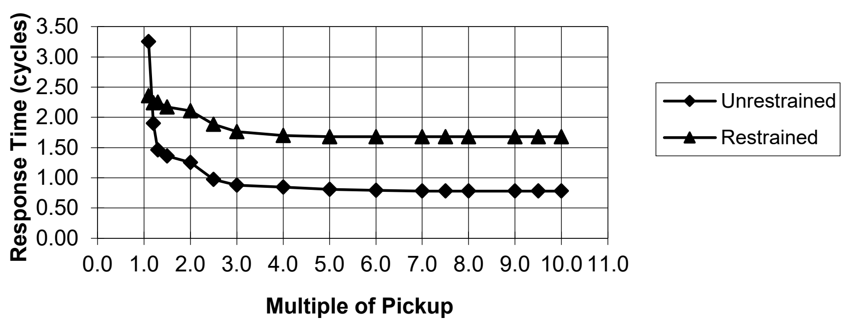


Figure 1-9. Typical 87 Response Characteristic Curves

87ND Neutral Differential Protection

Restrained Differential (87NDPU, 87NDT)

Pickup Accuracy

5 Ampere CT .... ±4% or ±75 mA, whichever is greater
1 Ampere CT .... ±4% or ±25 mA, whichever is greater

TAP Setting Range

5 Ampere CT .... 2 to 20 A
1 Ampere CT .... 0.4 to 4 A

Minimum Pickup (1 or 5 Ampere CT)

Setting Range .... 0.10 to 1.00 per unit

Restraint Slope

Setting Range (1 or 5 Ampere CT) .... 15 to 60%

Automatic Setting Group Characteristics

Number of Setting Groups: 4

Switch Level

Range .... 0-150% of the setting group 0 #51 Phase, Neutral, or Negative-Sequence pickup setting
Accuracy .... ±2% or ±50 mA (5 A), ±2% or ±10 mA (1 A)

Switch Timer

Range .... 0-150% of the setting group 0 #51 Phase, Neutral, or Negative-Sequence pickup setting
Accuracy .... ±0.5% or ±2 s, whichever is greater

BESTlogic

Update Rate .... ¼ cycle

General Specifications

AC Current Inputs

5 Ampere CT

Continuous rating .... 20 A
One second rating .... 400 A

For other current levels, use the formula $I = (K/t)^{1/2}$ where t = time in seconds and K = 160,000.

Begins to Clip (saturate) .... 150 A
Burden .... <10 mΩ at 5 Aac

1 Ampere CT

Continuous Rating .... 4 A
One second rating .... 80 A

For other current levels, use the formula $I = (K/t)^{1/2}$ where t = time in seconds and K = 6,400.

Begins to Clip (saturate) .... 30 A
Burden .... <22 mΩ at 1 Aac

Analog to Digital Converter

Type 16-bit
Sampling Rate .... 144 samples per cycle into digital filter
Digital Filter Output .... 24 samples per cycle
Frequency Tracking .... 40 to 63 Hz

Power Supply

Option 1

48, 110, and 125 Vdc .... Range 35 to 150 Vdc
67, 110, and 120 Vac .... Range 55 to 135 Vac

Option 2

110, 125, and 250 Vdc .... Range 90 to 300 Vdc
110, 120, and 240 Vac .... Range 90 to 270 Vac

Option 3

24 Vdc .... Range 17 to 32 Vdc

Frequency Range

Options 1 and 2 only .... 40 to 70 Hz

Burden

Options 1, 2, and 3: .... 12 W continuous, 16.5 W maximum with all outputs energized

Output Contacts

Make and Carry for Tripping Duty ....30 A for 0.2 seconds per IEEE C37.90; 7 A continuous
Break Resistive or Inductive ....0.3 A at 125 or 250 Vdc (L/R = 0.04 maximum)

Contact-Sensing Inputs

Turn-On Voltage

Contact-sensing turn-on voltages are listed in Table 1-1.

Table 1-1. Contact-Sensing Turn-On Voltages

Style Option	Nominal Input Voltage	Contact-Sensing Turn-On Voltage∗		
		Jumper (L) (Low Position) †	Jumper (H) (High Position)†	Jumper Not Installed†
xxxx1xxxxxx	48 Vdc or 125 Vac/dc	26 to 38 Vdc	69 to 100 Vdc 56 to 97 Vac	n/a
xxxx2xxxxxx	125/250 Vac/dc	69 to 100 Vdc 56 to 97 Vac	138 to 200 Vdc 112 to 194 Vac	n/a
xxxx3xxxxxx	24 Vdc	n/a	n/a	Approx. 5 Vdc

∗ AC voltage ranges are calculated using the default recognition time (4 ms) and debounce time (16 ms).

† Voltage ranges depend on Jumper configurations. See Section 3, *Input and Output Functions, Contact Sensing Inputs.*

Input Burden

Burden values shown in Table 1-2 assume nominal value of input voltage applied.

Table 1-2. Contact-Sensing Input Burden

Style Option	Nominal Input Voltage	Burden		
		Jumper (L) (Low Position)	Jumper (H) (High Position)	Jumper Not Installed
xxxx1xxxxxx	48 Vdc or 125 Vac/dc	22 kΩ	53 kΩ	n/a
xxxx2xxxxxx	125/250 Vac/dc	66 kΩ	123 kΩ	n/a
xxxx3xxxxxx	24Vdc	n/a	n/a	6 kΩ

Recognition Time

Programmable, 4 to 255 ms

NOTE

All timing specifications are for the worst-case response. This includes output contact operate times and standard BESTlogic operation timing but excludes input debounce timing and non-standard logic configurations. If a non-standard logic scheme involves feedback, then one or more BESTlogic update rate delays must be included to calculate the worst-case delay. An example of feedback is virtual outputs driving function block inputs. For more information, see Section 7, *BESTlogic Programmable Logic*.

IRIG

Standard ....200-98, Format B002
Input Signal...Demodulated (dc level-shifted digital signal)
Logic-High Voltage ....3.5 Vdc, minimum

Logic-Low Voltage .... 0.5 Vdc, maximum
Input Voltage Range .... +10 to –10 Vdc
Resistance .... Nonlinear, approximately 4 kΩ at 3.5 Vdc, approximately 3 kΩ at 20 Vdc

Real-Time Clock

Accuracy .... 1 second per day at 25°C (free running) or ±2 milliseconds (with IRIG synchronization)
Resolution .... 1 millisecond
Date and Time Setting Provisions .... Front panel, communications port, and IRIG. Leap year correction provided.
Clock Power Supply Holdup Capacitor.......................... 8 to 24 hours, depending on conditions
Clock Power Supply Holdup Battery.............................. Greater than 5 years
Backup Battery (Optional) .... Lithium battery 3.6 Vdc, 0.95 AH, Basler Electric p/n: 9318700012 or Applied Power p/n: BM551902

Communication Ports

Interface

Front RS-232 .... 300 to 19,200 baud, 8N1, full duplex
Rear RS-232 .... 300 to 19,200 baud, 8N1, full duplex
Rear RS-485 .... 300 to 19,200 baud, 8N1, half duplex

Display

Type: Graphic LCD (liquid crystal display) with LED (light emitting diode) back-light.
Operating Temperature: –40°C to 70°C (–40°F to 158°F). display contrast may be impaired at temperatures below –20°C (–4°F).

Isolation

2,000 Vac at 50/60 Hz in accordance with IEEE C37.90 and IEC 255-5. (Includes communication ports.)

Surge Withstand Capability

Oscillatory

Qualified to IEEE C37.90.1-2001, Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.

Fast Transient

Qualified to IEEE C37.90.1-1989, Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.

Radio Frequency Interference (RFI)

Qualified to IEEE C37.90.2-1995, Standard For Withstand Capability Of Relay Systems To Radiated Electromagnetic Interference From Transceivers.

Electrostatic Discharge (ESD)

8 kV contact discharges and 15 kV air discharges applied in accordance with IEC 60255-22.

Shock

Qualification: IEC 255-21-2, Class 1

Vibration

Qualification: IEC 255-21-1, Class 1

Environment

Temperature

Operating Range:	–40°C to 70°C (–40°F to 158°F)
Storage Range:	–40°C to 70°C (–40°F to 158°F)

Humidity

Qualified to IEC 68-2-38, 1st Edition 1974, Basic Environmental Test Procedures, Part 2: Test Z/AD: Composite Temperature Humidity Cyclic Test.

UL Certification

U.L. recognized per Standard 508, U.L. File Number E97033 (CCN NRGU2 / NRGU8). Note: Output contacts are not U.L. recognized for voltages greater than 250 V.

C.S.A. Certification

C.S.A. certified per Standard CAN/CSA-C22.2 -14-M91, C.S.A. File Number LR23131. Note: Output contacts are not C.S.A. certified for voltages greater than 250 volts.

Patent

U.S. Patent No. 5014153.

Physical

Weight

Unit Weight:	12 lb (5.4 kg) maximum
Shipping Weight:	Approximately 16.5 lb (7.5 kg)

Case Configurations

M Horizontal:	Panel or 19" rack-mount, draw-out
M Vertical:	M1, M2/FT31, FT32 size, draw-out
L Vertical:	L2/FT42 size, draw-out

SECTION 2 • QUICK START

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SECTION 2 • QUICK START

General

This section provides an overview of the BE1-CDS240 Current Differential System. You should be familiar with the concepts behind the user interfaces and BESTlogic before you begin reading about the detailed BE1-CDS240 functions. Sections 3 through 6 in this manual describe in detail each function of the BE1-CDS240.

The following information is intended to provide the reader with a basic understanding of the three user interfaces (front panel human-machine interface (HMI), ASCII serial communications link, and the BESTCOMS™ for BE1-CDS240 software) and the security features provided in the BE1-CDS240 relay. Detailed information on the operation of the HMI (human-machine interface) is in Section 10, and the information on ASCII command communications is in Section 11. BESTCOMS is a Windows® based software application (graphical user interface) that enhances communication between the PC user and the BE1-CDS240 relay. BESTCOMS for the BE1-CDS240 is provided free of charge with the BE1-CDS240 and details are provided in Section 14.

Also covered in this section is an overview of BESTlogic. BESTlogic is a highly flexible programmable logic system that allows the user to apply the available functions with complete flexibility and customize the system to meet the requirements of the protected power system. Detailed information on using BESTlogic to design complete protection and control schemes for the protected circuit can be found in Section 7, *BESTlogic Programmable Logic*, and Section 8, *Application*.

Sections 3 through 6 describe each function provided in the BE1-CDS240 relay and include references to the following items. Note that not all items are appropriate for each function.

- Human-machine interface (HMI) screens for setting the operational parameters.
- BESTCOMS for setting the operational parameters.
- BESTCOMS for setting up the BESTlogic required for functions in your protection and control scheme.
- Outputs from the function such as alarm and BESTlogic variables or data reports.
- HMI screens for operation or interrogation of the outputs and reports provided by each function.
- ASCII commands for operation or interrogation of the outputs and reports provided by each function.

About This Manual

The various application functions provided by this multifunction relay are divided into four functional categories: input/output functions, protection and control functions, metering functions, and reporting and alarm functions. Detailed descriptions of each individual function, setup, and use are covered in the Sections as shown in Table 2-1. Detailed information on using programmable logic to create your protection and control scheme is described in Section 7, *BESTlogic Programmable Logic*.

Table 2-1. Function Categories and Manual Sections Cross-Reference

Section Title	Section
Input and Output Functions	3
Protection and Control	4
Metering	5
Reporting and Alarm Functions	6
BESTlogic Programmable Logic	7
Application	8

BESTlogic

Each of the protection and control elements in the BE1-CDS240 is implemented as an independent function that is equivalent to a single function, discrete device counterpart. Each independent element has all of the inputs and outputs that the discrete component counterpart might have. Programming BESTlogic is equivalent to choosing the devices required by your protection and control scheme and drawing schematic diagrams to connect the inputs and outputs to obtain the desired operational logic. The concept is the same but the method is different in that you choose each element by enabling it and use Boolean logic expressions to connect the inputs and outputs. The result is that you have even greater flexibility in designing your system than you had using discrete devices. An added benefit is that you are not constrained by the limitations in flexibility inherent in many multifunction relays.

One user programmable, custom logic scheme created by the user may be programmed and saved in memory. Or, the user may choose from one preprogrammed logic scheme embedded in the relay firmware or several preprogrammed logic schemes in the BESTCOMS logic library that can be copied to the relay. Preprogrammed schemes can reduce or eliminate the need for programming by the user.

Preprogrammed logic settings can also be modified after being saved in the relay. This provides a good starting point for a custom logic scheme. To modify the preprogrammed scheme, it is necessary to enter a unique name for the new logic before modifying the settings. Naming the new logic distinguishes it from the preprogrammed logic scheme. In the 16 character preprogrammed logic name, the last 4 characters refer to revision A, dash (-), and BE (Basler Electric). When customizing a programmed logic scheme, it is recommended that the user include the revision level of their scheme and change the BE to a 2-digit code representative of the user's company name. For example, if VA Power were modifying the CDS240-BATX-A-BE the preprogrammed logic scheme might be CDS240-BATX-B-VP, the B standing for revision level B, and VP for VA Power.

There are two types of BESTlogic settings: element (function block) logic settings and output logic settings. These will be described briefly in the following paragraphs. Detailed information on using BESTlogic to design complete protection and control schemes for the protected circuit can be found in Section 7, *BESTlogic Programmable Logic* and Section 8, *Application*.

Characteristics of Protection and Control Elements

As stated before, each element (function block) is equivalent to a discrete device counterpart. For example, the transformer differential element in the BE1-CDS240 relay has all of the characteristics of a version of the BE1-87T transformer differential relay with similar functionality. Figure 2-1 shows the 87 phase differential element inputs and outputs.

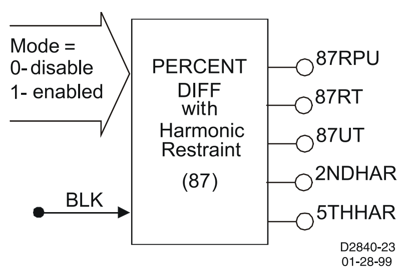

Figure 2-1. 87 Phase Differential Element

Two inputs:

- Mode (enable/disable 87 operation)
- BLK (block 87 operation)

Five outputs:

- 87RPU (87 Restrained Pickup)
- 87RT (87 Restrained Trip)
- 87UT (87 Unrestrained Trip)
- 2NDHAR (2nd Harmonic Inhibit Status)
- 5THHAR (5th Harmonic Inhibit Status)

Five operational settings:

- Minimum pickup
- Slope
- 2nd Harmonic Inhibit
- 5th Harmonic Inhibit
- Unrestrained Pickup

Of the above characteristics, the five operational settings are not included in the logic settings. They are included in the protection settings. This is an important distinction. Since changing logic settings is similar to rewiring a panel, the logic settings are separate and distinct from the operational settings such as pickups and time delays.

Element Logic Settings

To use a protection or control element, two items need to be set. These are the mode and the input logic. The mode is equivalent to deciding which devices you want to install in your protection and control scheme. You then must set the logic variables that will be connected to the inputs.

For example, the 51N element has two modes (disabled and enabled), and one input, block (torque control). To use this element, the logic setting command might be SL-51N=1,/IN2 for Set Logic-51N to be Mode 1 (enabled) with the element blocked when contact sensing Input 2 is not (/) energized. Contact Sensing Input 2 would be wired to a ground relay enable switch.

As noted before, the protection settings for this element, pickup, time dial, and curve, must be set separately in the setting group settings. The setting might be S0-51N=6.5,2.1,S1R for Set in Setting Group 0 - the 51N function = to pickup at 6.5 amps with a time dial of 2.1 using curve S1 with an integrating reset characteristic.

The 51N element has two logic output variables, 51NT (Trip) and 51NPU (Picked Up). The combination of the logic settings and the operational settings for the element govern how these variables respond to logic and current inputs.

Output Logic Settings

BESTlogic, as implemented in the BE1-CDS240, supports up to 16 output expressions. The output expressions are called virtual outputs to distinguish them from the physical output relays. In the BE1-CDS240, any virtual output (VO1 through VO16) can drive any physical output relay (OUT1 through OUT14). VOA is different in that it will always drives physical output relay, Out A which is the fail safe alarm output. Other virtual outputs may be assigned to or removed from OUTA, but VOA will always drive OUTA. In addition, any of the virtual outputs can be used for intermediate logic expressions.

For example, OUT1 is wired to the trip bus of a circuit breaker. To set up the logic to trip the breaker, the BESTlogic setting command might be SL-VO1=VO11+101T+BFPU for Set Logic - Virtual Output 1 = to Virtual Output 11 (which is the intermediate logic expression for all of the element tripping outputs) or (+) 101T (the trip output of the virtual breaker control switch) or (+) BFPU (the pickup output of the breaker failure element that indicates that breaker failure has been initiated). To assign this to OUT1, the BESTlogic command would be SL-OUT1=VO1.

User Interfaces

Three user interfaces are provided for interacting with the BE1-CDS240 relay: the front panel HMI, ASCII communications, and the BESTCOMS for BE1-CDS240 software. The front panel HMI provides access to a subset of the total functionality of the device. ASCII communications provides access to all settings, controls, reports, and metering functionality of the system. The BESTCOMS for BE1-CDS240 software provides a Windows based, user-friendly environment for editing settings files and uploading and downloading them from the relay (see Section 14 for details).

Front Panel HMI

The front panel HMI consists of a two line by a 16 character LCD (liquid crystal display) with four scrolling pushbuttons, an edit pushbutton, and a reset pushbutton. The *EDIT* pushbutton includes an LED to indicate when edit mode is active. There are five other LEDs for indicating power supply status, relay trouble alarm status, programmable major and minor alarm status, and a multipurpose *Trip* LED that flashes to indicate that a protective element is picked up. The *Trip* LED lights continuously when the trip output is energized and seals in when a protective trip has occurred to indicate that target information is being displayed on the LCD. A complete description of the HMI is included in Section 10, *Human-Machine Interface*.

The BE1-CDS240 HMI is menu driven and organized into a menu tree structure with six branches. A complete menu tree description with displays is also provided in Section 10, *Human-Machine Interface*. A list of the menu branches and a brief description for scrolling through the menu is in the following paragraphs.

1. REPORT STATUS. Display and resetting of general status information such as targets, alarms, recloser status, etc.
2. CONTROL. Operation of manual controls such as virtual switches, selection of active setting group, etc.
3. METERING. Display of real time metering values.
4. REPORTS. Display and resetting of report information such as time and date, demand registers, breaker duty statistics, etc.

5. PROTECTION. Display and setting of protective function setting parameters such as logic scheme, pickups, time delays, etc.
6. GENERAL SETTINGS. Display and setting of non-protective function setting parameters such as communications, LCD contrast, and CT ratio.

Each screen in the menu tree displays the path in the upper left hand corner of the screen. Additionally, each screen is assigned a number in the HMI section. The path indicates the branch and level in the menu tree structure. This path should help you to keep track of where you are when you leave the menu tree top level. You scroll through each level of the menu tree by using the right and left scrolling pushbuttons. To go to a level of detail, you use the down scrolling pushbutton. Each time you go to a lower level in the menu tree, another string is added to the path and separated by a backslash.

For example, to check or change the 51N pickup setting in Setting Group 3, you would press the right or left scrolling pushbuttons to get to Screen \PROT - *PROTECTION*. You would then press the down scrolling pushbutton to get to the next level of detail and the right or left scrolling pushbutton to get to Screen \PROT\SG3 - *SETTING GROUP 3*. To continue, you would press the down and then the right or left scrolling pushbuttons to get to Screen \PROT\SG3\51 *INVERSE TIME OVERCURRENT* and then Screen \PROT\SG3\51\51 - 51 Settings. On the screen shown in Figure 2-2, the pickup, time dial and curve settings for the 51P/N/Q functions can be read and/or edited. To return to the top level from this location, you would press the *Up* scrolling pushbutton three times.

```
\PROT\SG3\51\51
   MODE PU   TD   CRV
51P   1 10.3 9.99 B1R
51N   G  1.0 0.20 B5
51Q   0 xx.x x.xx C4R

<251            >151
```

D2840-35
04-02-03

Figure 2-2. 51 HMI Screen

ASCII Command Communications

The BE1-CDS240 relay has three independent communications ports for serial communications. *Basler Terminal* in BESTCOMS can be connected to any of the three ports so that the user may send commands to the relay. Alternatively, a computer terminal or PC running a terminal emulation program such as Windows Terminal can be used in the same manner. Communication with the relay uses a simple ASCII command language. When a command is entered via a serial port, the relay responds with the appropriate action. The ASCII command communications is designed for use in both human-to-machine interactions and in batch download type operations. The following paragraphs briefly describe the command structure and then discuss human-to-machine interactions and batch command text file operations for interacting with the relay. The operation of the ASCII commands is described in detail in Section 11, *ASCII Command Interface*.

Command Structure

An ASCII command consists of a command string made up of one or two letters followed by a hyphen and an object name. The first letter specifies the general command function and the second a sub-grouping. The object name is the specific function for which the command is intended. If the command string is entered by itself, it is a read command. If the command string is entered followed by an equal sign and one or more parameters, it is a write command. The general command groupings are organized into six major groups plus several miscellaneous commands. These commands are as follows:

C CONTROL. Commands to perform select before operate control actions such as tripping and closing the circuit breaker, changing the active setting group, etc. Sub-groupings include S for Select and O for Operate.

G GLOBAL. Perform global operations that do not fall into the other general groupings such as password security. Sub-groupings include S for security settings.

M METERING. Read all real time metering values. This general command grouping has no sub-groupings.

P PROGRAM. Subgroup command to read or program a setting.

R REPORTS. Read and reset reporting functions such as time and date, demand registers, breaker duty statistics, etc. Sub-groupings include: A for Alarm functions, B for Breaker monitoring functions, D for Demand recording functions, F for Fault summary reporting functions, G for General information and S for Sequence of Events recorder functions.

S SETTINGS. Set all setting parameters that govern the functioning of the relay. Sub-groupings include: 0,1,2,3 for settings in setting groups, A for alarm settings, B for breaker monitoring settings, G for general settings, L for logic settings.

MISCELLANEOUS. These include Access, Exit, and Help.

Examples of object names would be 51N for the neutral inverse time overcurrent element or PIA for the A phase, peak current demand register.

For example, to check the 51N pickup setting in Setting Group 3, you would enter S3-51N for Settings, Group 3-51N. The relay would respond with the current pickup, time dial, and curve settings for the 51N element. To edit these settings, the same command would be used with an = followed by the new settings and the enter pushbutton. The user should note that it is necessary to use the Access and Exit commands when using the write version of these commands.

Human-to-Machine ASCII Command Operations

The ASCII command scheme allows the user to read and/or write settings and operational items on a function-by-function basis. However, this also requires a great many commands. The mnemonic format of the commands is designed to facilitate interactive communications with the relay. It is not necessary to remember all of the object names. Most commands support a multiple read version where it is not necessary to specify a complete object name. You can enter the first two letters of a command and the relay will respond with all applicable objects.

For example, you want the relay to report the breaker operations counter reading. You can enter RB for Report Breaker and the relay will respond with all of the breaker report objects including the operations counter. If you had remembered that the object name is OPCNTR, you could have entered RB-OPCNTR and received only the operations counter report. Partial object names are also supported. For example, you wish to read the entire peak-since-reset demand registers. You can enter RD-PI for Report Demand - Peak Current (I) and the relay will respond with the values and time stamps for A, B, C, N and Q. To reset all five of the peak since reset demand registers, enter the command RD-PI=0. To read only the value for the neutral demand, the full object name would have been entered (RD-PIN).

Batch Command Text File Operations

With a few exceptions, each function of the relay uses one command to set it and each setting command operates on all of the parameters required by that element. See the example mentioned above in the paragraph titled *Command Structure*. This format results in a great many commands to fully set the relay. Also, the process of setting the relay does not use a prompting mode where the relay prompts you for each parameter in turn until you exit the setting process. For these reasons, a method for setting the relay using batch text files is recommended.

In batch upload type operations, the user creates an ASCII text file of commands and sends it to the relay. To facilitate this process, the response from a multiple read command is output from the BE1-CDS240 in command format. Therefore, the user need only enter S for Set (with no subgroup) and the relay responds with all of the setting commands and their associated parameters. If the user enters S2 for Set Group 2, the relay responds with all of the setting commands for Setting Group 2. The user may capture this response to a file, edit it using any ASCII text editor, and then send the file back to the relay. See Section 11, *ASCII Command Interface*, for a more detailed discussion of how to use ASCII text files for setting the relay.

BESTCOMS™ for BE1-CDS240, Graphical User Interface

Basler Electric's graphical user interface (GUI) software, BESTCOMS, is an alternative method for quickly developing setting files in a friendly, Windows based environment. Using the GUI, you may prepare setting files off-line (without being connected to the relay) and then upload the settings to the relay at your convenience. These settings include protection and control, operational and logic, breaker and transformer monitoring, metering and fault recording. Engineering personnel can develop, test, and replicate the settings before exporting it to a file and transmitting the file to technical personnel in the field. On the field end, the technician simply imports the file into the BESTCOMS database and uploads the file to the relay where it is stored in nonvolatile memory.

The GUI also has the same preprogrammed logic scheme that is stored in the relay in addition to a library of additional logic schemes. This gives the engineer the option (off-line) of developing his setting file using a preprogrammed logic scheme, customizing a preprogrammed logic scheme, or building a scheme from scratch. Files may be exported from the GUI to a text editor where they can be reviewed or modified. The modified text file may then be uploaded to the relay. After it is uploaded to the relay, it can be brought into the GUI, but it cannot be brought directly into the GUI from the text file. The GUI logic builder uses basic AND/OR gate logic combined with point and click variables to build the logic expressions. This reduces the design time and increases dependability.

The GUI also allows for downloading industry standard COMTRADE files for analysis of stored oscillography data. Detailed analysis of the oscillography files may be accomplished using BESTWAVE software. For more information on Basler Electric's Windows based BESTCOMS (GUI) software, refer to Section 14, *BESTCOMS™ Software*.

Getting Started

Connections

Figure 12-25, in Section 12, *Installation,* shows typical external dc control connections. If your relay has Power Supply Option 1 or 2, it can be supplied by normal 120 V ac house power. These two power supply options (1 and 2) are the midrange and high range AC/DC power supplies. The contact sensing inputs are half-wave rectified opto-isolators. The default contact recognition and debounce settings enable their use on ac signals as well as dc signals.

Section 12 also shows typical external ac sensing connections. The relay measures the A phase, B phase, and C phase current magnitudes directly from the three current sensing inputs on Circuit #1 (this is dependent on style configuration). Circuit #2 measures the A phase, B phase, and C phase current magnitudes directly from the three current sensing inputs. The neutral and negative-sequence magnitudes are calculated from the fundamental component of each of the three-phase currents. When evaluating the negative-sequence functions, the relay can be tested using a two-phase current source. To fully evaluate the operation of the relay in the power system, it is desirable to use a three-phase current source.

Connect a computer to the front RS-232 port (refer to Section 12, *Installation*, for connection diagrams). Apply power and set the clock using the RG-TIME= and RG-DATE= commands (refer to Appendix C, *Terminal Communication*, and Section 11, *ASCII Command Interface*, for additional information).

Entering Test Settings

Use BESTOMS to enter test settings (see Section 14, *BESTCOMS Software,* for details) or enter SG (Set General) to get a listing of the general setting commands with default parameters and put them in a text file as described previously in *Batch Command Text File Operations*. Then enter S0 (Setting Group Zero) to get a listing of the Setting Group 0 protection setting commands with default parameters and put them in a text file. With these two subgroups of settings, you will not see the global security settings, user programmable BESTlogic settings, settings for protection Setting Groups 1, 2, and 3, settings for alarm functions, and the settings for breaker monitoring functions.

Open the SG file in a text editor, change settings as required, and save the changes. For example:

- The ratios for the phase and neutral current transformers (CT2, CTG).
- The demand interval and CT circuit to monitor for the phase, neutral and negative-sequence currents (DIP, DIN, DIQ).
- The nominal system frequency (FREQ).
- The normal phase-sequence (ABC or ACB) for the system (PHROT).

Open the S0 file in a text editor, change settings, as required, and save the changes. For example:

- The differential taps setting by putting the 87 function in manual and selecting tap values (87).
- The pickup, time dial, and curve for the 51 functions (51P, 51N, 51Q).

While editing this file, it is necessary to set a logic scheme to be active using the SL-N= (Set Protection LOGIC) command. The default setting is BASIC-87, which means that several protection elements are enabled and interconnected but are disabled with settings of zero. See Section 8, *Application*, for diagrams that describe the BASIC-87 logic scheme.

Enter A= to gain setting access and then send each of these text files to the relay as described above under *Batch Command Text File Operations*. Do not forget to add E;Y (Exit; Save Settings? Yes) to the end of both files.

As you gain knowledge of the relay, you can experiment with the rest of the settings. To set up a file with all user settings, enter S and the relay will respond with all settings in command format. The acceptance test procedure in Section 13, *Testing and Maintenance*, provides a basic procedure for creating a file with all user settings.

Checking the State of Inputs

Section 8, *Application*, shows the Basic Differential (CDS240-BA87-A-BD) logic diagram. Review this logic to help understand the following discussion. In this scheme, IN1 and IN2 are being used to show the position of the breakers in the sequence of events record (SER). Input 3 is showing the status of the 86 lockout relay. Inputs 6 to 8 can be used for alarm annunciation. You can quickly review the state of the inputs in three different ways: one, through the front panel HMI, two, using the ASCII command interface, or three using BESTCOMS, *Metering* screen.

The front panel HMI displays the input status on Screen 1.4.1, *\STAT\OPER\INPUT*. A diagram showing all of the menu tree branches is located in Section 10, *Human-Machine Interface*. To get to this screen, press the *Up* scrolling pushbutton until you reach the top screen in the current branch. You know when you have reached the top screen because the screen stops changing when you press the *Up* scrolling pushbutton. From this position, press the *Right* scrolling pushbutton until you have reached the screen titled, *\STATUS BE1-CDS240 REPORT STATUS*. From this position, press the *Down* scrolling pushbutton one time (*\STAT\TARGETS*) and press the *Right* scrolling pushbutton three times. At this time, you should see the OPERATIONAL STATUS Screen, *\STAT\OPER_STAT*. If you press the *Down* scrolling pushbutton from this screen, you should see the INPUTS Screen, *\STAT\OPER\INPUT*.

Another method would be to use the ASCII command interface. One command that you can use to see the status of the inputs is RG-STAT. Another command is RG-INPUT. This command will only read the status of the inputs and nothing else.

Testing

To determine if the relay is responding correctly to each test, the following commands are useful.

- RG-TARG, (report general targets): reports the targets from the last fault.
- RF, (report faults): reports a directory listing of the twelve fault summary reports. The fault summary reports are numbered from 1 to 255, then wrap around, and start over. RF-### reports the ### report.
- RS-##, (report sequence of events record), ## events: reports the most recent ## changes of state in the protection and control logic.

FAQ/Troubleshooting

Frequently Asked Questions (FAQs)

1.) Will the *Trip* LED reset after pressing the *Reset* key on the front panel?

The *Reset* key is context sensitive. To reset the *Trip* LED or the targets, the *Targets* screen must be displayed. To reset the alarms, the *Alarms* screen must be displayed.

2.) Is the power supply polarity sensitive?

No, the power supply will accept either an ac or dc voltage input. However, the contact sensing for the programmable inputs is polarity sensitive. See Section 12, *Installation*, for a typical inter-connection diagram.

3.) What voltage level is used to develop current flow through the contact sensing inputs?

Voltage level is dependent on the power supply option (BE1-CDS240 style) and the position of the contact-sensing jumper. See Section 12, *Installation*, for additional information.

4.) How can the BE1-CDS240 be configured into a simple transformer differential relay?

Two preprogrammed schemes perform this function. One is CDS240-BA87-A-BE from the BESTCOMS logic library (Basic Differential) and the other is the embedded logic scheme CDS240-BATX-A-BE (Basic Transformer). See Section 8, *Application*, for additional information.

5.) How can the BE1-CDS240 be configured into a generator differential relay?

The BE1-CDS240 can be configured into a generator differential relay by loading the preprogrammed logic scheme CDS240-BA87-A-BE from the BESTCOMS library. You may disable the 2nd and 5th harmonic functions by setting these thresholds to zero. See Section 8, *Application*, for additional information.

6.) Do I have to connect my current transformers in a special way to compensate for the phase shift between the high side and low side of a transformer?

No, the BE1-CDS240 can compensate for phase shift. See Section 3, *Input and Output Functions*, for additional information.

7.) Should I be concerned about zero-sequence blocking in my CT connections?

No, the BE1-CDS240 can compensate for zero-sequence blocking. See Section 3, *Input and Output Functions*, for additional information.

8.) Does the BE1-CDS240 trip output contact latch after a fault?

The answer to the question is Yes and No. In general, once the fault goes away the output contacts open. The BE1-CDS240 does offer an option to ensure that the contact will stay closed for at least 200 milliseconds. See Section 3, *Input and Output Functions*, for additional information on that function. However, BESTlogic can latch the relay outputs. See Section 8, *Application*, *Application Tips,* for additional information.

9.) A function will not work when I put in settings such as the pickup and time delays.

Make sure that the logic function is enabled.

10.) How many overcurrent elements does the BE1-CDS240 have available?

The BE1-CDS240 has seventeen instantaneous overcurrent and thirteen time overcurrent elements. Just like any element, each of these elements can be assigned to any output for building logic equations.

11.) Can I make logic settings at the front panel?

No, the front panel cannot program logic settings. Logic settings must be programmed using the ASCII command interface or BESTCOMS communication software.

12.) Since the BE1-CDS240 is a programmable device, what are the factory defaults?

The factory default logic is BASIC-87 logic. Default settings are shown with each function in the instruction manual. For input or output default settings see Section 3, *Input and Output Functions*. For protection and control functions, see Section 4, *Protection and Control*.

13.) Does the BE1-CDS240 have a battery installed as the back-up power source for the internal clock on loss of power?

Yes, as an option. The relay also uses a capacitor as a back-up power source for the internal clock on loss of power. This design maintains the clock for at least eight hours. See Section 1, *General Information, Specifications*, for additional information.

14.) Since the BE1-CDS240 has overcurrent elements in addition to the differential protection functions, are the timing curves the same as Basler Electric's other numeric overcurrent relays?

Yes, the timing curves are the same as other Basler Electric numerical overcurrent relays such as the BE1-851, BE1-951, and BE1-IPS100.

15.) Why do I keep getting access conflict errors when I am communicating with the relay?

If you have tried to gain access to more than one port at a time, an access conflict results. The unit has three different communication ports. The front HMI and front RS-232 are considered the same port and are the first port (COM 0). The rear RS-232 (COM 1) is the second and the rear RS-485 (COM 2) is the third port. If you have gained access at the front panel HMI and the 5-minute timeout has not ended, you cannot gain access at another port. The front RS-232 can still be accessed because the HMI and front RS-232 are considered the same port. Access needs to be gained only when a write to the BE1-CDS240 is required (control or setting change or report reset). Data can be read and reports can be obtained without gaining access. After gaining access though one of the ports, the session can be ended with the Exit command. If access is gained, but the session is not ended, a 5-minute timeout will end the session and any changes that were not saved will be lost. If you are using the BESTCOMS program, the access and exit commands are executed for you.

16.) Why doesn't the trip LED behave as expected when the relay picks up and trips? A closely related question would be why don't the targets work?

If the logic is setup to the point were the protective element is tripping at the desired current level, but the targets, trip LED, and fault records are not behaving as expected, then there are two commands (SG-TRIGGER and SG-TARGET) that need to be checked for proper operation. The SG-TRIGGER command needs to have the PU trigger and TRIP trigger logic correctly programmed. This should initiate the fault record. The SG-TARGET command needs the protective element (function) enabled to log targets. See Section 6, *Reporting and Alarms, Fault Reporting*, to get more details on how to correctly program these commands. The trip LED has two different functions in the relay. When the SG-TRIGGER PU expression is true and the TRIP expression is false, the trip LED flashes. When both the SG-TRIGGER PU and TRIP expression are true, the trip LED lights solidly. When neither expression is true, the trip LED lights solidly if there are latched targets. A flashing LED means one of the protection elements is in a picked-up state and timing towards trip. Once the trip occurs, the LED turns on solidly. The LED will not change state until the target has been reset. If the fault has not cleared, the LED turns on again. Table 2-2 is a truth table for the Trip LED and it should help to interpret the LED indications.

Table 2-2. Trip LED Truth Table

Trip	PU	Targets	LED
0	0	0	Off
0	0	1	On
0	1	0	Flash
0	1	1	Flash
1	0	0	On
1	0	1	On
1	1	0	On
1	1	1	On

17.) Is the IRIG signal modulated or demodulated?

The IRIG signal is demodulated (dc level-shifted digital signal). See Section 1, *General Information;* Section 6, *Reporting and Alarms;* and Section 12, *Installation*, for additional information.

18.) Can the IRIG signal be daisy-chained to multiple BE1-CDS240 units?

Yes, multiple BE1-CDS240 units can use the same IRIG input signal by daisy-chaining the BE1-CDS240 inputs. The burden data is non-linear, approximately 4 kilo-ohms at 3.5 Vdc and 3 kilo-ohms at 20 Vdc. See Section 1, *General Information;* Section 6, *Reporting and Alarms;* and Section 12, *Installation*, for additional information.

19.) How can I find out the version number of my BE1-CDS240?

The application version can be found in three different ways.

1) Use the HMI, Screen 4.6.
2) Use the ASCII command interface with the RG-VER command.
3) Use BE1-CDS240 BESTCOMS (the version is provided on the *General Operation* Screen, *Identification* Tab).

20.) How are reports and other information obtained from the relay saved in files for future use?

Through BESTCOMS, select print from the dropdown menu and then select RTF export, which allows the user to save the file to any location. In addition, text transferred from the relay to your terminal emulation software can be selected and copied to the clipboard. The clipboard contents are pasted into any word processor such as Microsoft® Notepad and saved with an appropriate file name.

SECTION 3 • INPUT AND OUTPUT FUNCTIONS

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SECTION 3 • INPUT AND OUTPUT FUNCTIONS

General

BE1-CDS240 relays have four sets of three-phase current measurement inputs, an ground current measurement input, a three phase voltage measurement input, up to twelve contact sensing (programmable) inputs, four trip coil monitor inputs, up to fourteen general purpose output contacts, and one dedicated, fail-safe alarm output contact. Each input and output is isolated and brought out to separate terminal blocks. This section describes the functioning and setup of these inputs and outputs.

Power System Inputs

Power system inputs as described in the introduction, are sampled 144 times per cycle by the BE1-CDS240. The BE1-CDS240 measures the voltage and current from these samples and uses those measurements to calculate other quantities. Of the 144 samples, 24 samples per cycle are used to find fundamental, 2nd, and 5th harmonic components. Frequency is measured from zero crossing detectors on both the voltage and current inputs (details below). Measured inputs are then recorded every quarter cycle. The BE1-CDS240 measures the frequency and varies the sampling rate to maintain 144 samples per cycle. Frequency compensation applies to all power system measurements. Power system inputs are broken down in the following paragraphs into Current Measurement, Voltage Measurement, Frequency Measurement, and Measurement Functions Setup. After the power system inputs are discussed, the paragraphs on Power Calculations discuss calculating power quantities.

Current Measurements

Currents from the secondary of CTs in power system equipment are applied to internal current transformer primaries. The internal current transformers provide isolation from the monitored line currents and step the currents down to internal circuit levels. Secondary current from each internal CT is converted to a voltage signal, and filtered by an analog, low-pass, anti-aliasing filter.

Current Measurement Functions

The input waveforms are sampled by an analog-to-digital converter (ADC) at 144 samples per cycle and digitally filtered in a DSP (digital signal processor) using an FIR (finite impulse response) anti-aliasing filter algorithm. This high sampling rate allows the analog filter to have a high cutoff point, which virtually eliminates errors from the analog filter elements. The output from the digital filter is sample data reduced to 24 samples per cycle. From the digitally filtered samples, the relay extracts the magnitude and angle of the fundamental, second harmonic, and fifth harmonic components of each three-phase input and the fundamental of the optional independent ground current input.

Compensated Restraint and Operate Currents for Differential Protection

As described in Section 1, *General Information*, it is necessary to provide phase angle, zero-sequence, and tap compensation to the measured currents prior to their use by the differential protection. The current measurement function calculates compensated currents for restraint and operate currents and for second and fifth harmonic operate currents. Tap compensation setup is covered in Section 4, *Protection and Control, Differential Protection, 87 Differential Function*.

Neutral and Negative-Sequence Current Measurement

The BE1-CDS240 relay also calculates the neutral and negative-sequence components from the fundamental component of each of the three-phase current inputs. The relay can be set to accommodate either ABC or ACB phase-sequence in calculating the negative-sequence component.

Fast-Dropout Current Detector

The relay includes a separate, fast-dropout current measurement algorithm for use by the breaker failure function and the breaker trip speed monitoring function. This measurement algorithm has a sensitivity of 10% nominal rating and detects the interruption of current in the circuit breaker in less than a ½ cycle.

Virtual Circuit Measurement Functions

The BE1-CDS240 provides two sets of “virtual circuits.” These circuits are formed by computing the phasor sum of the actual analog current inputs. (**Note:** The current circuits being summed **must** have the same CT ratio.) The virtual circuits are user configurable to sum either two or three of the analog inputs. For each virtual circuit, the BE1-CDS240 calculates the summation and provides a sum for A, B, C phase currents, negative-sequence current, and neutral current. The virtual currents can be used throughout the BE1-CDS240 for any protective or metering function that accepts a circuit selection setting. Virtual circuits are referred to as Circuits 5 and 6.

Voltage Measurement

Three-phase voltage inputs are reduced to internal signal levels by a precision resistor divider network.

Voltage Measurement Functions

The input waveforms are sampled by an analog-to-digital converter (ADC) at 144 samples per cycle and digitally filtered in a DSP (digital signal processor) using an FIR (finite impulse response) anti-aliasing filter algorithm. This high sampling rate allows the analog filter to have a high cutoff point, which virtually eliminates errors from the analog filter elements. The output from the digital filter is sample data reduced to 24 samples per cycle. The relay extracts the magnitude and angle of the fundamental components of each three-phase voltage inputs.

VT Connections

When four-wire VT connections are used, the relay measures the AN, BN, and CN voltages and calculates the phase voltage quantities. Overvoltage and undervoltage functions (27/59) can be set to operate on either the phase-to-neutral (PN) or phase-to-phase (PP) quantities. Three-wire VT connections limit 27/59 operation to PP quantities. When single-phase VT connections are used, the 27/59 elements operate as appropriate for the single-phase voltage applied.

Zero-Sequence (V_0)Voltage

When four-wire VT connections are used, the BE1-CDS240 calculates the zero- sequence voltage. Zero-sequence voltage measurement is not available when single-phase or three-wire VT connections are used. The metering and protection elements utilize $3V_0$ quantities.

Negative-Sequence (V_2) Voltage

Negative-sequence voltage is calculated from the fundamental component of the three-phase voltage inputs. It is only available on three-phase, three-wire or three-phase, four-wire systems. V_2 is calibrated to the phase-to-neutral base. The effect is that the relay reports the same V_2 independent of whether the relay is in 3-wire or 4-wire mode. The metering and protective functions utilize V_2, not $3V_2$. Negative-sequence measurements can accommodate either ABC or ACB phase-sequence.

Positive-Sequence (V_1) Voltage

Positive-sequence voltage is calculated from the fundamental component of the three-phase voltage inputs. It is only available on three-phase, three-wire or three-phase, four-wire systems. V_1 is calibrated to the phase-to-neutral base. The effect is that the relay reports the same V_2 independent of whether the relay is in 3-wire or 4-wire mode. The metering functions utilize V_2, not $3V_2$. Positive-sequence measurements can accommodate either ABC or ACB phase-sequence.

Frequency Measurement

Power system frequency is monitored on the A-N voltage input or the AB voltage input when in three-wire mode and on A-phase current circuit one. When the applied signal is greater than 10 volts, or 0.5 amps (0.1 amps for 1 A CTs) the BE1-CDS240 measures the frequency. The measured frequency on the voltage input is used by the 81 function and applies to all measurements and calculations; the current input is used in the sampling rate determination.

Frequency Compensation

Using the frequency measured on the voltage input, the BE1-CDS240 varies the sampling rate to maintain 144 samples per cycle over a frequency of 40 to 63 hertz. If the voltage is too low for accurate frequency measurement, or if the measured frequency is out of range, the frequency measured on the current input is used to maintain the sample rate. If both voltage and current are too low or out of range the ADC defaults to a sampling rate appropriate for the relay’s nominal frequency setting. Protection is still provided for all functions except for negative-sequence current and voltage and volts/hz, but metering and harmonic analysis accuracy is degraded. The sampling rate is adjusted every 50 milliseconds.

Nominal Frequency

F_{nom} can be set for 20 to 60-hertz power systems. When the voltage and current are too low for reliable frequency measurement, the ADC sample rate defaults to operation at the nominal frequency setting. Nominal frequency is also used in the volts/hertz (24) overexcitation calculation.

Power Measurement

The measured fundamental component of current and voltage as described previously in this section, is used to calculate the power per the following equations. The current input used for power calculations is user selectable between any of the CT inputs or virtual circuit inputs.

For four-wire VT connection:

$$WATTs_{3\Phi} = V_A I_A \cos(\Phi_A) + V_B I_B \cos(\Phi_B) + V_C I_C \cos(\Phi_C) + V_C I_C$$ *Equation 3-1*

$$VARs_{3\Phi} = V_A I_A \sin(\Phi_A) + V_B I_B \sin(\Phi_B) + V_C I_C \sin(\Phi_C)$$ *Equation 3-2*

where $\Phi_x = \angle V_x - \angle I_x$

For three-wire VT connection, with ABC phase-sequence:

$$WATTs_{3\Phi} = V_{AB} I_A \cos(\Phi_A) + V_{CB} I_C \cos(\Phi_C)$$ *Equation 3-3*

$$VARs_{3\Phi} = V_{AB} I_A \sin(\Phi_A) + V_{CB} I_C \sin(\Phi_C)$$ *Equation 3-4*

where $\Phi_x = \angle V_{xy} - \angle I_x$

For three-wire VT connection, with ACB phase-sequence:

$$WATTs_{3\Phi} = V_{AC} I_A \cos(\Phi_A) + V_{BC} I_B \cos(\Phi_B)$$ *Equation 3-5*

$$VARs_{3\Phi} = V_{AC} I_A \sin(\Phi_A) + V_{BC} I_B \sin(\Phi_B)$$ *Equation 3-6*

where $\Phi_x = \angle V_{xy} - \angle I_x$

For AN, BN, or CN VT connection:

$$WATTs_{3\Phi} = 3 \text{ x } V_x I_x \cos(\Phi_x)$$ *Equation 3-7*

$$VARs_{3\Phi} = 3 \text{ x } V_x I_x \sin(\Phi_x)$$ *Equation 3-8*

where x = A, B, or C based on sensing type and $\Phi_x = \angle V_x - \angle I_x$

For AB, BC, or CA VT connection, with ABC phase-sequence:

$$WATTs_{3\Phi} = \sqrt{3} \text{ x } V_{xy} I_x \cos(\Phi - 30°)$$ *Equation 3-9*

$$VARs_{3\Phi} = \sqrt{3} \text{ x } V_{xy} I_x - \sin(\Phi - 30°)$$ *Equation 3-10*

where x and y = A, B or C based on sensing type and $\Phi = \angle V_{xy} - \angle I_x$

For AB, BC, or CA VT connection with ACB phase-sequence:

$$WATTs_{3\Phi} = \sqrt{3} \text{ x } V_{xy} I_x \cos(\Phi + 30°)$$ *Equation 3-11*

$$VARs_{3\Phi} = \sqrt{3} \text{ x } V_{xy} I_x - \sin(\Phi + 30°)$$ *Equation 3-12*

where x and y = A, B or C based on sensing type and $\Phi = \angle V_{xy} - \angle I_x$

Measurement Functions Setup

Table 3-1 lists the measurement functions settings.

Table 3-1. Power System Measurement Function Settings

Setting	Range	Increment	Unit of Measure	Default
Nominal Frequency	20 to 60	1	Hertz	60
Phase Rotation	ABC, ACB	N/a	N/a	ABC
Nominal Voltage	50 - 250	1	Sec volts	69.3
Nominal Current	0.1 – 2 A for 1 A CT 0.5 – 10 A for 5 A CT	0.01	Sec amps	1 A 5 A
VTP Setup, VT Ratio	1 - 10000	0.01	Turns ratio	1
VTP Setup, Connection	3W, 4W, AN, BN, CN, AB, BC, CA	N/a	N/a	4 W
VTP Setup, 27/59 Mode	PP, PN	N/a	N/a	PP
VTP Setup, 27R Mode	PP, PN	N/a	N/a	PP
VTP Setup, Winding	1 - 6	1	N/a	1
VTP Setup, Polarity	Normal or Reverse	N/a	N/a	Normal
CT Ratio, Inputs 1 - 4	1 - 50,000	1	Turns	1
CT Connection, Inputs 1 - 4	WYE, DAB, DAC, GND ∗	N/a	N/a	Wye
CT Ratio, Independent Ground Input	1-50,000	1	Turns	1
Trans. Connection, Inputs 1 - 4	WYE, DAB, DAC, ZAB, ZAC, NA, GND	N/a	N/a	Wye
Ground Source, Inputs 1 - 4	0 = No, 1 = Yes	N/a	N/a	0
Trans. Rotation Comp, Inputs 1 - 4	A, B, C	N/a	N/a	A
Trans Differential Circuit, Inputs 1 - 4	P, S, N	N/a	N/a	P
Virtual Circuit Setup	0 - 13	1	N/a	0

∗ GND is valid for CT 4 input only when configuring the BE1-CDS240 for a 2nd independent ground input.

Power System / VT Setup

To enter Power System or VT settings, select *General Operation* from the *Screens* pull-down menu. Then select the *Power System / VT Setup* tab. Refer to Figure 3-1.

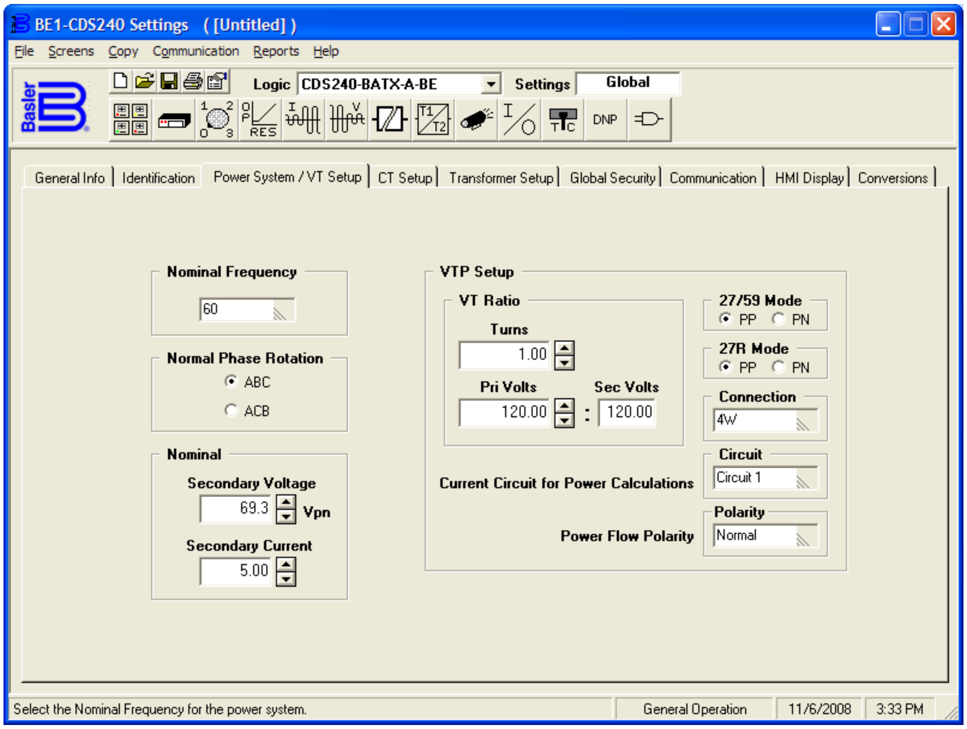


Figure 3-1. General Operation Screen, Power System/VT Setup Tab

Nominal Frequency. When the voltage and current signals are too low for the frequency to be reliably measured, the ADC circuit defaults to operation at the nominal frequency setting. This can be set for operation from 20 to 60-hertz power systems using BESTCOMS™, the optional HMI using Screen 6.3.2, SETUP\PWR_S\FREQ, and from the ASCII command interface using the SG-FREQ (settings general-frequency) command.

Normal Phase Rotation. The normal phase-sequence setting can be entered using BESTCOMS, the optional HMI using Screen 6.3.3, SETUP\PWR_S\P_SEQ, and from the ASCII command interface using the SG-PHROT command.

Nominal Secondary Voltage and *Current Settings,* Vnom and Inom, are used for the 60FL function and DNP3 analog event reporting functions. Vnom is also used in the volts/hertz (24) calculation and Inom is also used in the 46 time curve calculation (K factor) of the negative-sequence current (51Q) element.

In the BE-CDS240, Vnom is defined as the secondary phase-neutral voltage for all sensing connections. That is, even if the user has selected 3-wire, AB, BC or CA phase-phase sensing connections, Vnom must be set for the phase-neutral equivalent. For example, if a 3-wire open delta voltage source with a phase-phase voltage rating of 120 volts is connected, the nominal voltage must be set at 120/ $\sqrt{3}$ or 69.3 volts. Inom can be either the secondary rating of the CT (1 or 5 amp) or the secondary current allowed by the CT ratio.

In BESTCOMS for the BE1-CDS240, under *General Operation, Power System/VT Setup,* are settings for Nominal Voltage and Current. Settings can also be made from the ASCII command interface using the SG-NOM command. *Nominal Voltage (Vnom)* is the nominal voltage rating corresponding to 1 pu volts and is configured as a phase-neutral secondary value.

Nominal Current (Inom) is the nominal phase current rating for the system corresponding to 1 pu current and is configured in secondary amps. If 1 pu secondary current is unknown, then setting Inom to the secondary CT rating (1 or 5 A) is acceptable for most applications. However, this could degrade the expectation (not accuracy) of the time curve for the 51Q element as Inom is used to directly compute multiple of pickup (MOP) and time delay.

Dependency of other relay system elements on 1 pu Inom is far less critical and using the CT secondary rating will have little functional impact.

VTP Setup, VT Ratio. The BE1-CDS240 requires setting information about the VT ratio, the VT connections, the operating modes for the 27/59 and 51/27R functions, the current circuit that is used to compute power, and power flow polarity. These settings are used by the metering and fault reporting functions to display the measured quantities in primary units. The voltage input circuit settings also determine which power measurement calculations are used. Most of these connections such as 3W, 4W, AN, or AB are self-explanatory. These settings can be made using BESTCOMS, the optional HMI using Screen 6.3.1.1, \SETUP\PWR_S\CONN\VTP, and from the ASCII command interface using the SG-VTP command.

CT Setup

To enter settings for CT Inputs 1–4, select *General Operation* from the *Screens* pull-down menu. Then select the *CT Setup* tab. Refer to Figure 3-2.

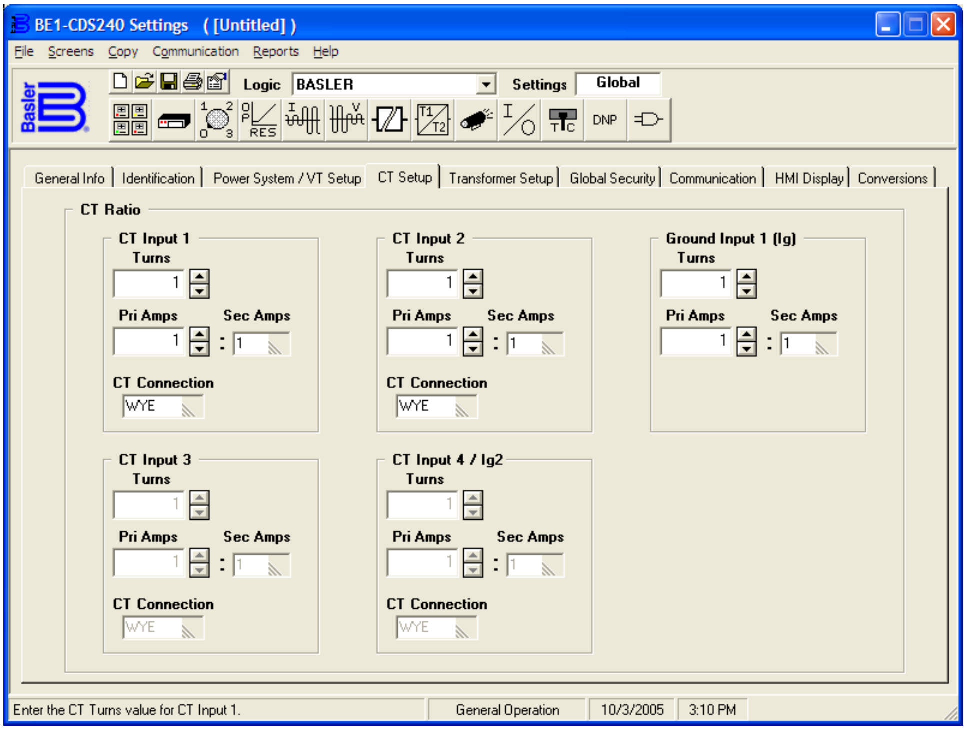


Figure 3-2. General Operation Screen, CT Setup Tab

Current Input Circuit Settings Setup. The BE1-CDS240 relay requires information on the CT connections and the characteristics of the protected zone. For each three-phase CT input circuit, it is necessary to enter the CT ratio and the CT connection. It is also necessary to enter the transformer connection (if applicable), whether there is a ground source, the phase relationship as compared to other circuits, and if the circuit is included in the differential calculation.

Each set of three-phase CTs can be connected in wye or one of two delta configurations as shown in Figure 3-3. As described in Section 1, *General Information, Differential Protection Application Considerations*, wye CT connections are recommended for most applications. The CT ratio should always be entered as the actual ratio and not the effective ratio. When the CTs are connected in delta, the secondary current under balanced conditions is increased by a factor of the square root of three, yielding an effective ratio that is lower than the actual CT ratio. The BE1-CDS240 automatically takes this factor into account so it is not necessary for the user to manually compensate when entering the CT ratio.

CT input circuit settings can be made using BESTCOMS, the optional HMI using Screen 6.3.1.2, \SETUP\PWR_S\CONN\CTP, and from the ASCII command interface using the SG-CTP command.

The BE1-CDS240 relay is equipped with an independent ground current input. The CT ratio must also be entered for that input. Ground input settings can be made using BESTCOMS, the optional HMI using Screen 6.3.1.4, \SETUP\PWR_S\CONN\CTG, and from the ASCII command interface using the SG-CTG command.

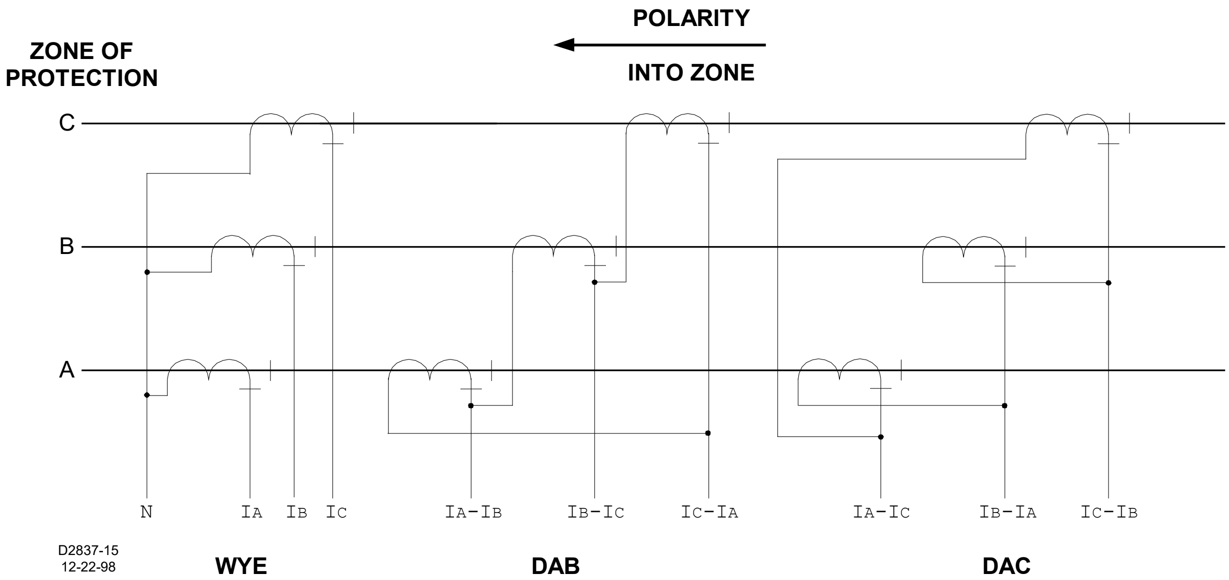


Figure 3-3. CT Connections

Transformer Setup

To enter Transformer settings, select *General Operation* from the *Screens* pull-down menu. Then select the *Transformer Setup* tab. Refer to Figure 3-4.

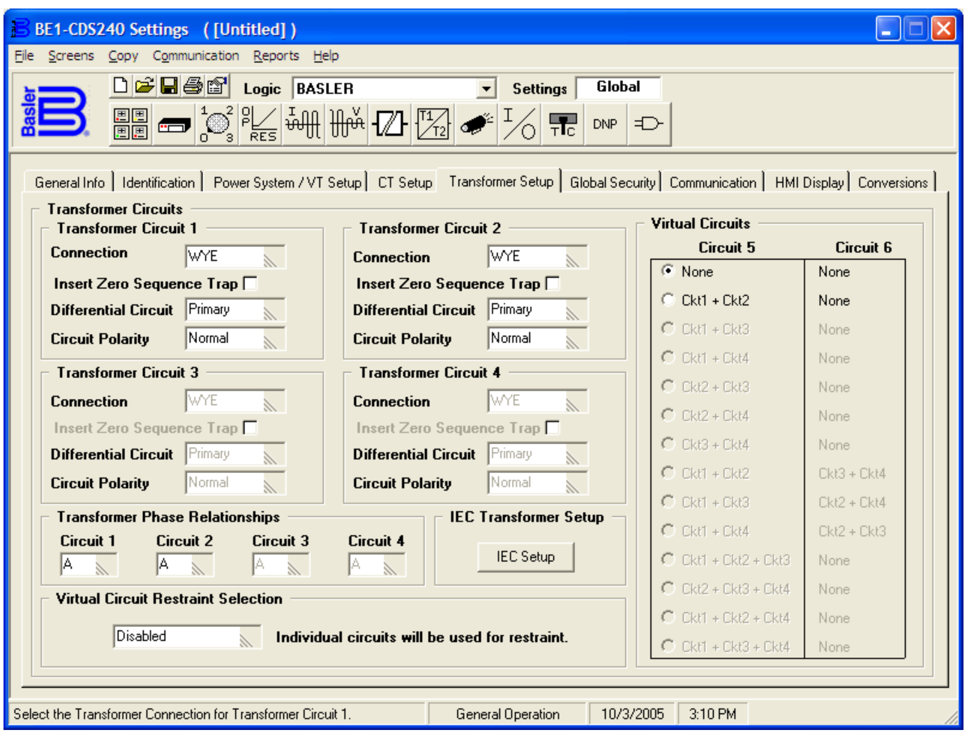


Figure 3-4. General Operation Screen, Transformer Setup Tab

Use the pull down menus and check boxes to setup transformer circuits. Settings can also be made using the HMI Screen 6.3.1.3, \SETUP\PWR_S\CONN\TXC, or from the ASCII command interface using the SG-CKT command. For each circuit, you can set *Connection, Insert Zero Sequence Trap, Differential Circuit,* and *Circuit Polarity.* You can also set *Transformer Phase Relationships, Individual circuits to be used for restraint,* and *Virtual Circuits.*

As described in Section 1, *General Information, Differential Protection Application Considerations*, when the zone of protection includes a transformer, it may be necessary to provide phase angle and zero sequence compensation to the currents used by the differential protection elements (see Figure 3-5). For each input circuit, a setting is provided to enter the transformer connections associated with that input. If there is no transformer within the protected zone, this setting should be set to *NA (not applicable)*.

Determining the Transformer Connection Parameters

Wye and Autotransformer Windings. The transformer connection for a CT input circuit that is connected to either a wye or autotransformer winding should be classified as a wye winding.

Delta Transformer Windings. The transformer connection for a CT input circuit that is connected to a delta winding could be classified as one of two delta connections: Delta IA-IB (DAB) or Delta IA-IC (DAC). A delta configuration is defined by the currents that flow in the primary phases connected to the delta. The wye winding phase connections are used as the point of reference since the current that flows in the wye winding is the same as the current in the wye side primary phases. Figure 3-5a shows an example of a transformer with a DAB connection. Figure 3-5b shows an example of the same transformer with the phases reconnected to provide a DAC connection. If there is no wye winding to use as reference, as is the case with a delta/delta transformer, the definition of the delta configuration is not important.

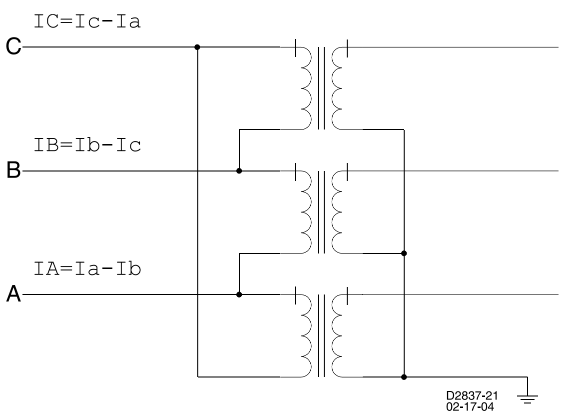


Figure 3-5a. DAB Delta

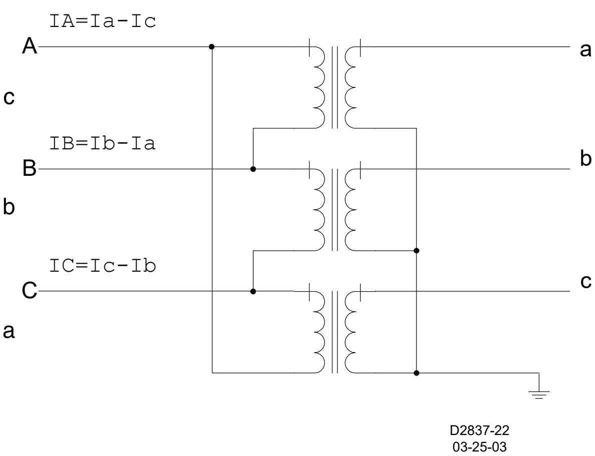


Figure 3-5b. DAC Delta

Figure 3-5. DAB/DAC Delta

With the appropriate CT and transformer connection information, the relay can automatically determine the correct compensation required. Normally, all circuits are compensated to obtain their equivalent delta currents. If all transformer windings and CTs are connected in wye, a special case exists and no compensation is required. For this case, wye currents can be used directly.

Total compensation is accomplished by summing the appropriate phasors from each of the CT inputs prior to using them in the differential function. For a WYE to DAB connection, the WYE CT phasors must first be phase-compensated to match the DAB circuit's 30° shift. This is done using the DAB compensator, which provides a phasor sum of Ia + Ib to form I'a for comparison to the DAB's Ia CT current. A similar operation is used to form I'b and I'c.

Total compensation uses six phase compensation factors: DAB, DAC, REV, Rotation Factors R1 and R2, WYE, and Double Delta DDAB. The compensation factors are used in various combinations to compensate for the ±30°, ±60°, ±90°, ±120°, ±150°, and ±180° phase shifts that are possible in transformers and sensing CT configurations.

Mathematically, the compensation factors provide the following:

Note: A 1/(square root of 3) factor is missing from the compensation equations. See Table 3-6 for the net compensation equations.

DAB: $\hat{I}'a = \hat{I}a - \hat{I}b$, $\hat{I}'b = \hat{I}b - \hat{I}c$, $\hat{I}'c = \hat{I}c - \hat{I}a$ (+30)

DAC: $\hat{I}'a = \hat{I}a - \hat{I}c$, $\hat{I}'b = \hat{I}b - \hat{I}a$, $\hat{I}'c = \hat{I}c - \hat{I}b$ (-30)

REV: $\hat{I}'a = -\hat{I}a$ $\hat{I}'b = -\hat{I}b$ $\hat{I}'c = -\hat{I}c$ (+180)

R1: $\hat{I}'a = \hat{I}c$, $\hat{I}'b = \hat{I}a$, $\hat{I}'c = \hat{I}b$ (+120)

R2: $\hat{I}'a = -\hat{I}b$, $\hat{I}'b = -\hat{I}c$, $\hat{I}'c = -\hat{I}a$ (+240)

DDAB: $\hat{I}''a = \hat{I}'a - \hat{I}'b$, $\hat{I}''b = \hat{I}'b - \hat{I}'c$, $\hat{I}''c = \hat{I}'c - \hat{I}'a$ (0 or +60)

The net effect of DDAB compensation is as follows:

$$\hat{I}''a = \hat{I}'a - 2\cdot\hat{I}'b + I'c \qquad \hat{I}''b = \hat{I}a + \hat{I}b - 2\cdot\hat{I}c \qquad \hat{I}''c = -2\cdot\hat{I}a + I\hat{b} + \hat{I}c$$

WYE: $\hat{I}'a = \hat{I}a$, $\hat{I}'b = \hat{I}b$, $\hat{I}'c = \hat{I}c$ (no compensation)

Tables 3-2, 3-3, 3-4, and 3-5 illustrate how the various phase compensation factors are applied to different winding and CT configurations.

The BE1-CDS240 can also compensate for phase “mismatch”. That is, if A phase of the incoming system is connected to the transformer primary H1 and A phase of the secondary system is connected to X2, the phases can be matched at the relay with this feature. Phase matching can be set through BESTCOMS, under *General Operation, Transformer Setup, Transformer Phase Relationships*.

Settings for the current measurement functions are provided in Tables 3-2 through 3-5. These tables indicate the transformer circuit, CT settings, and type of phase compensation applied for various transformer applications. The settings are indicated on a per circuit basis. A circuit consists of one of the transformer’s 3-phase windings and its corresponding set of 3-phase CT’s.

Table 3-2 indicates settings when applying the BE1-CDS240 in a non-transformer application. This table should be used for inputs that are not part of the transformer’s circuit. Applying CT circuit #4 for auxiliary ground is one possible example. The table also specifies the settings for a transformer case where all of the 3-phase windings and all of the 3-phase CTs are connected in wye.

Tables 3-3 and 3-4 are applied when a combination of delta and wye connections are present in the transformer and CT circuits. Table 3-3 is applied when only one type of delta connection is present in the transformer and CT circuits, such as DAB or DAC. This table is used for the majority of applications. If the application requires a combination of delta circuits, such as both DAB and DAC connections being present, Table 3-4 is applied. The only exceptions are when all CT and winding connections are wye as indicated above. Or, when one or more of the individual transformer windings are connected in delta or zigzag and has its corresponding CTs connected in delta.

Table 3-5 is applied when one or more of the individual transformer windings is connected in delta or zigzag and has its corresponding CTs connected in delta. The special connection can require up to two delta compensations for the other windings depending on the circuit’s configuration.

Table 3-2. CT Input Circuit Settings for Non-transformer or Wye-only Application

Transformer Connection	**CT Input Connection**	**BE1-CDS240 Settings**		**Compensation Applied**	
		TX	**CT**	**Phase**	**Rotation**
N/A	WYE	NA	WYE	WYE	NONE
	DAB	NA	DAB	WYE	NONE
	DAC	NA	DAC	WYE	NONE
	GND (CTCKT 4)	NA	GND	WYE	N/A
All WYE ∗	All WYE ∗	WYE	WYE	DAB	NONE

∗ Special case where all transformer windings and all CTs are connected in wye.

Table 3-3. CT Input Circuit Settings 1 for Delta/Wye Circuit Applications

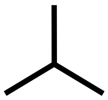
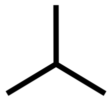
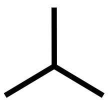
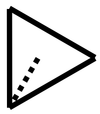
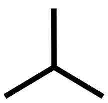
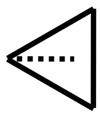
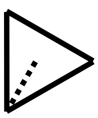
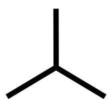
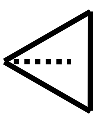
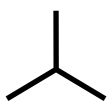
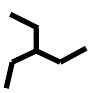
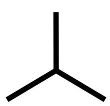
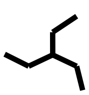
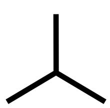
Transformer Connection	CT Input Connection	BE1-CDS240 Settings		Compensation Applied	
		TX	**CT**	**Phase**	**Rotation**
WYE 	WYE 	WYE	WYE	DAB for DAB connections DAC for DAC connections	NONE
WYE 	DAB 	WYE	DAB	WYE	NONE
WYE 	DAC 	WYE	DAC	WYE	NONE
DAB 	WYE 	DAB	WYE	WYE	NONE
DAC 	WYE 	DAC	WYE	WYE	NONE
ZAB 	WYE 	ZAB	WYE	WYE	NONE
ZAC 	WYE 	ZAC	WYE	WYE	R2

Table 3-4. CT Input Circuit Settings 2 for Delta/Wye Circuit Applications

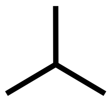
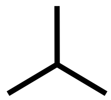
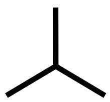
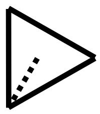
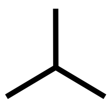
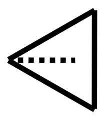
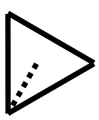
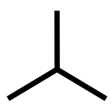
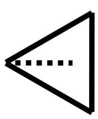
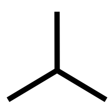
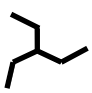
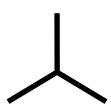
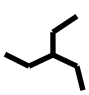
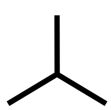
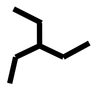
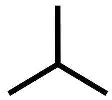
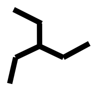
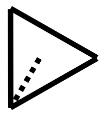
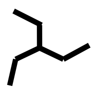
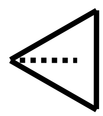
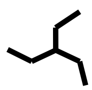
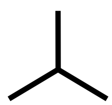
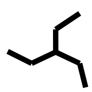
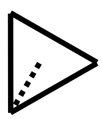
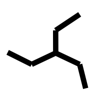
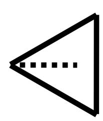
Transformer Connection	CT Input Connection	BE1-CDS240 Settings		Compensation Applied	
		TX	CT	Phase	Rotation
WYE 	WYE 	WYE	WYE	DAB	NONE
WYE 	DAB 	WYE	DAB	WYE	NONE
WYE 	DAC 	WYE	DAC	WYE	R2
DAB 	WYE 	DAB	WYE	WYE	NONE
DAC 	WYE 	DAC	WYE	WYE	R2
ZAB 	WYE 	ZAB	WYE	WYE	NONE
ZAC 	WYE 	ZAC	WYE	WYE	R2

Table 3-5. CT Input Circuit Settings 3 for Delta/Wye Circuit Applications

Transformer Connection	CT Input Connection	BE1-CDS240 Settings		Compensation Applied	
		TX	CT	Phase	Rotation
WYE	WYE	WYE	WYE	DDAB	NONE
WYE	DAB	WYE	DAB	DAB	NONE
WYE	DAC	WYE	DAC	DAB	R2
DAB	WYE	DAB	WYE	DAB	NONE
DAB	DAB	DAB	DAB	WYE	NONE
DAB	DAC	DAB	DAC	WYE	R2
DAC	WYE	DAC	WYE	DAB	R2
DAC	DAB	DAC	DAB	WYE	R2
DAC	DAC	DAC	DAC	WYE	R1

Transformer Connection	CT Input Connection	BE1-CDS240 Settings		Compensation Applied	
		TX	CT	Phase	Rotation
ZAB 	WYE 	ZAB	WYE	DAB	NONE
ZAB 	DAB 	ZAB	DAB	WYE	NONE
ZAB 	DAC 	ZAB	DAC	WYE	R2
ZAC 	WYE 	ZAC	WYE	DAB	R2
ZAC 	DAB 	ZAC	DAB	WYE	R2
ZAC 	DAC 	ZAC	DAC	WYE	R1

NOTE

The CT input circuit settings are used by the auto-tap calculation function to calculate the correct tap adjustment factor for the differential functions. When entering these settings via the ASCII command interface, the validation routine and auto-tap calculation is performed on exit after all parameters have been entered.

When entering these settings using the optional HMI, the validation routine and auto-tap calculation is performed on exit of each screen. This may cause an O*ut of Range* error message from the auto-tap calculation function. The user is advised to enter valid CT input circuit settings on Screen 6.3.1.1, SETUP\PWR_S\CON\CTP prior to entering the auto-tap calculation settings. If the user has previously set the auto-tap calculation settings and needs to change the CT input circuit settings, it may be necessary to temporarily change the auto-tap function setting to *manual* on Screens 5.1.1.3, 5.2.1.3, 5.3.1.3 and 5.4.1.3, \PROT\SG#\87\TAP in order to enter the new CT settings.

See Section 4, *Protection and Control, Phase Differential Protection,* for more information on the auto-tap calculation function.

See Section 4, *Protection and Control, Phase Differential Protection,* for more information on the auto-tap calculation function.

Additionally, as described in Section 1, *General Information, Differential Protection Application Considerations*, *Problem 5,* if there is a ground source within the protected zone, the user can apply a numerical, zero-sequence trap to remove the zero-sequence components from the current to prevent misoperation on external ground faults when a ground bank is in the zone of protection. This setting is optional. It is not required to enter a ground source setting of 1 to describe a grounded wye transformer connection. Even though not all grounded wye transformer connections are ground sources, the relay always assumes that a wye transformer connection is a ground source so that it is secure. Zero-sequence current unbalance can occur in three legged core transformers due to the phantom tertiary effect. In all cases, the relay chooses delta compensation for a wye transformer connection so that the zero-sequence components are blocked.

Figure 3-6 shows how the currents will be calculated for each set of current inputs for use by the phase differential protection function. The calculation is dependent upon the phase compensation chosen as shown in Tables 3-4, 3-5, and 3-6 and the ground source setting.

Table 3-6. Internal Compensation Chart

Compensation	Ground Source	A Phase	B Phase	C Phase
Wye (none)	0 = No	I_A	I_B	I_C
Wye (none)	1 = Yes	$I_A - I_0$	$I_B - I_0$	$I_C - I_0$
DAB	0 = No or 1 = Yes	$(I_A - I_B) / \sqrt{3}$	$(I_B - I_C) / \sqrt{3}$	$(I_C - I_A) / \sqrt{3}$
DAC	0 = No or 1 = Yes	$(I_A - I_C) / \sqrt{3}$	$(I_B - I_A) / \sqrt{3}$	$(I_C - I_B) / \sqrt{3}$
DDAB	0 = No or 1 = Yes	$(I_A - 2I_B + I_C) /3$	$(I_A + I_B - 2I_C) /3$	$(-2I_A + I_B + I_C) /3$

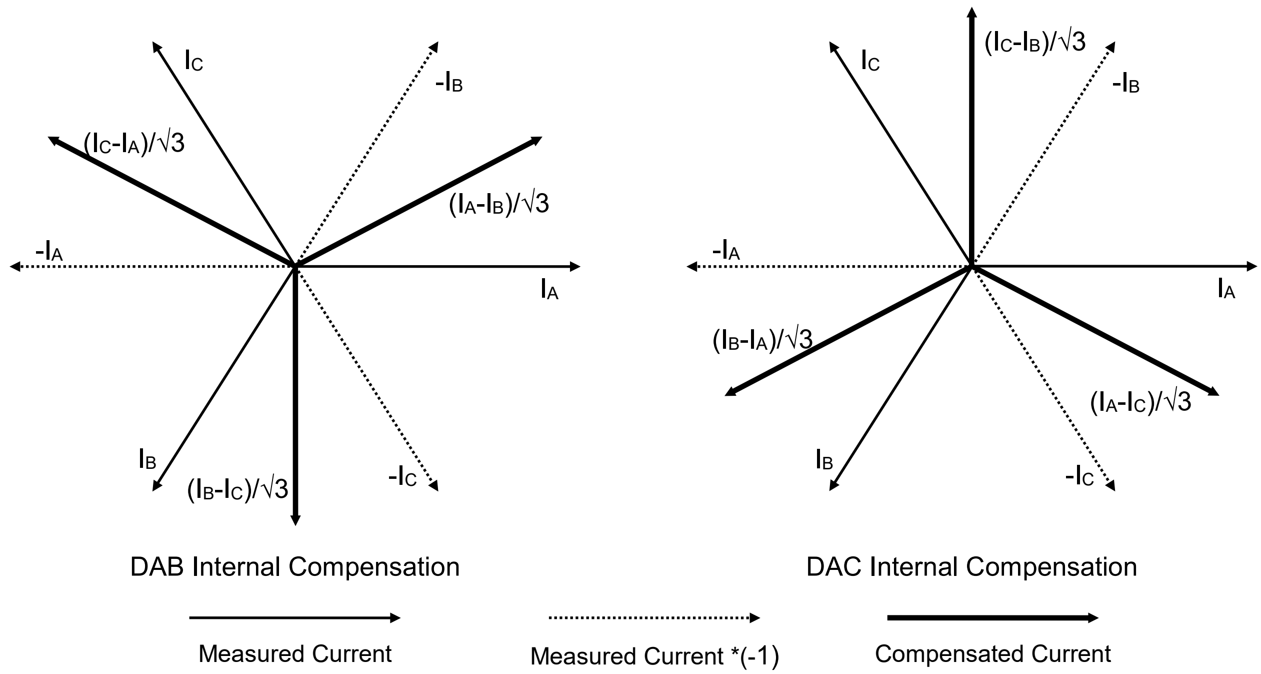


Figure 3-6. Internal Phase and Zero-Sequence Compensation

IEC Transformer Setup

Using BESTCOMS, navigate to the *General Operation, Transformer Setup* tab and select the *IEC Setup* button. On this screen (Figure 3-7), you can setup Windings 1 through 4. Press the *Save* button when finished.

The IEC setup table is aimed at describing transformers that use phase shifts and winding designs that are more commonly found outside the US market. As can be found in the IEC standards, phase and bushing names of U, V, W, will be used generally, rather than A, B, and C, or H and X. Specifying phase shift and transformer connection is accomplished with the D-Y-Z + clock method. For instance, a transformer connection will be Dy1 rather than a DAB/Y, though some dual designations will be used for clarity. The number associated with the winding (Dy1) can be almost any hour of the clock, hence the term “around the clock” phase shifting.

In transformer standards such as IEEE C57.12.00 and IEC-60076-1, there will be many variations on the nomenclature and figures used to show how the phases are identified in a three-phase system. For details on IEC transformer connections, go to www.basler.com and download the technical paper titled *Three Phase Transformer Winding Configurations and Differential Relay Compensation*, which was presented at the 2004 Western Protective Relay Conference.

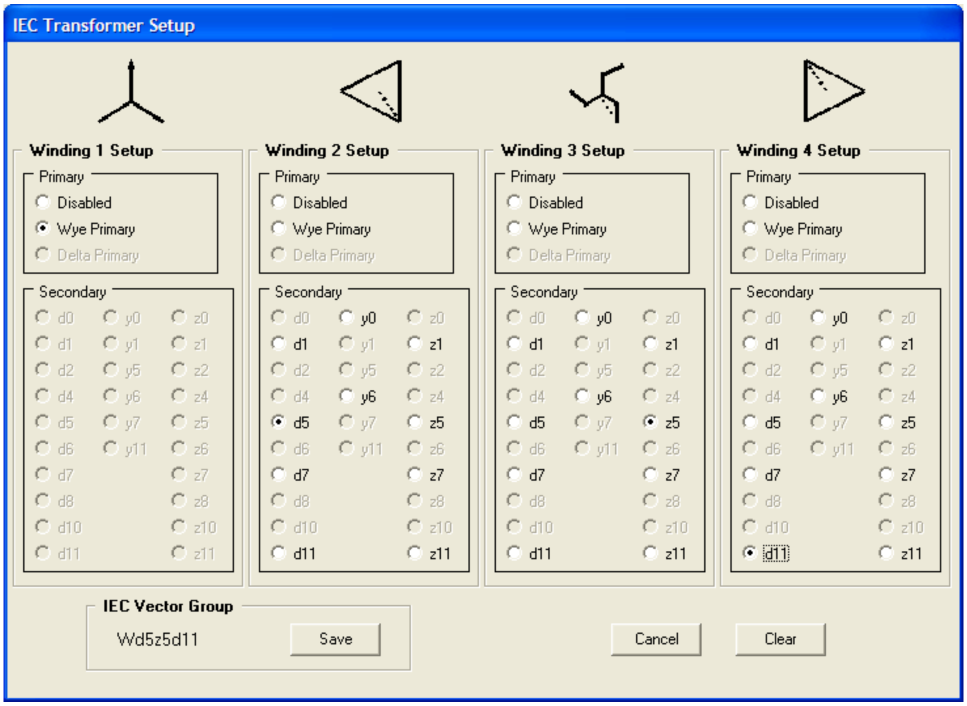


Figure 3-7. IEC Transformer Setup Screen

Contact-Sensing Inputs

BE1-CDS240 relays have eight or twelve contact-sensing inputs depending on style number to initiate BE1-CDS240 relay actions. These inputs are isolated and require an external wetting voltage. Nominal voltage(s) of the external dc source(s) must fall within the relay dc power supply input voltage range. To enhance user flexibility, the BE1-CDS240 relay uses wide range ac/dc power supplies that cover several common control voltage ratings. To further enhance flexibility, the input circuits are designed to respond to voltages at the lower end of the control voltage range while not overheating at the high end of the control voltage range.

Energizing levels for the contact-sensing inputs are jumper selectable for a minimum of approximately 5 Vdc for 24 Vdc nominal sensing voltages, 26 Vdc for 48 Vdc nominal sensing voltages, or 69 Vdc for 125 Vdc nominal sensing voltages. See Table 3-7 for the contact-sensing turn-on voltages.

Table 3-7. Contact-Sensing Turn-On Voltages

Style Option	Nominal Input Voltage	Contact-Sensing Turn-On Voltage *		
		Jumper (L) (Low Position)	Jumper (H) (High Position)	Jumper Not Installed
xxxx1xxxxxx	48 Vdc or 125 Vac/dc	26 to 38 Vdc	69 to 100 Vdc 56 to 97 Vac	n/a
xxxx2xxxxxx	125/250 Vac/dc	69 to 100 Vdc 56 to 97 Vac	138 to 200 Vdc 112 to 194 Vac	n/a
xxxx3xxxxxx	24 Vdc	n/a	n/a	Approx. 5 Vdc

* AC voltage ranges are calculated using the default recognition time (4 ms) and debounce time (16 ms).

Each BE1-CDS240 with a mid- or high-range power supply is delivered with the contact-sensing jumpers installed (H position) for operation in the higher end of the control voltage range. If the contact-sensing inputs are to be operated at the lower end of the control voltage range, the jumpers must be changed to L position. See Section 12, *Installation,* for details on how to set the jumper positions in the contact-sensing input circuits.

Digital Input Conditioning Function

The relay scans the inputs for status once per 1.0 ms. The relay uses digital contact recognition and debounce timers that are user settable to condition the signals applied to the inputs. The user can adjust these parameters so that the optimum compromise between speed and security can be attained for the specific application. The digital input conditioning function is evaluated every 4 ms.

If the sampled status of the monitored contact is detected closed for the recognition time, the logic variable changes from an open (logic zero or FALSE) state to a closed (logic one or TRUE) state. Once the contact closure has been recognized, the logic variable will remain in the closed state until the sampled status of the monitored contact is detected to be open for longer than the debounce time. At this point, the logic variable will change from a closed (logic one or TRUE) state to an open (logic zero or FALSE) state.

Setting the Digital Input Conditioning Function

Settings and labels for the digital input conditioning function are set using BESTCOMS. Alternately, settings may be made using the SG-IN ASCII command.

Each of the inputs has two settings and three labels. The settings are *Recognition Time* and *Debounce Time*. The labels include a label to describe the input, a label to describe the *Energized State*, and a label to describe the *De-Energized State*. Labels are used by the BE1-CDS240's reporting functions.

To edit the settings or labels, select *Inputs and Outputs* from the *Screens* pull-down menu. Then select the *Inputs 1-6* or *Inputs 7-12* tab. Refer to Figure 3-8.

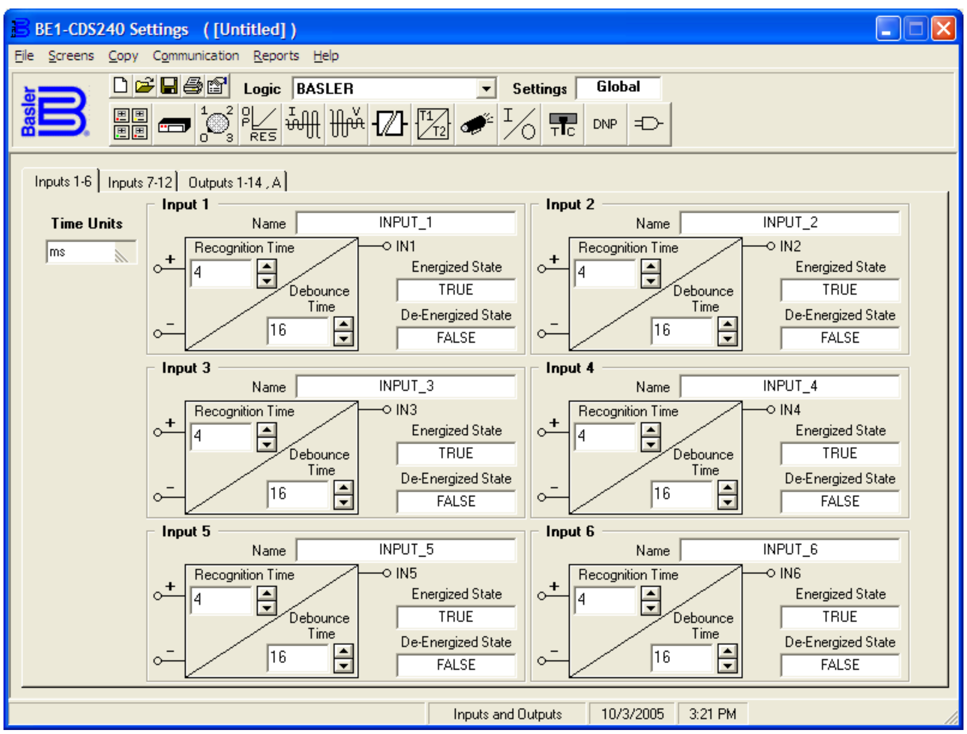


Figure 3-8. Inputs and Outputs Screen, Inputs 1-6 Tab

Table 3-8. Digital Input Conditioning Function Settings

Setting	Range	Increment	Unit of Measure	Default
Recognition Time	4 to 255	1	Milliseconds	4
Debounce Time	4 to 255	1	Milliseconds	16
Time Units	Pull-down menu that selects the unit of measure for *Recognition Time* and *Debounce Time*. Units of measure available are milliseconds (ms), seconds, minutes, and cycles. The default is milliseconds.			
Name	User programmable label for the input contact. Used by the reporting function to give meaningful identification to the input contact. This label may be up to 10 characters long.			
Energized State	User programmable label for the contact's energized state. Used by the reporting function to give meaningful identification to the state of the input contact. This label may be up to seven characters long.			
De-Energized State	User programmable label for the contact's de-energized state. Used by the reporting function to give meaningful identification to the state of the input contact. This label may be up to seven characters long.			

If the user desires that the relay reject ac voltage that may become coupled into the contact sensing circuits, the recognition time can be set to greater than one-half of the power system cycle period to take advantage of the half-wave rectification provided by the input circuitry.

If the user desires to use an ac wetting voltage, the recognition time can be set to less than one-half of the power system cycle period and the debounce timer can be set to greater than one-half of the power system cycle period to ride through the negative half cycle. The default settings of 4 milliseconds recognition and 16 milliseconds debounce time allow the relay to be used with ac wetting voltage at 60 Hz. A setting of 5 milliseconds recognition and 20 milliseconds would be used for 50 Hz.

Retrieving Input Status Information from the Relay

The status of the inputs can be determined by using BESTCOMS *Metering* screen, the optional HMI using Screen 1.4.1, STAT\OPER\INPUT, and from the ASCII command interface using the RG-STAT command. See Section 6, *Reporting and Alarms, General Status Reporting,* for more information.

Outputs

BE1-CDS240 relays have ten or fourteen general-purpose output contacts (OUT1 through OUT14) and one fail-safe, normally closed (relay in de-energized state), alarm output contact (OUTA). Each output is isolated and rated for tripping duty. All relays outputs are high speed (one-quarter cycle nominal operating time). OUT1 and OUT2 are Form C (single-pole, double-throw), OUTA is Form B (normally closed), and all remaining OUT3 through OUT14 are Form A (normally open).

Hardware Outputs and Virtual Outputs

To operate a hardware output, OUT1 through OUT14 or OUTA, the hardware outputs must be driven by one or more of the BESTlogic output expressions VO1 through VO14 and VOA (Virtual Outputs 1 through 14 and A). Since the use of each output contact is completely programmable, the user can assign meaningful labels to each output, as well as, to the zero and one states. See Section 7, *BESTlogic Programmable Logic,* for more information on programming output expressions in your programmable logic scheme.

A virtual output (VOn) exists only as a logical state inside the relay. A hardware output (OUTn) is a physical, output relay contact. The state of the output contact can vary from the state of the output logic expression for several reasons: 1) the relay trouble alarm disables all outputs; 2) the programmable hold timer function; 3) the select before operate logic override control function; or 4) a virtual output is not assigned to a hardware output. Figure 3-9 shows a diagram of the output contact logic for the general-purpose output contacts. Figure 3-10 shows a diagram of the output contact logic for the fail-safe alarm output contact. Virtual output A, VOA is always assigned to the fail-safe alarm contact OUTA.

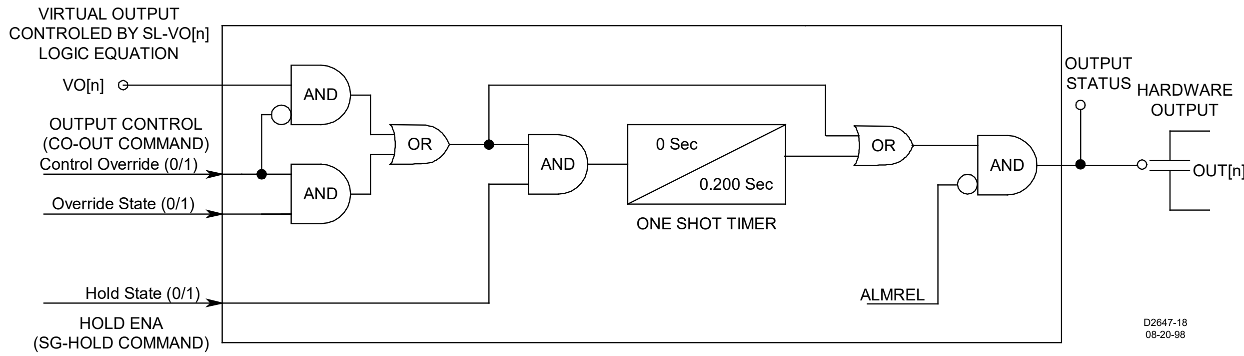


Figure 3-9. Output Logic, General Purpose Output Contacts

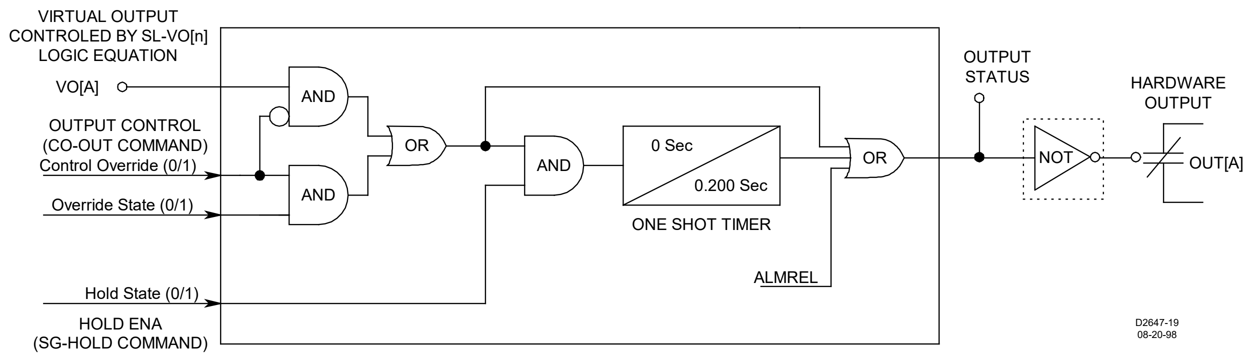


Figure 3-10. Output Logic, Fail-Safe Alarm Output Contact

Retrieving Output Status

Output status is determined through BESTCOMS by selecting *Metering* from the *Reports* pull-down menu and selecting the *Start Polling* button in the upper portion of the screen. Alternately, status can be determined through the HMI Screen 1.4.2, STAT\OPER\OUT and from the ASCII command interface using the RG-STAT command. See Section 6, *Reporting and Alarms, General Status Reporting,* for more information.

Relay Trouble Alarm Disable

When the relay self-diagnostics function detects a problem in the relay, it sets internal alarm condition ALMREL. See Section 6, *Reporting and Alarms, Alarms Function* for more details on this function. This alarm condition disables the outputs and de-energizes the OUTA relay closing the OUTA contact.

Programmable Hold Timer

Historically, trip contact seal-in circuits have been provided in electromechanical relays. These seal-in circuits consisted of a dc coil in series with the relay trip contact and a seal-in contact in parallel with the trip contact. The seal-in feature serves several purposes for the electromechanical relays. One is to provide mechanical energy to drop the target. Two is to carry the dc tripping current from the induction disk contact, which may not have significant closing torque for a low resistance connection. Three is to prevent the relay contact from dropping out until the current has been interrupted by the 52a contacts in series with the trip coil. If the tripping contact opens before the dc current is interrupted, the contact may be damaged. The first two of these items are not an issue for solid-state relays, but the third item is an issue.

To prevent the output relay contacts from opening prematurely, a hold timer can hold the output contact closed for a minimum of 200 milliseconds. Alternatively, if the protection engineer desires seal-in logic with feedback from the breaker position logic, they can provide this logic by modifying the BESTlogic expression for the tripping output. This process is described in Section 8, *Application, Application Tips, Output Contact Seal-In.*

The hold timer can be enabled for each input from the ASCII command input using the SG-HOLD command. Hold timer settings are shown in Table 3-9.

To enable the hold timer using BESTCOMS, select *Inputs and Outputs* from the *Screens* pull-down menu, and select the *Outputs 1-14, A* tab. To enable the hold timer for a desired output, check the box labeled *Hold Attribute* by clicking in the box with the mouse pointer. Refer to Figure 3-11.

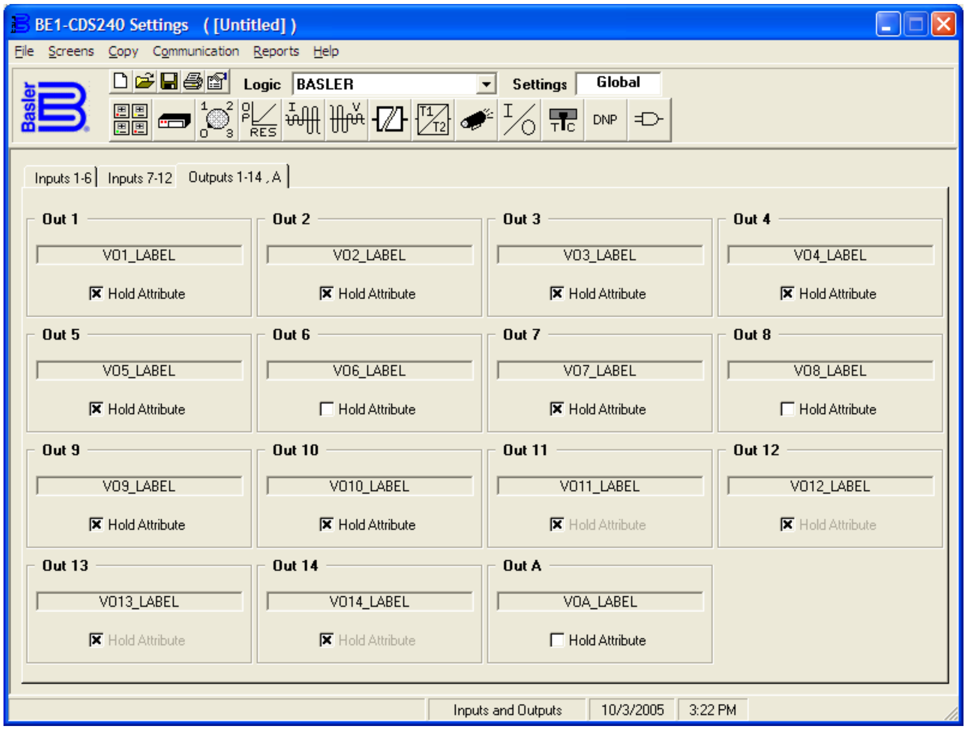


Figure 3-11. Inputs and Outputs Screen, Outputs 1-14, A Tab

Table 3-9 lists the default setting for the hold timer attributes.

Table 3-9. Output Hold Function Settings

Setting	Range	Default
Output Hold Timer	0 = disabled 1 = enabled	OUTA = 0 OUT1 - OUT14 = 1

Output Logic Override Control

The state of each output contact can be controlled directly using the select before operate, output control function. The virtual output logic expression that normally controls the state of an output contact can be overridden and the contact pulsed, held open, or held closed. This function is useful for testing purposes. An alarm point is available in the programmable alarm function for monitoring when the output logic has been overridden. See Section 6, *Reporting and Alarms*, *Alarms Function,* for more information on programmable alarms. Write access to control functions is required to use the select before operate control functions from either the optional HMI or the ASCII command interface. It cannot be achieved using BESTCOMS.

Enabling Logic Override Control

The logic override control must be enabled before the function can be used. The default state is disabled. Enabling output logic override control cannot be accessed from the HMI. It can only be accessed from the ASCII command interface using the CS/CO-OUT=ena/dis (control select/control operate-output override=enable or disable) command. This command only enables or disables logic override control. It does not enable or disable the outputs themselves.

Pulsing an Output Contact

Outputs can be pulsed to provide the push-to-energize function provided in Basler Electric solid-state relays. This is useful in trip testing the protection and control system. When pulsed, the contact changes from the current state as determined by the virtual output logic expression to the opposite state for 200 milliseconds. After 200 milliseconds, the output contact is returned automatically to logic control.

Pulse override control can be accessed from the HMI using Screen 2.4, \CTRL\OUT and entering a P in the field for the output contact. Control can be accessed from the ASCII command interface using the CS/CO-OUTn=P (control select/control operate - output contact n = pulse) command.

Holding an Output Contact Open or Closed

An output can be forced to a closed (logic one or TRUE) state or to an open (logic zero or FALSE) state. This is useful in testing to disable a contact during testing. Open or close logic override control can be accessed from the HMI using Screen 2.4, \CTRL\OUT and entering a one for closed or a zero for open in the field for the output contact. Control can be accessed from the ASCII command interface using the CS/CO-OUTn=0/1 (control select/control operate - output contact n = 0/1) command.

Returning an Output Contact to Logic Control

When the logic has been overridden and the contact is held in an open or closed state, it is necessary to return the contact to logic control manually.

Return to logic control can be accessed from the HMI using Screen 2.4, \CTRL\OUT and entering an L for return to logic control in the field for the output contact. Control can be accessed from the ASCII command interface using the CS/CO-OUTn=L (control select/control operate-output contact n = logic control) command.

The output control commands require the use of Select Before Operate logic. First, the command must be selected using the CS-OUT command. After the command is selected, there is a 30-second window during which the CO-OUT control command can be entered. The control selected and operation selected must exactly match or the command is blocked. If the command is not entered within the 30-second window, the command is blocked. If the control command is blocked, an error message is output.

Output control commands, except for ENA and DIS, are acted on immediately. To take effect, the ENA or DIS output control command changes must be saved with the EXIT command. The output control status is saved to nonvolatile memory and, if power is lost, it is restored after power returns.

1. Enable the output control feature.
   >CS-OUT=ENA
   `OUT=ENA SELECTED`
   >CO-OUT=ENA
   `OUT=ENA EXECUTED`
   >E *(exit)*
   `Save Changes (Y/N/C)?`
   >Y *(yes)*

2. Test all outputs by pulsing momentarily.
   >CS-OUT=P
   `OUT=P SELECTED`
   >CO-OUT=P
   `OUT=P EXECUTED`

3. Disable the trip output (OUT1) by holding it at logic 0.
   >CS-OUT1=0
   `OUT1=0 SELECTED`
   >CO-OUT1=0
   `OUT1=0 EXECUTED`

4. Return OUT1 to logic control.
   >CS-OUT1=L
   `OUT1=L SELECTED`
   >CO-OUT1=0
   `OUT1=L EXECUTED`

5. Disable the output control feature.
   >CS-OUT=DIS
   `OUT=DIS SELECTED`
   >CO-OUT=DIS
   `OUT=DIS EXECUTED`
   >E *(exit)*
   `Save Changes (Y/N/C)?`
   >Y *(yes)*

Retrieving Output Logic Override Status

The status of the output contact logic override control can be accessed from the HMI using Screen 1.4.2, \STAT\OPER\OUT. Screen 2.4, \CTRL\OUT is output control but can also display the status. The status of the output logic can also be accessed from the ASCII command interface using the RG-STAT (report general-status) command or RG-OUTCNTRL (report general-output control status) command. See Section 6, *Reporting and Alarms, General Status Reporting,* for more information.

An L indicates that the state of the output is controlled by logic. A zero or one indicates that the logic has been overridden and the contact is held in the open (0) or closed (1) state. A P indicates that the contact is being pulsed and will return to logic control automatically.

SECTION 4 • PROTECTION AND CONTROL

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SECTION 4 • PROTECTION AND CONTROL

General

BE1-CDS240 relays provide many functions that can be used for protection and control of power system equipment in and around the protected zone. Four settings groups are provided for adapting the coordination under various operating conditions with options for controlling which settings are active by automatic or programmable logic criteria. Protection and control functions include phase and neutral differential protection, overcurrent protection, breaker failure protection, general-purpose logic timers and virtual control switches.

To use a function, three things must occur:

1. The function block must be enabled in the active logic scheme by SL-<function> command or enabled through BESTCOMS™. To enable or disable a function that is part of a preprogrammed logic scheme, the user must first create a custom name for the new scheme.
2. The inputs and outputs of that function must be connected properly in a logic scheme.
3. Operational characteristics or settings for the function must be programmed by the user and based on the specific application requirements.

Items 1 and 2 may be skipped if a preprogrammed logic scheme is used for a typical application. Most of the schemes are general in nature and unneeded capabilities may be disabled by programming the operational characteristics setting to zero.

Example: The second negative-sequence instantaneous overcurrent function is enabled in the logic scheme but is not needed for this application. Set the 150TQ function pickup setting to zero (S#-150TQ=0) or set 150TQ to zero using the *Overcurrent* Screen in BESTCOMS.

More information on each individual function for item 1 is provided in this section. More information on items 2 and 3 is provided in Section 7, *BESTlogic Programmable Logic* and Section 8, *Application*.

Setting Groups

BE1-CDS240 relays provide a normal setting group, SG0, and up to three auxiliary setting groups SG1, SG2, and SG3 (See Figure 4-1). Auxiliary setting groups allow adapting the coordination settings to optimize them for a predictable situation. Sensitivity and time coordination settings can be adjusted to optimize sensitivity or clearing time based upon source conditions or to improve security during overload conditions. The possibilities for improving protection by eliminating compromises in coordination settings with adaptive setting groups are endless.

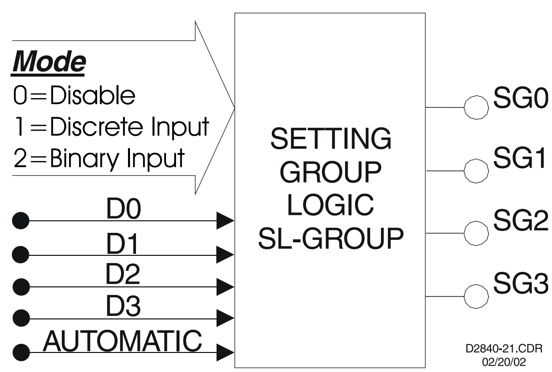

Figure 4-1. Setting Group Control Logic Block

The group of settings that are active at any point in time is controlled by the setting group control function. This function allows for manual (logic) or automatic control. When manual control is enabled by the AUTO logic input not being asserted, the function monitors logic inputs D0, D1, D2, and D3 and changes the active setting group according to the status of these inputs. These inputs can be connected to logic expressions such as contact sensing inputs. When automatic control is enabled by the AUTO logic input being asserted, the relay monitors loading or unbalance conditions and changes the active setting group according to the *switch to* and *return* criteria set. The change criteria for manual and automatic control are described in more detail later in this section.

The setting group control function has four logic variable outputs, SG0, SG1, SG2, and SG3. The appropriate variable is asserted when each setting group is active. These logic variables can be used in programmable logic to modify the logic based upon which setting group is active. For example, it may be desired for the 51P to trip the low side breaker through OUT2 under normal conditions, but to trip the 86T lockout relay through OUT1 when in Setting Group 3. The logic for OUT1 would include the term 51PT∗SG3 so that 51PT only actuates OUT1 when SG3 is asserted.

The setting group control function also has an alarm output variable SGC (Setting Group Changed). This output is asserted whenever the relay switches from one setting group to another. The SGC alarm bit is asserted for the SGCON time setting. This output can be used in the programmable alarms function if it is desired to monitor when the relay changes to a new setting group. See Section 6, *Reporting and Alarms, Alarms Function,* for more information on using alarm outputs.

The SGCON time setting also serves to provide anti-pump protection to prevent excessive changing between groups. Once a change in active group has been made, another change cannot take place for two times the SGCON setting.

When the relay switches to a new setting group, all functions are reset and initialized with the new operating parameters. The setting change occurs instantaneously so at no time is the relay off line. The active setting group is saved in nonvolatile memory so that the relay will power up using the same setting group as it was using when it was powered down. To prevent the relay from changing settings while a fault condition is in process, setting group changes are blocked when the relay is in a picked-up state. Since the relay is completely programmable, the fault condition is defined by the pickup logic expression in the fault reporting functions. See Section *6, Reporting and Alarms, Fault Reporting,* for more information.

The selection of the active setting group provided by this function block can also be overridden. When the logic override is used, a setting group is made active and the relay stays in that group regardless of the state of the automatic or manual logic control conditions.

BESTlogic Settings for Setting Group Control

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. The BESTCOMS screen used to select BESTlogic settings for the *Setting Group Selection* function is illustrated in Figure 4-2. To open the *BESTlogic Function Element* screen for *Setting Group Selection*, select *Setting Group Selection* from the *Screens* pull-down menu. Then select the *BESTlogic* button in the lower left hand corner of the screen. Alternately, settings may be made using the SL-GROUP ASCII command.

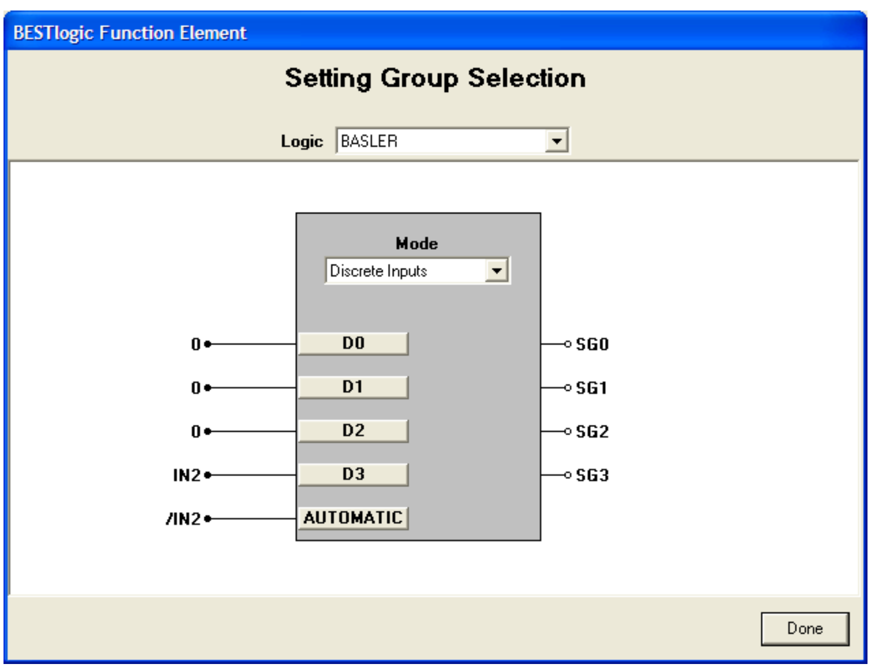

Figure 4-2. BESTlogic Function Element Screen, Setting Group Selection

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme

must be created and selected in the Logic pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the *Setting Group Selection* function by selecting its mode of operation from the *Mode* pull-down menu. To connect the functions inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, See Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-1 summarizes the BESTlogic settings for Setting Group Control.

Table 4-1. BESTlogic Settings for Setting Group Control

Function	Range/Purpose	Default
Mode	0 = Disabled, 1 = Discrete Inputs, 2 = Binary Inputs (If Auto mode is desired, logic mode must be either 1 or 2.)	1 (Discrete Inputs)
D0	Logic expression. Meaning is dependent upon the Mode setting.	0
D1	Logic expression. Meaning is dependent upon the Mode setting.	0
D2	Logic expression. Meaning is dependent upon the Mode setting.	0
D3	Logic expression. Meaning is dependent upon the Mode setting.	0
Automatic	Logic Expression. When TRUE, automatic control is enabled and when FALSE, logic control is enabled.	/0

Example 1. Make the following settings to the setting group selection logic. Refer to Figure 4-2.

Mode: Discrete Inputs
D0: 0
D1: 0
D2: 0
D3: IN2
AUTOMATIC: /IN2

Manual (logic) control reads the status of the logic inputs to the setting group control function block to determine what setting group should be active. For the logic inputs to determine which setting group should be active, the AUTO input must be logic 0. The function block logic mode setting determines how it reads these logic inputs. There are three possible logic modes as shown in Table 4-1.

When the setting group control function block is enabled for Mode 1, there is a direct correspondence between each discrete logic input and the setting group that will be selected. That is, asserting input D0 selects SG0, asserting input D1 selects SG1, etc. The active setting group latches in after the input is read so they can be pulsed. It is not necessary that the input be maintained. If one or more inputs are asserted at the same time, the numerically higher setting group will be activated. A pulse must be present for approximately one second for the setting group change to occur. After a setting group change occurs, no setting group change can occur within two times the SGC alarm-on time. Any pulses to the inputs will be ignored during that period.

Figure 4-3 shows an example of how the inputs are read when the setting group control function logic is enabled for Mode 1. Note that a pulse on the D3 input while D0 is also active doesn't cause a setting group change to SG3 because the AUTO input is active.

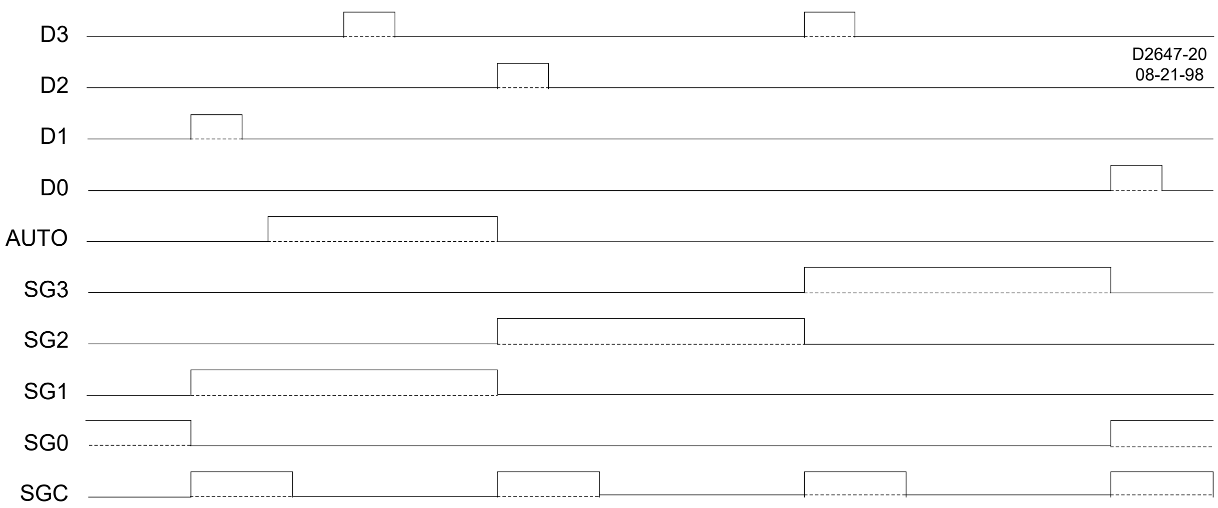

Figure 4-3. Input Control Mode 1

When the setting group control function block is enabled for Mode 2, inputs D0 and D1 are read as binary encoded (Table 4-2). Inputs D2 and D3 are ignored. A new coded input must be stable for approximately 1 second for the setting group change to occur. After a setting group change occurs, no setting group change can occur within two times the SGC alarm on time.

Table 4-2. Setting Group Binary Codes

Binary Code		Decimal Equivalent	Setting Group
D1	**D0**		
0	0	0	SG0
0	1	1	SG1
1	0	2	SG2
1	1	3	SG3

When using control Mode 2, the active setting group is controlled by a binary signal applied to discrete inputs D0 and D1. This requires separate logic equations for only D0 and D1 if all setting groups are to be used. Figure 4-4 shows how the active setting group follows the binary sum of the D0 and D1 inputs except when blocked by the AUTO input. Note that a pulse on the D1 input while D0 is also active doesn't cause a setting change to SG3 because the AUTO input is active.

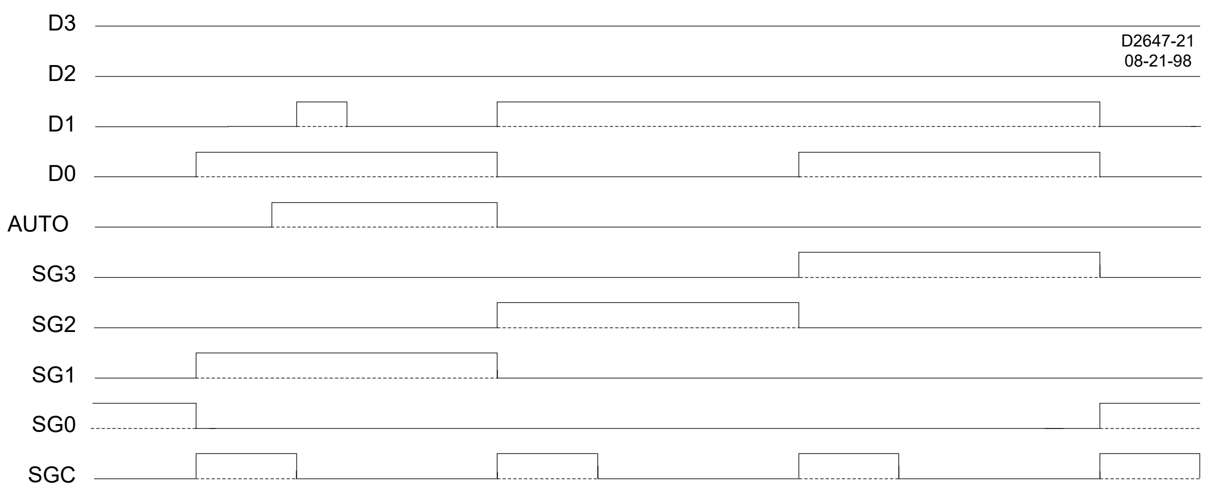

Figure 4-4. Input Control Mode 2

Figure 4-4 shows an example of how the inputs are read when the setting group control function block is enabled for Mode 2. Note that a pulse on the D1 input while D0 was also active does not cause a setting group change to SG3 because the AUTO input is active.

Operating Settings for Setting Group Control

Operating settings are made using BESTCOMS. Figure 4-5 illustrates the BESTCOMS screen used to select operational settings for the *Setting Group Selection* function. To open the *Setting Group Selection* screen, select *Setting Group Selection* from the *Screens* pull-down menu. Alternately, settings may be made using the SP-GROUP ASCII command.

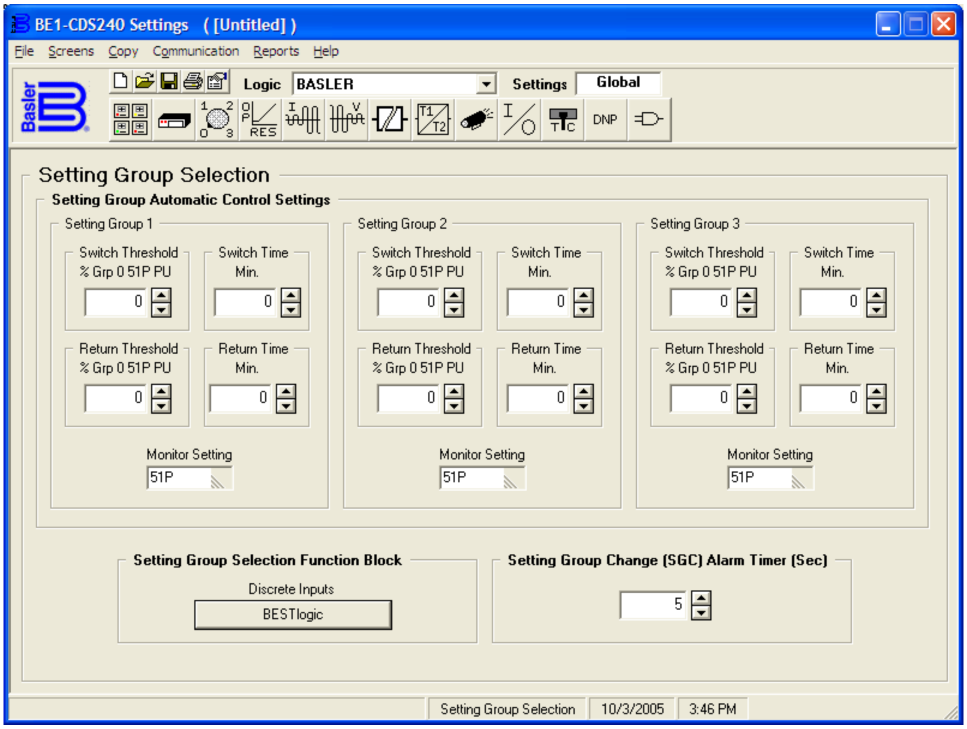

Figure 4-5. Setting Group Selection Screen

At the top center of the screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*. To the right of the *Logic* pull-down menu is a pull-down menu labeled *Settings.* The Settings menu is used to select the setting group that the elements settings apply to.

Using the pull-down menus and buttons, make the application appropriate settings to the *Setting Group Selection* function. Table 4-3 summarizes the operating settings for Setting Group Control.

Table 4-3. Operating Settings for Setting Group Control

Setting	Range	Purpose	Default
Switch Time	1 to 60 0 = Disabled	Time in minutes that determines when a setting change occurs once the *Switch Threshold* setting is exceeded.	0
Switch Threshold	0 to 150	Percentage of the SG0 *Monitor Setting* that must be exceeded for a setting group change to occur.	0
Return Time	1 to 60 0 = Disabled	Time in minutes that determines when a return to SG0 will occur once the monitored current has decreased below the *Return Threshold* setting.	0
Return Threshold	0 to 150	Percentage of the SG0 *Monitor Setting* that the monitored current must decrease below in order for a return to SG0.	0
Monitor Setting	x51P, x51N, x51Q, 451N	Determines when automatic setting group changes occur. Time overcurrent elements x51P, x51N, x51Q, or 451N can be selected so that setting group changes are based on load current. **Note:** x = none, 1, 2, or 3.	51P
Setting Group Change (SGC) Alarm Timer	1 to 10 0 = Disabled	Measured in seconds, the SGC alarm timer sets the amount of time the alarm is on.	5

Automatic control of the active setting group allows the relay to automatically change configuration for optimum protection based on the current system conditions. For example, in locations where seasonal variations can cause large variations in loading, the overcurrent protection can be set with sensitive settings during the majority of the time and switch to a setting group with lower sensitivity (higher pickups) during the few days of the year when the loading is at peak.

There are five settings for each group that are used for automatic control. Each group has a *switch to* threshold and time delay, a *return* threshold and time delay and a monitored element. The *switch to* and *return* thresholds are a percentage of the SG0 pickup setting for the monitored element. The monitored element can be any of the 51 protective functions. Thus, if you wish to switch settings based upon loading, you could set it to monitor 51P. If you wish to switch settings based upon unbalance, you could set it to monitor 51N or 51Q. When the monitored element is 51P, any one phase must be above the *switch to* threshold for the *switch to* time delay for the criteria to be met. All phases must be below the *return* threshold for the *return* time delay for the return criteria to be met.

Figure 4-6 shows an example of using the automatic setting group selection settings to change settings groups based upon loading. Note that the AUTO input must be at a TRUE logic state in order to allow the automatic logic to operate. At time = 0, current begins to increase. When current reaches 75 percent of pickup, Setting Group 2 begins timing (30 minutes). When current reaches 90 percent of pickup, Setting Group 3 begins timing (5 minutes). After 5 minutes, at time = 37, with the current still above Setting Group 3 threshold, Setting Group 3 becomes active and the setting group change output pulses. At time = 55, Setting Group 2 timer times out but no setting group change occurs because a higher setting group takes precedence. The faint dashed line for SG2, between time = 55 and 75 shows that Setting Group 2 would be active except for Setting Group 3. Current decreases to 75 percent at time = 70 and Setting Group 3 return timer begins timing. Current varies but stays below 75 percent for 5 minutes and at time = 75, Setting Group 2 becomes active and the setting change output pulses. After 20 minutes, Setting Group 0 becomes active and the setting change output pulses.

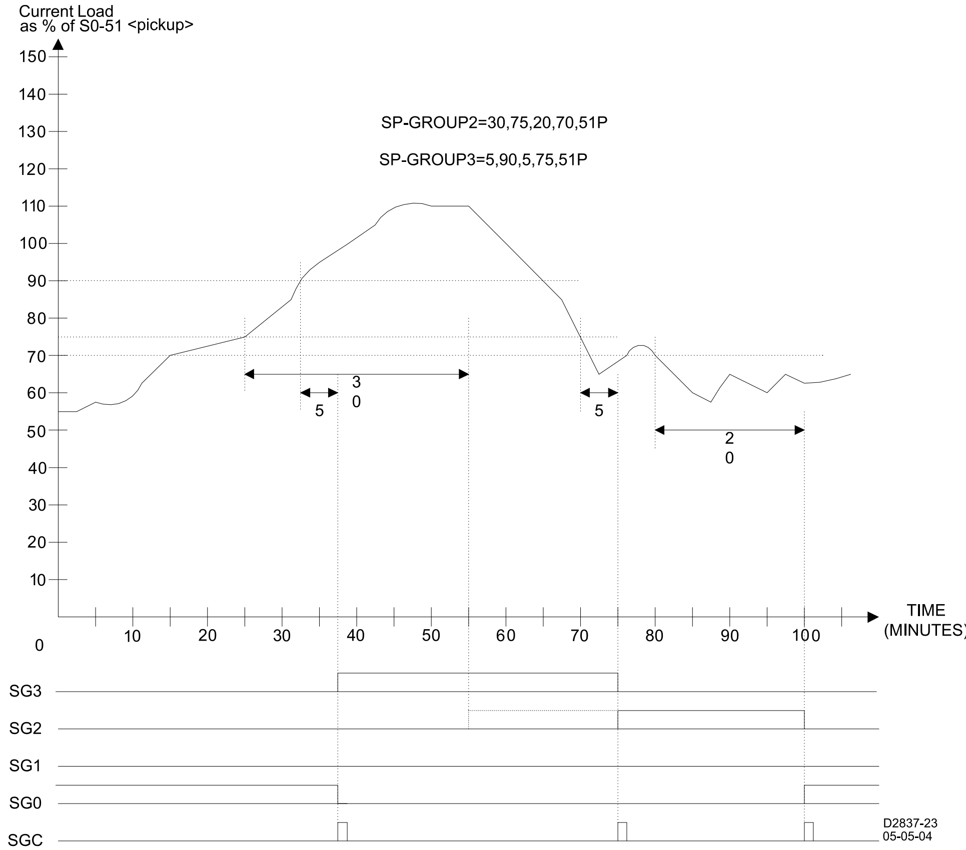

Figure 4-6. Automatic Operation Based on Load Change

This function can also be used to automatically change the active setting group for cold load pickup conditions. If the *switch to* threshold for a group is set to 0%, the function will switch to that group when there is no current flow for the time delay period indicating that the breaker is open or the circuit source is out of service. The threshold for this is 10% nominal rating of the relay current input.

Figure 4-7 shows how the active setting group follows the load current and time delay settings for Setting Group 1. Note that the AUTO input must be at a TRUE (1) logic state in order to allow the automatic logic to operate. When the breaker opens, the load current falls to zero at time = 15 minutes. After 10 minutes, Setting Group 1 becomes active and the setting group change output pulses TRUE. When the breaker is closed at time = 40 minutes, load current increases to approximately 90 percent of pickup. As the load current decreases to 50 percent of pickup, the Setting Group 1 return timer begins timing. After ten minutes, Setting Group 1 output goes FALSE, the setting group returns to Setting Group 0 and the setting group change output pulses TRUE.

When the *switch-to* criteria is met for more than one setting group at a time, the function will use the numerically higher of the enabled settings groups. If the *switch-to* time delay setting is set to 0 for a setting group, automatic control for that group is disabled. If the *return* time delay setting is set to 0 for a setting group, automatic return for that group is disabled and the relay will remain in that setting group until returned manually of by logic override control.

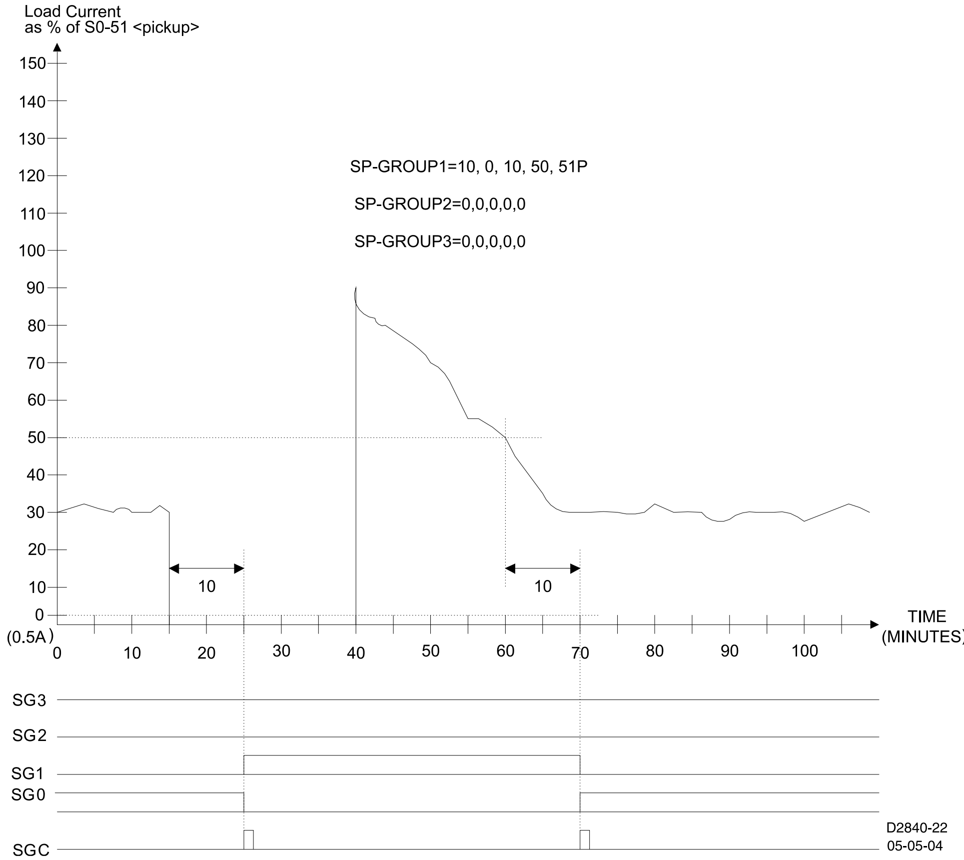

Figure 4-7. Automatic Operation Based on Cold Load Pickup

Logic Override of the Setting Group Control Function

Setting group selection can be overridden to allow manual setting group selection. Manual setting group control and selection is achieved through HMI Screen 2.3, \CTRL\SG, or by using the CS/CO-GROUP command. It cannot be achieved using BESTCOMS. The CS/CO-GROUP command uses select-before-operate logic. A setting group must be selected using the CS-GROUP command before the setting group is activated using the CO-GROUP command. The process of selecting and then placing a setting group in operation is summarized in the following two paragraphs.

Use the CS-GROUP command to select the desired setting group. After the CS-GROUP command is issued, there is a 30-second window during which the setting group can be activated using the CO-GROUP command.

Use the CO-GROUP command to activate the setting group already selected. The setting group activated with the CO-GROUP command must match the setting group selected with the CS-GROUP command. If the setting group specified in each command doesn't match or the CO-GROUP command isn't entered during the 30-second window, the CO-GROUP command is blocked and an error message is returned.

CS/CO-GROUP commands are executed without having to use the EXIT command to save setting changes.

When a setting group change is made, any subsequent setting change is blocked for two times the duration of the SGC alarm output time setting. Refer to the *Setting Groups* subsection for more information about SGC Alarm settings.

CS/CO-GROUP Command

Purpose: Read or change logic override settings for setting group selection.

Syntax: GROUP[=<mode>]

Comments: mode = Setting Group 0, 1, 2, 3, or L. L returns group control to the automatic setting group logic. <mode> entry of CS-GROUP command and CO-GROUP command must match or setting group selection will be rejected. If more than 30 seconds elapse after issuing a CS-GROUP command, the CO-GROUP command will be rejected.

CS/CO-GROUP Command Examples:

Example 1. Read the status of setting group override.

>CO-GROUP

```
L
```

Example 2. Override logic control and change the active setting group to SG1.

>CS-GROUP=1

```
GROUP=1 SELECTED
```

>CO-GROUP=1

```
GROUP=1 EXECUTED
```

Example 3. Return control of the active setting group to the automatic setting group logic.

>CS-GROUP=L

```
GROUP=L SELECTED
```

>CO-GROUP=L

```
GROUP=L EXECUTED
```

Retrieving Setting Group Control Status from the Relay

The active setting group can be determined from HMI Screen 1.4.4, \STAT\OPER\ACTIVEG, or by using the RG-STAT command. Section 6, *Reporting and Alarms, General Status Reporting*, provides more information about determining the active setting group. The active group can also be determined using BESTCOMS *Metering* screen.

Logic override status can be determined from HMI Screen 2.3, \CTRL\SG, or through the RG-STAT command. Section 6, *Reporting and Alarms, General Status Reporting*, provides more information about determining logic override status. Logic override cannot be determined using BESTCOMS.

Differential Protection

87 - Phase Differential Protection

BE1-CDS240 relays provide three-phase percentage restrained differential protection with high-speed unrestrained instantaneous differential protection. The differential protection includes harmonic restraint to improve security in transformer applications. The 87 function (see Figure 4-8) has nine outputs 87RPU (restrained pickup), 87RT (restrained trip), 87UT (unrestrained trip), 2NDHAR (second harmonic A, B, C restraint picked up), and 5THHAR (fifth harmonic A, B, C restraint picked up).

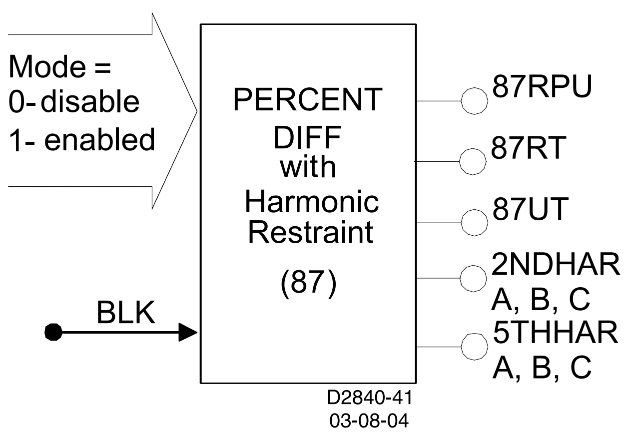

Figure 4-8. Phase Differential Logic Block

A *Block* logic input is provided to block operation of the differential protection. When this expression is TRUE, the function is disabled. For example, this may be an input wired to a differential cutoff switch.

Section 1, *General Information, Differential Protection Application Considerations,* describes application of percentage restrained differential protection. This section discusses the details of how the function works and how to set it up. Figure 4-9 shows a detailed functional diagram of one phase of the phase differential protection function. These functions and comparators are duplicated for each phase.

The measured currents are phase, zero-sequence, and tap compensated. Section 3, *Input and Output Functions, Power System Inputs,* describes the setup of the relay for phase and zero-sequence compensation. Setup of the tap adjustment compensation is described later in this section. The restraint current function uses the compensated current to calculate the restraint current magnitude (in multiples of tap). Depending on the setting, it calculates the maximum or average restraint current. The Operating Current Function determines the magnitude of the fundamental, second and fifth harmonic differential current as the phasor sum of those components of the compensated currents. Section 3 also discusses "virtual Circuits 5 and 6" and how they can be applied. Their use as an input to the "Virtual Restraint Function" is discussed later in this section.

Figure 4-10 shows the characteristic of the Restrained Element function. This comparator has a slope setting and a minimum pickup setting. The slope setting is the ratio of operate current to restraint current. The slope setting should be set above the maximum mismatch caused by excitation losses, tap mismatch, and load tap changers. The minimum pickup setting determines the minimum sensitivity of the restrained element. If the ratio of operate current to restraint current is above the slope setting and the operate current is above the minimum pickup setting for any of the three phases, the 87RPU (87 restrained element picked up) logic output is set.

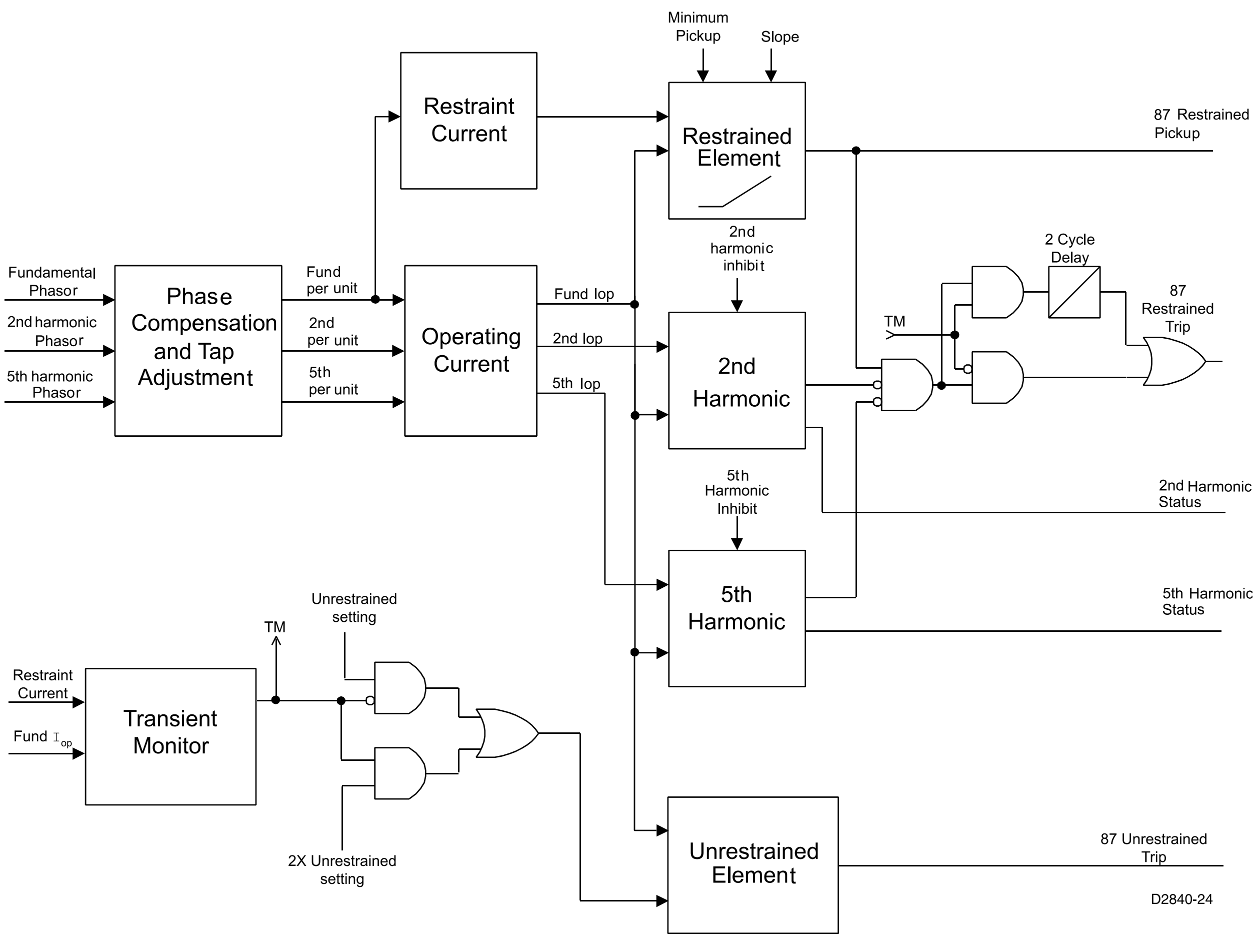

Figure 4-9. 87 Phase Differential Protection Functional Block Diagram

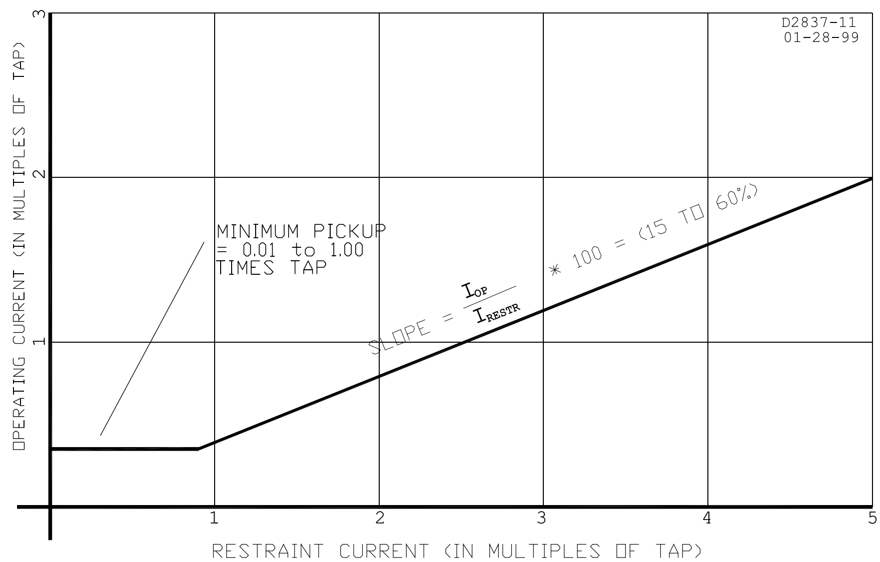

Figure 4-10. Percentage Restrained Differential Characteristic

If the target is enabled for the restrained element, the target reporting function will record an 87R target for the appropriate phases when the 87RT output is TRUE and the fault recording function *trip* logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting,* for more details on the target reporting function.

The differential protection function includes a transient monitor to detect the effects of CT saturation during a through fault. It does this by monitoring the change in restraint current versus the change in operate current. For an internal fault, the restraint current and operate current will experience a step increase at the same time. For an external fault, there should be no operate current. If CT saturation occurs during a through fault, the operate current will increase at some time after the restraint current increases. In this case, a two-cycle delay is added to the restrained differential output to enhance security.

The second and fifth harmonic functions check the ratio of the second and fifth harmonic operate current to the fundamental operate current. Traditional harmonic restraint units operate on the ratio of harmonic current to total operate current versus the ratio to only the fundamental operate current used by the BE1-CDS240. For this reason, the relay will provide greater security for inrush and overexcitation with the same harmonic inhibit ratio settings used with traditional differential relays. When either of these two comparators is above the threshold, the percentage-restrained output is blocked from setting the 87RT (87 restrained trip) logic output. If the second or fifth harmonic inhibit comparators are picked up for any of the three phases, the 2NDHAR and 5THHAR logic outputs respectively are also set.

In many cases, the second harmonic content of the inrush current may show up primarily in only one or two phases, which can cause one or two phases to not be inhibited. The BE1-CDS240 relay allows the second harmonic currents to be shared between the three phases. When second harmonic sharing is enabled, the magnitude of the second harmonic operating current is summed from all three phases and this magnitude is used by the second harmonic comparator for each phase instead of the second harmonic operate current for only that phase. This is superior to other methods of cross blocking since each phase element operates independently in its comparison of operating current to harmonic current. Thus, security is enhanced without sacrificing dependability because a faulted phase will not be restrained by inrush on unfaulted phases as is the case with cross blocking schemes.

The Unrestrained Element function provides high-speed tripping for high-grade faults inside the zone of protection. This comparator has a minimum pickup setting. If the operate current is above the threshold, for any of the three phases, the 87UT (87 unrestrained element trip) logic output is set. The transient monitor function also enhances security for this function by doubling the pickup threshold when CT saturation is detected. The minimum setting for the unrestrained trip threshold should be the maximum inrush current with a small margin.

If the target is enabled for the unrestrained element, the target reporting function will record an 87U target for the appropriate phases when the 87UT output is TRUE and the fault recording function *trip* logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting,* for more details on the target reporting function.

An alarm variable is also provided in the programmable alarms function that can be used to indicate an alarm condition if the percentage restrained differential protection is nearing a trip condition on load. This alarm triggers a diagnostic routine that attempts to determine the source of the mismatch that is causing the differential unbalance. See Section 6, *Reporting and Alarms, Alarms Function,* for more details on the alarm reporting function.

BESTlogic Settings for Phase Differential

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-11 illustrates the BESTCOMS screen used to select BESTlogic settings for the 87 function. To open the *BESTlogic Function Element* screen, select *Percentage Differential* from the *Screens* pull-down menu. Then select the *87 Phase* tab. Open the *BESTlogic Function Element* screen by selecting the *BESTlogic* button. Alternately, these settings can be made using the SL-87 ASCII command.

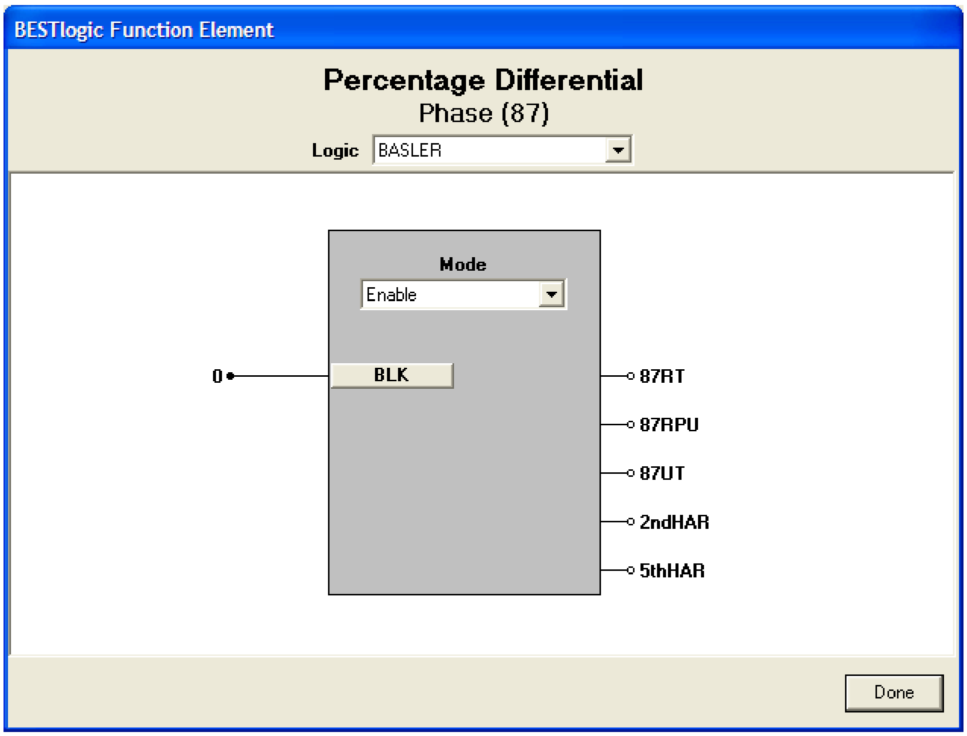

Figure 4-11. BESTlogic Function Element Screen, Phase (87)

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the 87 function by selecting its mode of operation from the *Mode* pull-down menu. To connect the element's input, select the button for the input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-4 summarizes the BESTlogic settings for Phase Differential.

Table 4-4. BESTlogic Settings for Phase Differential

Function	Range/Purpose	Default
Mode	0 = disabled 1 = enabled	1
BLK	Logic expression that disables function when TRUE.	0

Tap Compensation Settings for Phase Differential

As discussed in Section 1, *General Information, Differential Protection Application Considerations,* the measured currents must be tap adjusted to eliminate magnitude mismatch prior to being used by the 87 phase differential protection function. The tap adjust factors can be manually calculated per Equation 4-1. Or, the user can enter the MVA and KV base parameters (Table 4-5) and the relay will calculate the tap adjust factors using CTR and Compensation Factor parameters from the current measurement input function settings. See Section 3, *Input and Output Functions, Power System Inputs,* for more details on these settings. For a transformer application, the mismatch will be at a minimum if the actual transformer voltage ratings are used taking the no-load tap changer into consideration. If the transformer has a load tap changer, the voltage rating at the middle of the adjustment range should be used. This is generally at neutral. Table 4-6 lists the tap compensation settings for Phase Differential.

$$TAPn = \frac{MVA * 1000 * COMPn}{\sqrt{3} * kVn * CTRn}$$

Equation 4-1. Calculate Tap Adjust Factors

Table 4-5. MVA and KVn Base Parameters

Parameter	Description	Explanation
Tapn	Restraint winding	CDS240 has up to 4 restraint windings (4 taps).
MVA	MVA base	Full load MVA or top rating of the protected equipment.
kVn	kV base for CT input n	L-L Voltage in kV for each CT input circuit.
CTRn	CT ratio for CT input n	Actual ratio not effective ratio.
COMPn	Phase compensation adjustment factor for CT input n	√3 if CTs are connected in Delta (CTcon = DAB or DAC). 1 in all other cases. See Section 3, *Input and Output Functions*.

Table 4-6. Tap Compensation Settings for Phase Differential

Setting	Range		Increment	Unit of Measure	Default
	5A	1A			
Auto-tap MVA base	Manual = auto-tap disabled 0.5 to 9999	Manual = auto-tap disabled 0.5 to 9999	0.1	N/A MVA	Manual
Tap CT Input 1 **or** Auto-tap KV base	2.0 to 20.0 **or** 0.01 to 1000.0	0.40 to 4.00 **or** 0.01 to 1000	0.01 for 2.00 to 9.99 0.1 for 10.0 to 20.0 **or** 0.01	Sec. amps **or** Primary KV	2
Tap CT Input 2 **or** Auto-tap KV base	2.0 to 20.0 **or** 0.01 to 1000.0	0.40 to 4.00 **or** 0.01 to 1000	0.01 for 2.00 to 9.99 0.1 for 10.0 to 20.0 **or** 0.01	Sec. amps **or** Primary KV	2
Tap CT Input 3 **or** Auto-tap KV base	2.0 to 20.0 **or** 0.01 to 1000.0	0.40 to 4.00 **or** 0.01 to 1000	0.01 for 2.00 to 9.99 0.1 for 10.0 to 20.0 **or** 0.01	Sec. amps **or** Primary KV	2
Tap CT Input 4 **or** Auto-tap KV base	2.0 to 20.0 **or** 0.01 to 1000.0	0.40 to 4.00 **or** 0.01 to 1000	0.01 for 2.00 to 9.99 0.1 for 10.0 to 20.0 **or** 0.01	Sec. amps **or** Primary KV	2

The input currents can be tap adjusted up to a spread ratio of 10:1. If the ratio between TAP1, and TAP2, 3, or 4 is greater than ten, it will be necessary to adjust the CT ratios to bring the tap factors closer together. When the auto-tap calculation feature is used, the relay will give an error message if the spread ratio is greater than ten.

If one of the calculated taps is outside the acceptable range (2.0 to 20 for 5 ampere units or 0.4 to 4.0 for 1 ampere units), the auto-tap calculation feature will select the nearest acceptable tap and calculate the other tap (two at a time) so that the correct spread ratio is maintained. If the user is manually calculating the taps, the same adjustment should be made.

BESTCOMS can be used to provide auto tap calculation by filling in the appropriate fields on the *Percentage Differential* screen (Figure 4-12) and pressing the calculate button or manual tap values can be entered. Also, the auto-tap calculation settings can be entered for each setting group from the optional HMI using Screen 5.#.1.2, \PROT\SG#\87\MVA. The manual tap compensation settings can be entered for each setting group from the optional HMI using Screen 5.#.1.3, \PROT\SG#\87\TAP. These two screens are mutually exclusive. If the user enters settings on the *TAP* Screen, the MVA and KV settings on the MVA Screen will be zeroed out. If the user enters settings on the *MVA* Screen, the automatically calculated taps are shown on both screens.

The auto-tap calculation settings or the manual tap settings can be entered for each setting group with BESTCOMS or from the ASCII command interface using the S<g>-TAP87 command.

NOTE to users of the BE1-87T Transformer Differential Relay:

Three-phase versions of the BE1-87T also allow internal phase compensation. The jumper settings for the BE1-87T correspond to the internal compensation for the BE1-CDS240 as follows: Δ1 = DAC and Δ2 = DAB.

When calculating the tap adjust settings for the BE1-87T, the √3 COMPn factor has to be included regardless of whether phase compensation is done by connecting the CTs in delta or by using internal delta compensation. The BE1-CDS240 automatically takes the √3 factor into account prior to the tap adjustment when internal phase compensation is applied to a set of CT input currents. Thus, the tap adjust factors for these two relays will not be the same in applications using internal phase compensation.

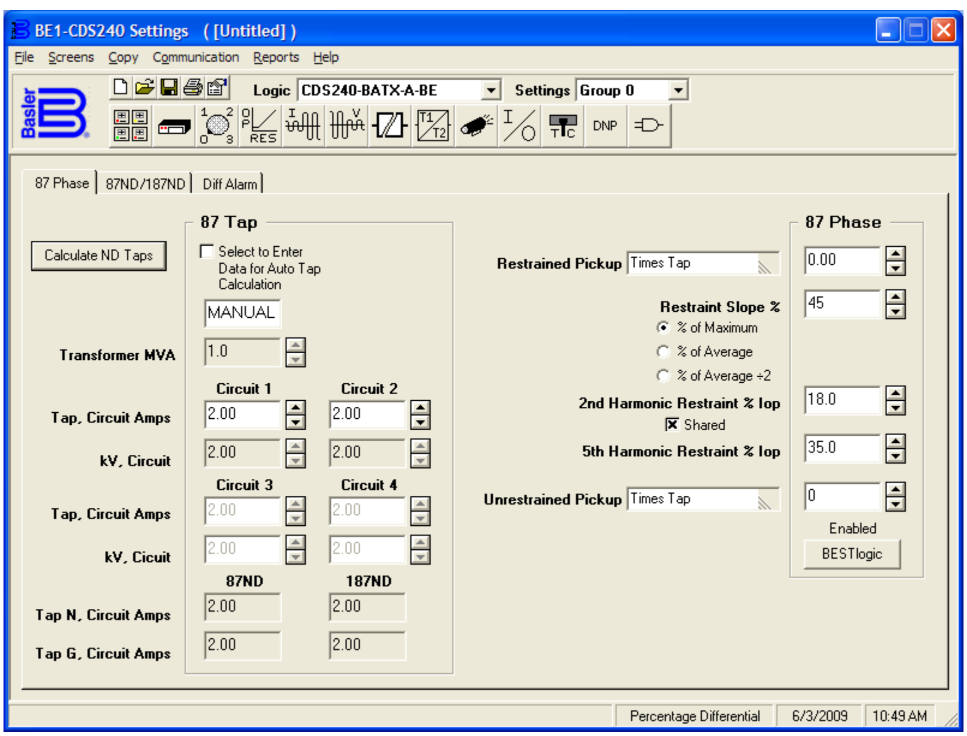

Figure 4-12. Percentage Differential Screen, 87 Phase Tab

NOTE

The CT input circuit settings are used by the auto-tap calculation function to calculate the correct tap adjustment factor for the differential functions. When entering these settings via the ASCII command interface, the validation routine and auto-tap calculation is performed on exit after all parameters have been entered.

When entering these settings using the optional HMI, the validation routine and auto-tap calculation is performed on exit of each screen. This may cause an **OUT OF RANGE** error message from the auto-tap calculation function. The user is advised to enter valid CT input circuit settings on Screen 6.3.1.1, SETUP\PWR_S\CON\CTP prior to entering the auto-tap calculation settings. If the user has previously set the auto-tap calculation settings and needs to change the CT input circuit settings, it may be necessary to temporarily change the auto-tap function setting to **MANUAL** on Screens 5.1.1.3, 5.2.1.3, 5.3.1.3, and 5.4.1.3 \PROT\SG#\87\TAP in order to enter the new CT settings.

See Section 3, *Input and Output Functions, Power System Inputs,* for more information on CT input circuit settings.

The tap factors calculated by the auto-tap calculation feature can be determined in several ways. They are displayed on the optional HMI using Screen 5.#.1.2, \PROT\SG#\87\MVA. Alternatively, the current check record provided by the differential alarm function includes a listing of the compensation parameters in the setting group that was active at the time that the record was triggered. See Section 6, *Reporting and Alarms, Differential Current Monitoring Function, Setting Differential Current Monitoring Alarms,* for more details on this report.

Operating Settings for Phase Differential

Operating settings for the 87 function consist of *Restrained Pickup*, *Restraint Slope*, *2nd and 5th Harmonic Restraint*, and *Unrestrained Pickup* values.

Operating settings are made using BESTCOMS. Figure 4-12 illustrates the BESTCOMS screen used to select operational settings for the 87 function. To open the screen, select *Percentage Differential* from the *Screens* pull-down menu. Then select the *87 Phase* tab. Alternately, settings may be made using S<g>-87 ASCII command or through the optional HMI Screens 5.#.1.1, \PROT\SG#\87\87.

The operating settings for Phase Differential are provided in Table 4-7.

The settings for restrained minimum pickup and unrestrained trip are set in multiples of tap. If the ideal taps calculated by Equation 4-1 fell within the acceptable range, the sensitivity settings will be in *Per Unit* on the MVA Base used in the equation. For example, a 100 MVA, 115 KV transformer has a full load (1 per unit) current of 500 amperes. A pickup setting of 10 times tap for the unrestrained output pickup (URO) element is equivalent to 5,000 primary amperes of differential current.

If the taps had to be adjusted upwards or downwards to fit within the acceptable range, the sensitivity settings for these protective elements should be adjusted as well. Equation 4-2 gives the adjustment factor. The definitions for the variables in Equation 4-2 are the same as those for Equation 4-1. For example, the ideal taps ($TAPn_I$) were calculated using Equations 4-2 and 4-3 to be 1.6 and 5.0. They had to be adjusted upwards so that the actual taps ($TAPn_A$) are 2.0 and 6.25. Per Equation 4-2, X is 0.8. It is desired that the minimum pickup of the restrained element be 0.35 per unit on the circuit base. The actual setting should be 0.35 $*$ 0.8 = 0.28 to achieve the same sensitivity.

The pickup settings in *Times Tap* can be related to primary amps by Equation 4-3. *Minpu* is the minimum pickup setting in Times Tap. The definitions for the remaining variables in Equation 4-3 are the same as those for Equation 4-1.

$$X = \frac{TAPnI}{TAPnA} = \frac{MVA * 1000 * COMPn}{TAPnA * \sqrt{3} * KVn * CTRn}$$

Equation 4-2. Tab Adjustment Equation

$$Ipri = \frac{Mpu * TAPn * CTRn}{COMPn}$$

Equation 4-3. Calculate Primary Amps

Table 4-7. Operating Settings for Phase Differential

Setting	Range	Increment	Unit of Measure	Default
Minimum Pickup (minpu)	0 = Disabled 0.10 to 1.00	0.01	Times tap	0
Restraint Slope % - % of Maximum, % of Average, % of Average ÷ 2	15 to 60	1	N/A	45
2nd Harmonic Inhibit	0 = Disabled 5.0 to 75.0	0.5	% of 2nd vs. fundamental I operate	18
5th Harmonic Inhibit	0 = Disabled 5.0 to 75.0	0.5	% of 5th vs. fundamental I operate	35
Unrestrained output pickup (URO)	0 = Disabled 0 to 21	1	Times tap	10
2nd Harmonic sharing between phases	0 = Independent 1 = Shared	n/a	N/A	1

% of Maximum - The maximum of the compensated input currents is used. For example, the restraint current for phase A would be $I_{RA} = max\ (I_{AXCOMPS})$ where x = 2, 3, or 4 depending on the number of current inputs.

% of Average - The average of the compensated input currents is used. For example, the restraint current for phase A would be given by Equation 4-4.

$$I_{RA} = \frac{\text{Sum of } I_{AxCOMPS}}{\text{Number of Inputs}}$$

Equation 4-4. Calculate Restraint Current for Phase A, % of Average

% of Average ÷ 2 - The sum of the compensated input currents divided by 2 is used. For example, the restraint current for phase A would be given by Equation 4-5.

$$I_{RA} = \frac{\text{Sum of } I_{AxCOMPS}}{2}$$

Equation 4-5. Calculate Restraint Current for Phase A, % of Average ÷ 2

Retrieving Phase Differential Status from the Relay

The status of each logic variable can be determined from the ASCII command interface using the RG-STAT command. Status can also be determined using BESTCOMS *Metering* screen. See Section 6, *Reporting and Alarms, General Status Reporting,* for more information.

Virtual Restraint Element

Transformer differential applications associated with high and/or low side ring bus or breaker-and-a-half arrangements normally include the breakers in the transformer differential zone of protection (Figure 4-13).

That is, the restraint currents for the differential relay are derived from each breaker connected to the transformer. However, using normal restraint methods on a lightly loaded transformer combined with a high impedance fault could cause the differential relay to *restrain* when in fact it should *trip.* To avoid this condition, the BE1-CDS240 provides a **Virtual Restraint Element** that derives its restraint from the vector sum of two or more high or low side breaker CT inputs (see Section 3, *Input and Output Functions,* for details on the virtual circuit measurement function and settings).

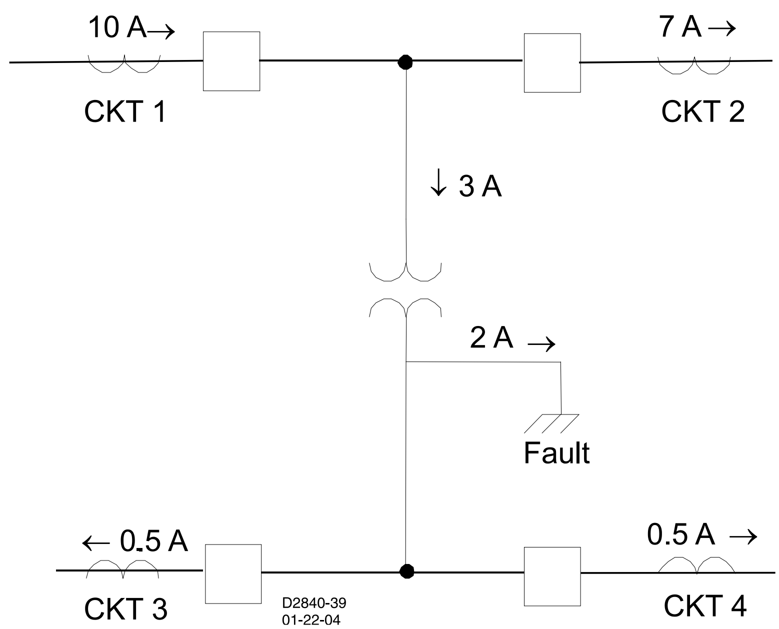

Figure 4-13. Breakers in the Differential Zone of Protection

With the breakers included in the transformer differential zone of a traditional arrangement, and using the "maximum restraint current mode," the restraint value is the "maximum" current of CT Circuits 1, 2, 3, or 4, and the operate current is the vector sum of CT Circuits 1, 2, 3, and 4. Using this mode, Equation 4-6 applies:

$$I_{RESTRAINT} = 10\text{ A}, \qquad I_{OPERATE} = 2\text{ A}, \qquad \therefore \%_{SLOPE} = \frac{I_{OPERATE}}{I_{RESTRAINT}} \cdot 100\% = 20\%$$

Equation 4-6. Slope Calculation, Maximum Restraint Current Mode

If the relay is set for a typical slope of 45%, the 87R will not operate because the relay responds to the restraint current flowing thought CT Circuits 1 and 2.

Using the relay's "average restraint current mode" offers some improvement by "averaging" the four CT inputs to determine the restraint current. However, is still below the typical 45% setting, providing borderline 87R operation. Using this mode, Equation 4-7 applies:

$$I_{RESTRAINT} = 4.5\text{ A}, \qquad I_{OPERATE} = 2\text{ A}, \qquad \therefore \%_{SLOPE} = \frac{I_{OPERATE}}{I_{RESTRAINT}} \cdot 100\% = 44.4\%$$

Equation 4-7. Slope Calculation, Average Restraint Current Mode

The only way to make the 87R operate is to either add a CT at location VCKT5 (Figure 4-14) or make the element more sensitive by reducing the percent restraint setting. The latter however, could make 87R prone to false operation when full load or external fault current flows through the transformer. Virtual restraint provides a practical way to solve this problem without adding an additional CT.

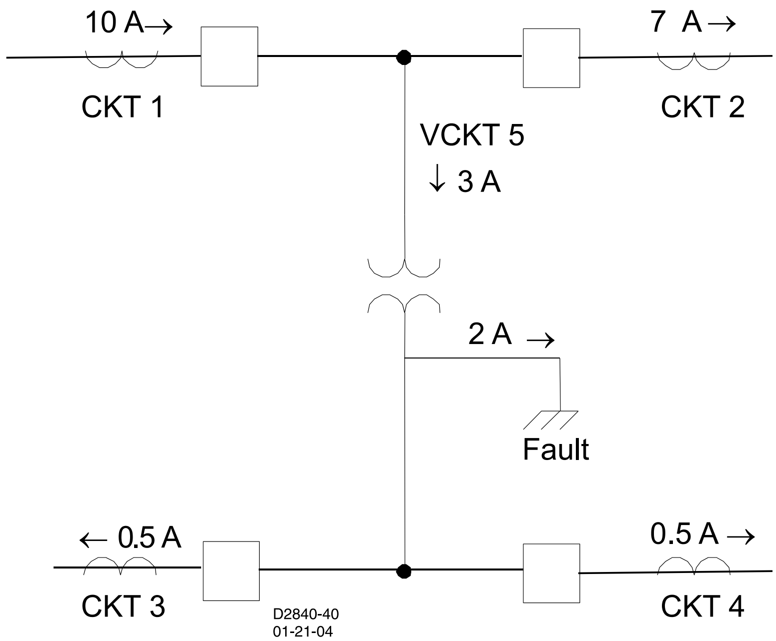

Figure 4-14. Virtual Circuit with a CT

Virtual restraint was specifically designed for applications where high per unit current flows through the primary or secondary breaker current transformers without flowing though the protected transformer. Using the same example as above, first configure Virtual Circuit 5 for the vector sum of CT Circuits 1 and 2. Next, enable virtual restraint to use Virtual Circuit 5 as one of its restraining inputs. When virtual restraint is enabled to use Virtual Circuit 5, the BE1-CDS240 automatically excludes Circuits 1 and 2 from the restraint calculations.

The restraint current is then determined from Virtual Circuit 5 and CT Circuits 3 and 4. The operate current is determined as before from the vector sum of CT Circuits 1, 2, 3, and 4.

Virtual Circuit 5 becomes the vector sum of Circuits 1 and 2 and is equal to 3 A. Using the maximum mode, Equation 4-8 applies:

$$I_{RESTRAINT} = 3\text{ A},\ I_{OPERATE} = 2\text{ A}, \qquad \therefore \%_{SLOPE} = \frac{I_{OPERATE}}{I_{RESTRAINT}} \cdot 100\% = 66.6\%$$

Equation 4-8. Slope Calculation, using VCKT5

Using the typical setting of 45% slope, 87R easily operates for the same fault condition that restrained in the original example (Figure 4-13*)*. By using virtual restraint, the high current flowing thought CT Circuits 1 and 2 has no impact on the restraint calculations. By using virtual restraint, the restraint current is only proportional to current actually flowing through the protected transformer. This avoids the need to apply a separate CT at VCKT5 location (Figure 4-14) and maintains a good balance between sensitivity and security.

87ND - Neutral Differential Protection

BE1-CDS240 relays can provide sensitive differential protection for ground faults on the grounded side of a delta/wye transformer. On impedance grounded systems, ground fault levels may be reduced below the sensitivity of the phase differential protection. The result is that ground faults within the protected zone have to be cleared by time delayed backup overcurrent protection if sensitive differential protection is not available.

The function block in Figure 4-15 has two outputs: 87NDPU (pickup) and 87NDT (trip). A *BLK* (block) logic input is provided to block operation of the differential protection. When this expression is TRUE, the function is disabled. For example, this may be an input wired to a differential cutoff switch.

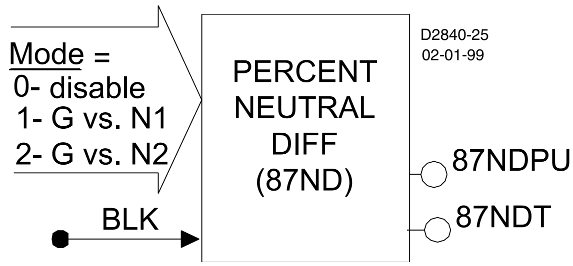

Figure 4-15. Neutral Differential Logic Block

To use this function, the relay must always be installed with the optional independent ground sensing input I_G that is the zero-sequence current entering the zone of protection. Figure 4-16 shows the configuration of this protective function. The zero-sequence current exiting the zone of protection is the calculated neutral for the three-phase CT input circuit designated by the BESTlogic mode setting.

Note: Circuit 4 is not used on 187ND because it is the ground current (I_{G2}) for that function.

NOTE

The CTs for this three-phase input circuit must be connected in wye with zero-sequence compensation for the grounded winding provided by internal delta compensation. If the CTs are connected in delta to provide external zero-sequence compensation, the calculated $3I_0$ (neutral) current exiting the zone will always be zero since it is filtered out by the CTs delta connection.

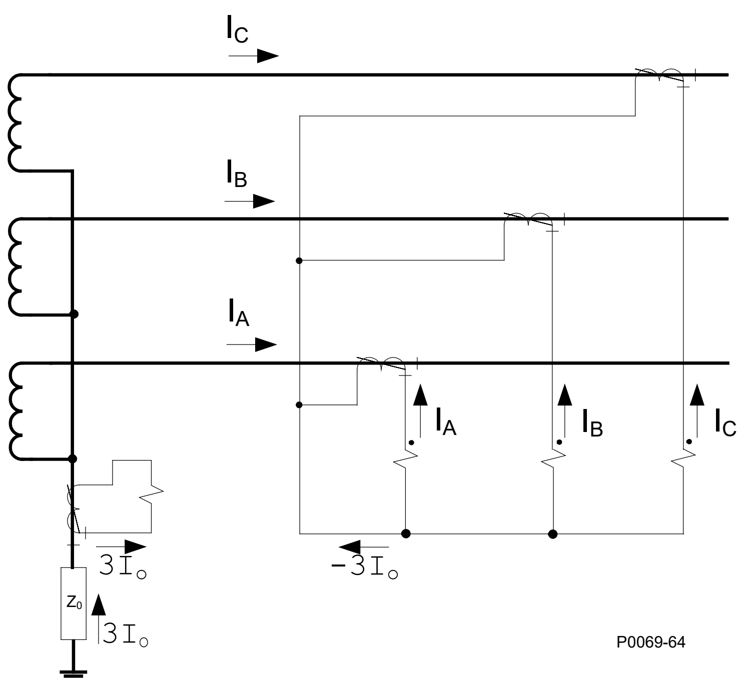

Figure 4-16. 87ND Polarity Configuration

These paragraphs discuss the details of how the function works and how to set it up. Figure 4-17 shows a detailed functional block diagram of the neutral differential protection function. The measured ground current and the neutral current are tap adjusted to eliminate magnitude mismatch. The Restraint Current function determines the magnitude of the restraint current as the maximum of the compensated currents in multiples of tap. The Operating Current function determines the magnitude of the differential current as the phasor sum of the compensated currents.

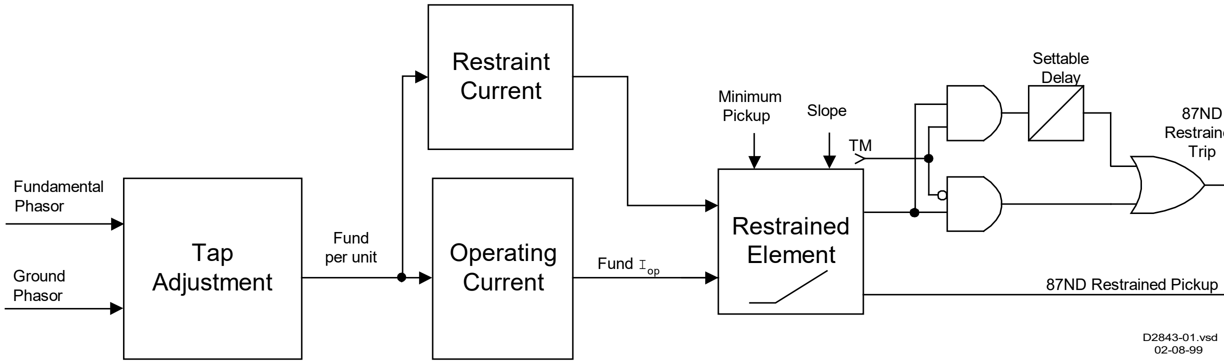

Figure 4-17. 87 Neutral Differential Protection Functional Block Diagram

The characteristic of the Restrained Element function is the same as that for the phase differential shown in Figure 4-10. The current used for restraint is user-selectable in BESTCOMS for Max of IN, IG or Max of IA, IB, IC, IG. This element has a slope setting and a minimum pickup setting. The slope setting is the ratio of operate current to restraint current. The minimum pickup setting determines the minimum sensitivity. If the ratio of operate current to restraint current is above the slope setting and the operate current is above the minimum pickup setting, the 87NDPU (87 neutral element picked up) logic output is set.

A timer provides security from misoperation on false residual caused by CT saturation during a through fault. If the transient monitor function from the 87 phase differential function detects CT saturation, the 87NDT trip logic output is routed through the timer. The timer should be set longer than the normal clearing time for a fault just outside the zone of protection to allow it to ride-through until the external fault is cleared.

If the target is enabled for this function, the target reporting function will record an 87ND target when the 87NDT logic output is TRUE and the fault recording function *trip* logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting,* for more details on the target reporting function.

BESTlogic Settings for Neutral Differential

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-18 illustrates the BESTCOMS screen used to select BESTlogic settings for the 87ND function. To open the *BESTlogic Function Element* screen, select *Percentage Differential* from the *Screens* pull-down menu. Then select the *87ND/187ND* tab. Select the appropriate *BESTlogic* button for 87ND or 187ND. Alternately, these settings can be made using the SL-87ND and SL-187ND ASCII commands.

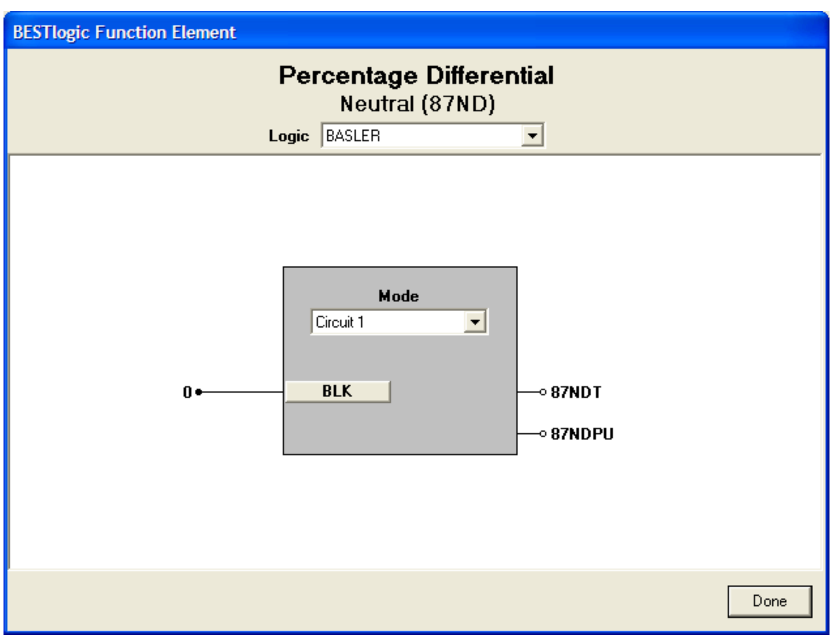

Figure 4-18. BESTlogic Function Element Screen, Neutral (87ND)

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme

must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the 87 function by selecting its mode of operation from the *Mode* pull-down menu. To connect the element's input, select the button for the input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-8 summarizes the BESTlogic settings for Neutral Differential.

Table 4-8. BESTlogic Settings for Neutral Differential

Function	Range/Purpose	Default
Mode	0 = Disabled, 1 = IG vs. CT Input 1 Neutral, 2 = IG vs. CT Input 2 Neutral, 3 = IG vs. CT Input 3 Neutral, 4 = IG vs. CT Input 4 Neutral, 5 = IG vs. CT Input 5 Neutral, 6 = IG vs. CT Input 6 Neutral.	0
BLK	Logic expression that disables function when TRUE.	0

Auto-Tap Compensation Settings for Neutral Differential

The tap adjustment factors are automatically calculated such that Equation 4-9 is TRUE. CTRn is the CT ratio for the three-phase CT input circuit designated by the 87ND or 187ND setting in the active logic. The CTR settings are entered using BESTCOMS (see Figure 4-12). See Section 3, *Input and Output Functions, Power System Inputs,* for more details on these settings.

The CT input with the highest CTR is selected as the driving tap and set to the minimum setting (2.0 for 5-ampere units or 0.4 for 1-ampere units). Equation 4-9 is solved for the other tap. The currents can be tap adjusted up to a spread ratio of 10:1. If the ratio between TAPN and TAPG is greater than 10, it will be necessary to adjust CT ratios to bring the tap factors closer together. The relay will give an error message if the spread ratio is greater than 10.

$$\text{TAPN} * \text{CTRn} = \text{TAPG} * \text{CTRG}$$

Equation 4-9. Solve for the other Tap (TAPN or TAPG)

NOTE

Since the calculated neutral used by the 87ND function is designated by BESTlogic, you may get an auto-tap error when changing the 87ND logic setting in the user programmable logic settings.

The tap factors calculated by the auto-tap calculation feature can be determined in several ways. They are displayed on the optional HMI using Screen 5.#.2.1, \PROT\SG#\87ND\87ND. Or, the current check record provided by the differential alarm function includes a listing of the compensation parameters in the setting group that was active at the time that the record was triggered. See Section 6, *Reporting and Alarms, Differential Current Monitoring Function, Setting Differential Current Monitoring Alarms,* for more details on this report.

Operating Settings for Neutral Differential

Operating settings are made using BESTCOMS. Figure 4-19 illustrates the BESTCOMS screen used to select operational settings for the 87ND and 187ND functions. To open the screen, select *Percentage Differential* from the *Screens* pull-down menu. Then select the *87ND/187ND* tab. Alternately, settings may be made using S<g>-87ND and S<g>-187ND ASCII commands or through the optional HMI Screens 5.#.2.1, \PROT\SG#\87ND\87ND, 5.#.2.2, \PROT\SG#\187ND\187ND.

The operating settings for Neutral Differential are provided in Table 4-9.

The minimum pickup is set in multiples of tap. Equation 4-10 can be used to convert the Minpu setting to primary current. The 87ND auto-tap calculation routine uses the minimum allowable taps to allow the minimum pickup to be set to allow maximum sensitivity to ground faults.

$$Ipri = Minpu * TAPn * CTRn$$

Equation 4-10. Convert the Minpu setting to Primary Current

Table 4-9. Operating Settings for Neutral Differential

Setting	Range	Increment	Unit of Measure	Default
Restrained Pickup (minpu)	0 = Disabled 0.10 to 1.00	0.01	Times tap	0
Restraint Slope %	15 to 60	1	% I operate vs. restraint	20
Time Delay	50 to 999 ms	1 m	Milliseconds	500
	0.05 to 60 sec	0.1 for 0.1 to 9.9 s 1.0 for 10 to 60 s	Seconds	
	0 to 3600 (60 Hz) or 0 to 2500 (50 Hz)	∗	Cycles	
Restrained Mode	IN, IG or IA, IB, IC, IG	n/a	n/a	IN, IG

∗ Time delays less than 10 cycles can be entered to the nearest 0.1 cycles from the optional HMI. All time delays can be entered to the nearest 0.01 cycles from the ASCII command interface. Time delays entered in cycles are converted to milliseconds or seconds. Increment precision after conversion is limited to that appropriate for each of those units of measure.

The 87ND neutral differential operational settings may be entered with BESTCOMS (Figure 4-19), or from the optional front panel HMI from Screens 5.#.2.1, \PROT\SG#\87ND7\87ND, or from the ASCII command interface using the S<g>-87ND command.

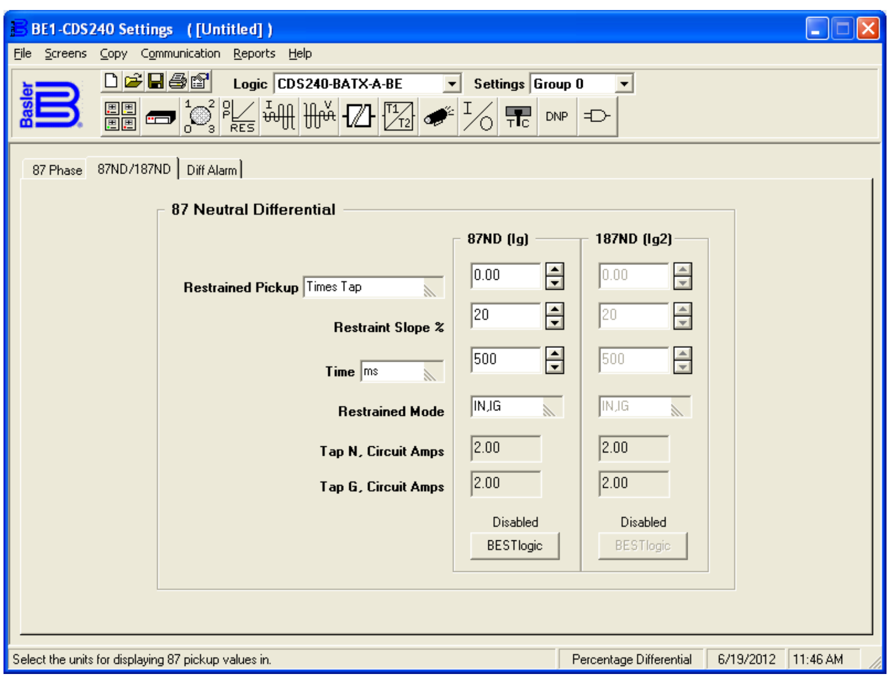

Figure 4-19. Percentage Differential Screen, 87ND/187ND Tab

Retrieving Neutral Differential Status from the Relay

The status of each logic variable can be determined from the ASCII command interface using the RG-STAT command or using the BESTCOMS *Metering* screen. See Section 6, *Reporting and Alarms, General Status Reporting,* for more information.

Overcurrent Protection

50T - Instantaneous Overcurrent Protection with Settable Time Delay

There are eight independent function blocks for phase (50TP, 150TP, 250TP, 350TP, 450TP, 550TP, 650TP, 750TP), five for neutral (50TN, 150TN, 250TN, 350TN, 450TN), and four for negative-sequence (50TQ, 150TQ, 250TQ, 350TQ) instantaneous overcurrent protection. Each function block can be attached to any of the four hardware CT input circuits or the two virtual current circuits by the BESTlogic mode setting. See Section 3, *Inputs and Outputs,* for details on the virtual current circuits.

The instantaneous overcurrent protective functions in the BE1-CDS240 relay are labeled 50T because each has a settable time delay. If the time delay is set to zero, they operate as instantaneous overcurrent relays.

Figure 4-20 shows the 50TP phase instantaneous over-current as a typical 50T function. Each of the nine independent functions has two logic outputs: #50TnPU (picked up) and #50TnT (trip) where n indicates whether it is a P (phase), N (neutral), or Q (negative-sequence) and the #50 differentiates between the protective functions (50, 150, etc.).

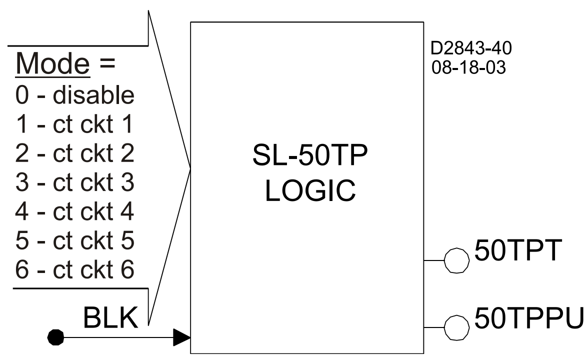

Figure 4-20. Instantaneous Overcurrent Logic Block

A *Block* logic input is provided to each function and can be used to disable the function. When this expression is TRUE, the function is disabled by forcing the outputs to logic zero and resetting the timers to zero. For example, this could be used similar to a torque control contact on an electromechanical relay.

Each instantaneous overcurrent function has a pickup and a time delay setting. When the measured current is above the pickup threshold, the pickup logic output, 50TPPU (for example) = TRUE and the timer is started. If the current stays above pickup for the time delay, the trip logic output, 50TPT (for example) = TRUE. If the current falls below the dropout ratio, which is 95%, the timer is reset to zero.

The phase overcurrent protective functions include three independent comparators and timers, one for each phase. If the current is above the pickup setting for any one phase, the pickup logic output is asserted and if the trip condition is TRUE for any one phase, the trip logic output is asserted.

If the target is enabled for the function, the target reporting function will record a target for the appropriate phase when the protective function trip output is TRUE and the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting Functions,* for more details on the target reporting function.

BESTlogic Settings for Instantaneous Overcurrent

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-21 illustrates the BESTCOMS screen used to select BESTlogic settings for the 50T elements. To open the *BESTlogic Function Element* screen, select *Overcurrent* from the *Screens* pull-down menu. Then select the *50T/150T, 250T/350T, 450T/550T,* or *650T/750T* tab. Open the *BESTlogic Function Element* screen for the desired element by selecting the *BESTlogic* button corresponding with the desired element. Alternately, these settings can be made using the SL-x50T ASCII commands (where x = blank, 1, 2, 3, 4, 5, 6, or 7).

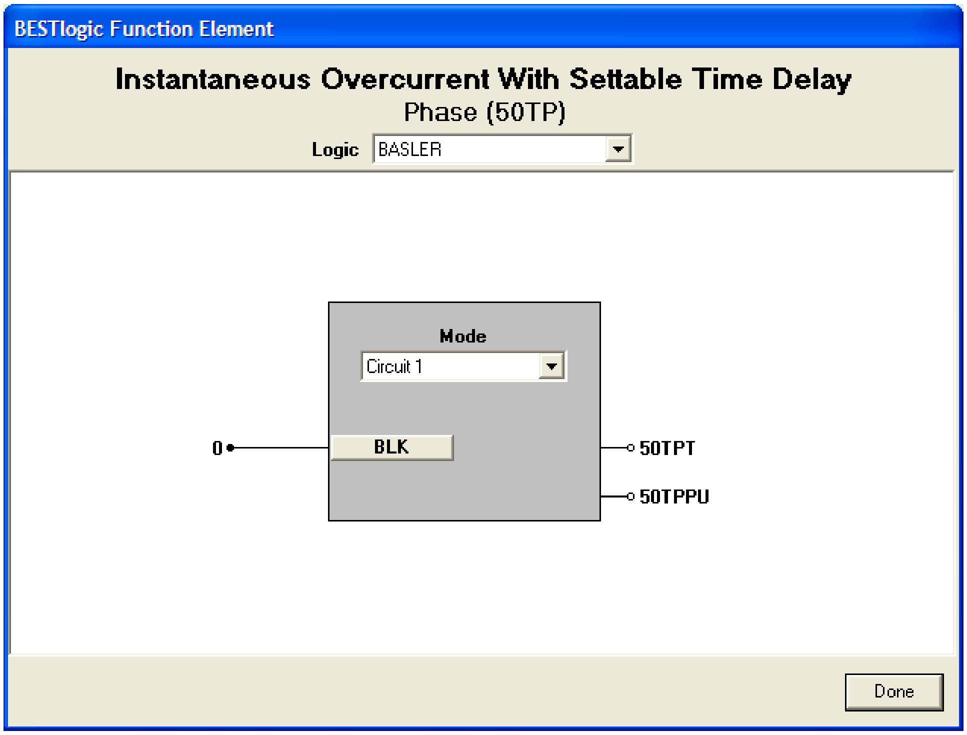

Figure 4-21. BESTlogic Function Element Screen, Phase (50TP)

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the 50T, 150T, 250T, etc. function by selecting its mode of operation from the *Mode* pull-down menu. To connect the element's inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, See Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-10 summarizes the BESTlogic settings for Instantaneous Overcurrent.

Table 4-10. BESTlogic Settings for Instantaneous Overcurrent

Function	Range/Purpose	Default
Mode	0 = Disabled 1 = CT Input Circuit 1 2 = CT input Circuit 2 3 = CT Input Circuit 3 4 = CT Input Circuit 4 5 = Virtual Input Circuit 5 6 = Virtual Input Circuit 6 G = Independent Ground Input (#50TN functions only)	0
BLK	Logic expression that disables function when TRUE.	0

NOTE

If the unit has five ampere phase inputs and a one ampere independent ground input, the valid pickup setting range of the neutral overcurrent functions will be dependent upon the logic mode setting which designates whether the three-phase residual or the independent ground input is to be monitored. If changing logic schemes or settings causes a neutral overcurrent setting to be OUT OF RANGE, the out of range setting will be forced in-range by multiplying or dividing the current setting by five.

Operating Settings for Instantaneous Overcurrent

Operating settings for the 50T functions consist of *Pickup* and *Time* delay values. The *Pickup* value determines the level of current required for the element to start timing toward a trip. *Time* delays can be set in milliseconds, seconds, or cycles. The default is milliseconds if no unit of measure is specified. Minimum timing resolution is to the nearest one-quarter cycle. A time delay setting of zero makes the element instantaneous with no intentional time delay.

Operating settings are made using BESTCOMS. Figure 4-22 illustrates the BESTCOMS screen used to select operational settings for the 50T elements. To open the screen, select *Overcurrent* from the *Screens* pull-down menu. Then select the *50T/150T, 250T/350T,* etc. tab. Alternately, settings may be made using S<g>-x50T ASCII command or through the optional HMI Screens 5.#.3.1 - 5.#.3.4, \PROT\SG#\x50T\.

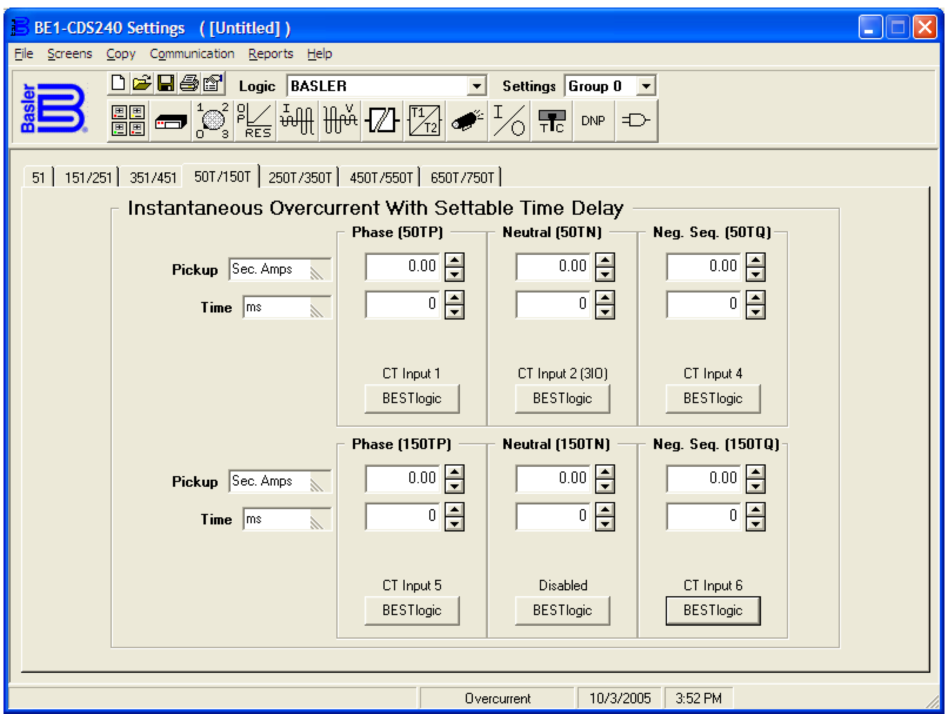

Figure 4-22. Overcurrent Screen, 50T/150T Tab

The default unit of measure for the *Pickup* setting is secondary amps. Primary amps (Pri Amps), per unit amps (Per U Amps), and percent amps (% Amps) can also be selected as the pickup setting unit of measure. The unit of measure for the *Time* setting that represents the element's time delay, defaults to milliseconds. It is also selectable for seconds, minutes, and cycles.

If time delay settings are made in cycles, they are converted to seconds or milliseconds (per the nominal frequency setting stored in EEPROM) before being stored and rounded to the nearest whole millisecond. See Section 3, *Input and Output Functions, Power System Inputs, Current Measurement*, for more information about this setting. If the nominal frequency setting is being changed from the default (60 hertz) and time delay settings are being set in cycles, the frequency setting should be entered and saved before making any time delay settings changes.

Beside the *Logic* pull-down menu is a pull-down menu labeled *Settings*. The Settings menu is used to select the setting group that the element's settings apply to.

Table 4-11 summarizes the operating settings for Instantaneous Overcurrent.

Table 4-11. Operating Settings for Instantaneous Overcurrent

<table>
<tr><th rowspan="2">Setting</th><th colspan="2">Range</th><th rowspan="2">Increment</th><th rowspan="2">Unit of Measure</th><th rowspan="2">Default</th></tr>
<tr><th>5 A</th><th>1 A</th></tr>
<tr><td>Pickup</td><td>0 = Disabled
0.5 to 150</td><td>0 = Disabled
0.1 to 30</td><td>0.01 for 0.01 to 9.99
0.1 for 10.0 to 99.9
1.0 for 100 to 150</td><td>Secondary amps</td><td>0</td></tr>
<tr><td rowspan="3">Time Delay</td><td colspan="2">0 to 999 milliseconds</td><td>1 m</td><td>Milliseconds</td><td rowspan="3">0</td></tr>
<tr><td colspan="2">0.1 to 60 seconds</td><td>0.1 for 0.1 to 9.9 sec
1.0 for 10 to 60 sec</td><td>Seconds</td></tr>
<tr><td colspan="2">0 to 3600 (60 Hz) or 0 to 2500 (50 Hz)</td><td>∗</td><td>Cycles</td></tr>
</table>

∗ Time delays less than 10 cycles can be entered to the nearest 0.1 cycles from the optional HMI. All time delays can be entered to the nearest 0.01 cycles from the ASCII command interface. Time delays entered in cycles are converted to milliseconds or seconds. Increment precision after conversion is limited to that appropriate for each of those units of measure.

Retrieving Instantaneous Overcurrent Status from the Relay

The status of each logic variable can be determined from the ASCII command interface using the RG-STAT command or using BESTCOMS *Metering* screen. See Section 6, *Reporting and Alarms, General Status Reporting,* for more information.

> **NOTE**
>
> When changing settings with the relay in service, an error message (PU TOO LOW) will be generated if the new setting is within approximately 90% of the metered current level. This is intended to prevent the user from inadvertently causing a trip when changing a setting.

51 - Time Overcurrent Protection

There are four independent functions for phase (51P, 151P, 251P, 351P), five for neutral (51N, 151N, 251N, 351N, 451N), and four for negative-sequence (51Q, 151Q, 251Q, 351Q) inverse time overcurrent protection. Each function can be attached to any of the four hardware CT input circuits or the two virtual current circuits by the BESTlogic mode setting. See Section 3, *Inputs and Outputs*, for details on the virtual current circuits.

Figure 4-23 shows the 51P (phase time overcurrent) as a typical 51 function. Each of the nine independent functions has two logic outputs #51nPU (picked up) and #51nT (trip) where n indicates whether it is a P (phase), N (neutral), or Q (negative-sequence). The # differentiates between the protective functions (51, 151, etc).

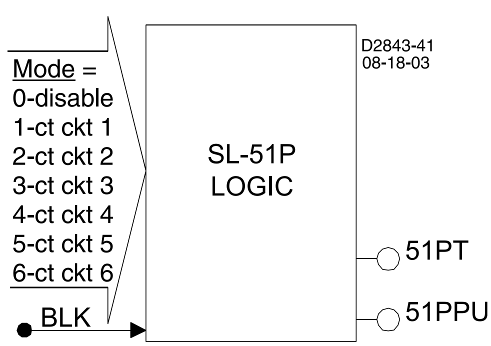

Figure 4-23. Time Overcurrent Logic Block

A *BLK* (Block) logic input is provided to each function that can be used to disable the function. When this expression is TRUE, the function is disabled by forcing the outputs to logic zero and resetting the timers to zero. For example, this could be used similar to a torque control contact on an electromechanical relay.

Each inverse time overcurrent function has a pickup, a time dial, and a curve setting. See Appendix A, *Time Overcurrent Characteristic Curves,* for details on each of the curves available. To make the protective element use integrated reset and emulate an electromechanical induction disk reset characteristic, the user can append an R to the selected time current characteristic curve. A programmable curve is available that can be used to create a custom curve by selecting coefficients in the inverse time characteristic equation.

When the measured current is above the pickup threshold, the pickup logic output, 51PPU (for example) = TRUE and inverse timing is started per the selected characteristic. If the current stays above pickup until the function times out, the trip logic output, 51PT (for example) = TRUE. If the current falls below the dropout ratio, which is 95%, the function will either reset instantaneously or begin timing to reset depending on the user's setting.

The phase overcurrent protective functions use the highest of the three measured phase currents. If the current is above the pickup setting for any one phase, the pickup logic output is asserted. If the trip condition is TRUE, the trip logic output is asserted.

If the target is enabled for the function block, the target reporting function will record a target for all phases that are above pickup when the protective function trip output is TRUE and the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting,* for more details on the target reporting function.

BESTlogic Settings for Time Overcurrent

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-24 illustrates the BESTCOMS screen used to select BESTlogic settings for the *Time Overcurrent* function. To open the screen, select *Overcurrent* from the *Screens* pull-down menu and select the *51, 151/251,* or *351/451* tab. Then select the *BESTlogic* button that corresponds with the element to be modified. Alternately, settings may be made using the SL-51 command.

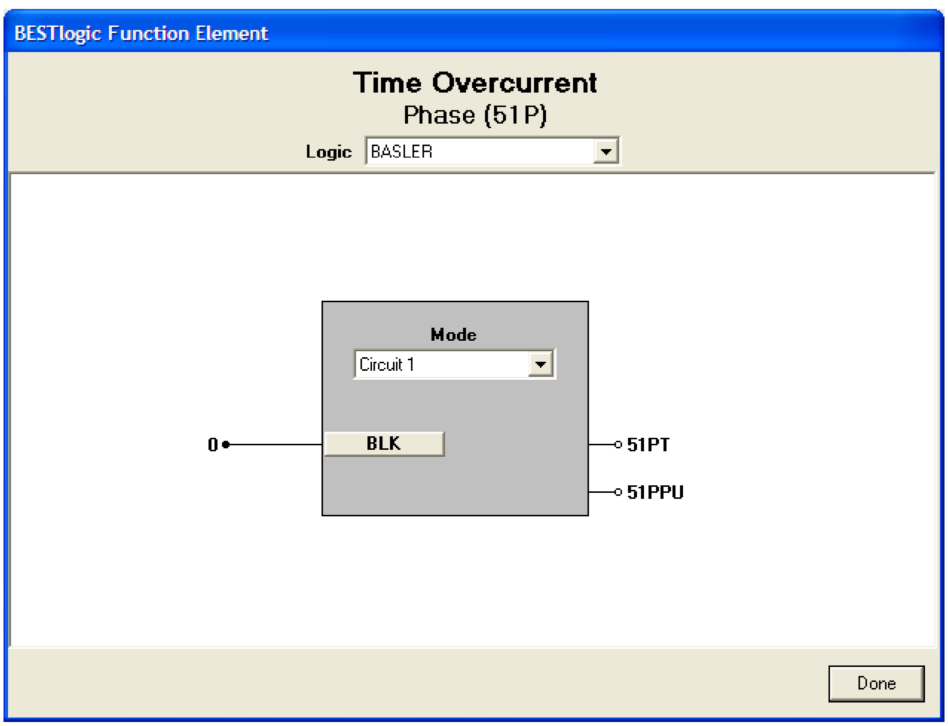

Figure 4-24. BESTlogic Function Element Screen, Phase (51P)

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the *Time Overcurrent* function by selecting its mode of operation from the *Mode* pull-down menu. To connect the functions inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

The BESTlogic settings for Time Overcurrent are provided in Table 4-12. These settings enable an element by attaching it to the CT input circuits and provide blocking control as determined by the logic expression assigned to the block input.

Table 4-12. BESTlogic Settings for Time Overcurrent

Function	Range/Purpose	Default
Mode	0 = disabled, 1 = CT Input Circuit 1, 2 = CT input Circuit 2, 3 = CT Input Circuit 3, 4 = CT Input Circuit 4, 5 = CT Input Circuit 5, 6 = CT Input Circuit. G = Independent Ground Input (#51N functions only)	0
BLK	Logic expression that disables function when TRUE.	0

Example 1. Make the following settings to the 51P element using BESTCOMS. See Figure 4-24.

Mode: Circuit 1

BLK: 0

NOTE

If the unit has five ampere phase inputs and a one ampere independent ground input, the valid pickup setting range of the neutral overcurrent functions will be dependent upon the logic mode setting which designates whether the three-phase residual or the independent ground input is to be monitored. If changing logic schemes or settings causes a neutral overcurrent setting to be OUT OF RANGE, the out of range setting will be forced in-range by multiplying or dividing the current setting by five.

Operating Settings for Time Overcurrent

Operating settings are made using BESTCOMS. Figure 4-25 illustrates the BESTCOMS screen used to select operational settings for the *Time Overcurrent* element. To open the screen, select *Overcurrent* from the *Screens* pull-down menu and select either the *51, 151/251,* or *351/451* tab. Alternately, settings may be made using S<g>-51 ASCII command or from the optional HMI Screens 5.#.4.1 through 5.#.4.3, \PROT\SG#\51\.

See *Negative-Sequence Overcurrent Protection* later in this section for information on setting the negative-sequence overcurrent protection.

The default unit of measure for the *Pickup* setting is secondary amps. Primary amps (Pri Amps), per unit amps (Per U Amps), and percent amps (% Amps) can also be selected as the pickup setting unit of measure. The unit of measure for the *Time* setting that represents the element's time delay defaults to milliseconds. It is also selectable for seconds, minutes, and cycles.

Beside the *Logic* pull-down menu is a pull-down menu labeled *Settings*. The Settings menu is used to select the setting group that the element's settings apply to.

Table 4-13 summarizes the operating settings for Time Overcurrent.

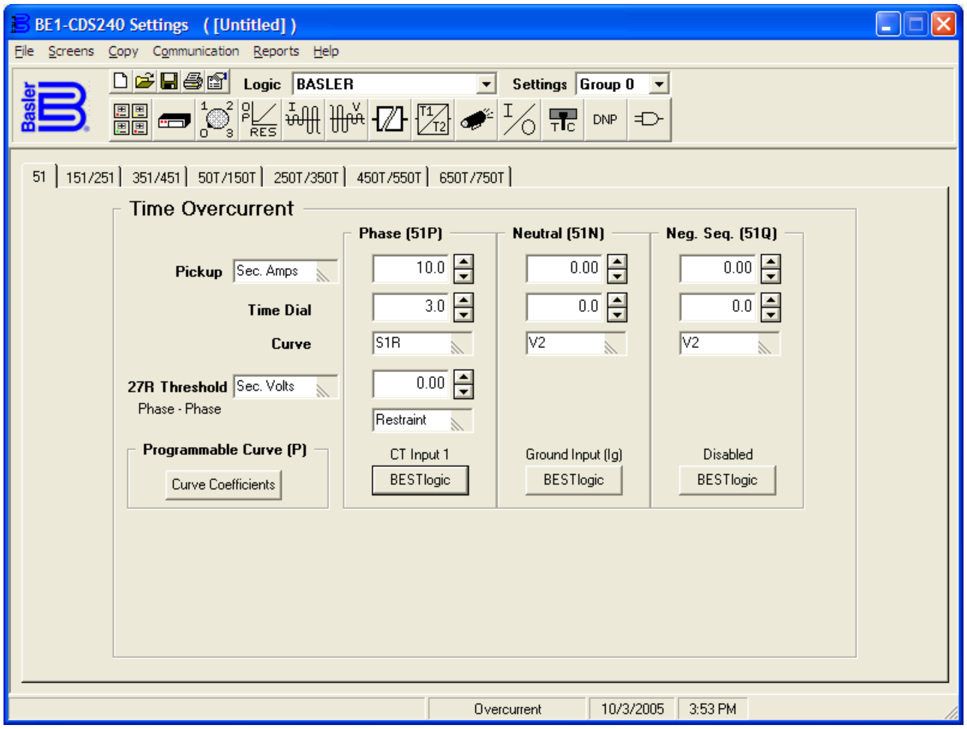

Figure 4-25. Overcurrent Screen, 51 Tab

Table 4-13. Operating Settings for Time Overcurrent

Setting	Range		Increment	Unit of Measure	Default
	5 A	1 A			
Pickup	0 = Disabled 0.5 to 16	0 = Disabled 0.1 to 3.2	0.01 for 0.01 to 9.99 0.1 for 10.0 to 16.0	Sec. Amps	0
Time Dial	0.0 to 9.9		0.1	N/A	0
Curve	See Appendix A		N/A	N/A	V2

Example 1. Make the following settings to the Phase 51P time overcurrent element in BESTCOMS. Refer to Figure 4-25.

Pickup: 10 secondary amps
Time Dial: 3.0
Curve: S1R

Retrieving Time Overcurrent Status from the Relay

The status of each logic variable can be determined through the ASCII command interface using the RG-STAT (report general-status) command. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information. The status can also be determined using BESTCOMS *Metering* screen.

Voltage Restraint/Control for Time Overcurrent Protection

The 51P, 151P, 251P, 351P, and 451P protection functions can be set for voltage control or voltage restraint mode of operation (51V). This feature is used to allow increased overcurrent sensitivity while providing security from operation due to load current. This feature is also often used for generator backup protection to ensure delayed tripping during a short-circuit where the fault current contribution from the generator falls to a value close to the full-load rating of the generator.

When set for *Control* mode of operation, the phase overcurrent element is disabled until the measured voltage drops below the threshold. Thus, as long as the voltage on the appropriate phase is above the 27R threshold setting, the overcurrent element will be blocked. When set for this mode of operation, the x51P pickup setting is typically set near or below load current levels.

When set for *Restraint* mode of operation, the *pickup* of the phase overcurrent element is adjusted based upon the magnitude of the measured voltage. Figure 4-26 shows how the overcurrent pickup threshold setting is adjusted in response to the measured voltage level. Equation 4-1 determines the pickup level for the 51P elements when the measured voltage is between 25% and 100% of the 27R threshold setting. Below 25%, the pickup level stays at 25%. Above 100%, the pickup level stays at 100%. For example, if the 27R threshold is set for 120V and the measured voltage on the appropriate phase is 100V (83% of the 27R threshold setting), the overcurrent pickup level for that phase will be reduced to 83% of its setting. When set for this mode of operation, the x51P pickup setting is typically set above worst case, load current levels.

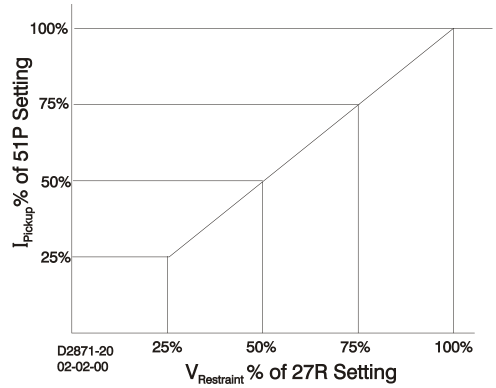

Figure 4-26. x51P Pickup Level Compensation

The 51/27R function can be set to monitor either Vpp or Vpn depending upon the VTP connection settings. See Section 3, *Input and Output Functions, Power System Inputs*, for more detail on how to set the VTP Connections. Table 4-14 shows which voltage measurements are used by each phase overcurrent element for each possible VTP connection and 51/27 voltage monitoring mode setting.

Table 4-14. VTP Connection Cross Reference

VTP Connection	51/27 Mode	51A	51B	51C
4W	Vpp	Vab	Vbc	Vca
4W	Vpn	Van	Vbn	Vcn
3W	Vpp	Vab	Vbc	Vca
AN	Vpn	Van	N/A	N/A
BN	Vpn	N/A	Vbn	N/A
CN	Vpn	N/A	N/A	Vcn
AB	Vpp	Vab	N/A	N/A
BC	Vpp	N/A	Vbc	N/A
CA	Vpp	N/A	N/A	Vca

When single-phase voltage sensing is used, only the overcurrent element on the phase with voltage magnitude information is affected by the 51/27R feature. Thus, in voltage control mode, the x51 elements on the two unmonitored phases will always be disabled. In voltage restraint mode, the 51 elements on the two unmonitored phases will not have their overcurrent pickup settings adjusted from 100%.

NOTE

For single-phase sensing, the unmonitored phase is not restrained or controlled. These phases are marked in the table by N/A (not applicable).

The VT fuse loss detection function (60FL) can also be set to supervise the 51/27R function. It is possible to set the 60FL function to automatically prevent mis-operation on loss of sensing voltage. When the 51/27R function is set for control and a 60FL condition is detected, the phase overcurrent elements will be disabled. When the 51/27R function is set for restraint and a 60FL condition is detected, the phase overcurrent elements will remain enabled but the pickup will not be adjusted from 100% of its setting. See the paragraph titled *Voltage Transformer Fuse Loss Detection*, later in this section for more information.

Operating Settings for Voltage Restraint/Control for Time Overcurrent

See the previous Figure 4-25 for setting the Time Overcurrent elements. Using the pull-down menus and buttons, make the appropriate settings to the x*51P Voltage Restraint/Control* element. Table 4-15 summarizes the operating settings for Voltage Restraint/Control for Time Overcurrent.

Table 4-15. Operating Settings for Voltage Restraint/Control for Time Overcurrent

Setting	Range	Increment	Unit of Measure	Default
Pickup	30 to 250, 0 = Disable	0.1 for 30 to 99, 1.0 for 100 to 250	Volts	0
Mode	C (control), R (restraint)	N/A	N/A	R

Pickup Threshold. A setting of zero disables voltage restraint/control and allows the x51P time overcurrent function to operate normally. When voltage restraint or control is desired, the pickup value can be set over a range of 30 to 250 volts. Setting curve coefficients is discussed later in this section.

Mode Setting (Mode). Two mode settings are available: Restraint and Control.

Restraint I. In Restraint mode, the x51P pickup level is reduced linearly when the sensing voltage decreases below the restraint pickup level. The x51P pickup level is determined by Equation 4-1.

$$\text{Actual Pickup Level} = \frac{\text{sensing voltage level}}{\text{restraint pickup setting}} \times (\text{x51P pickup setting})$$

Equation 4-11. Restraint Pickup Level

Control I. In Control Mode, pickup level is as selected by the 27R pickup setting.

Control or restraint operation can also be set by the S<g>-27R ASCII command.

Programmable Curves

Time current characteristics for trip and reset programmable curves are defined by Equation 4-2 and Equation 4-3 respectively. These equations comply with IEEE standard C37.112-1996. The curve specific coefficients are defined for the standard curves as listed in Appendix A, *Time Overcurrent Characteristic Curves*. When time current characteristic curve P is selected, the coefficients used in the equation are those defined by the user. Definitions for these equations are provided in Table 4-16.

Equation 4-12. Time OC Characteristics for Trip

$$T_T = \frac{AD}{M^N - C} + BD + K$$

Equation 4-13. Time OC Characteristics for Reset

$$T_R = \frac{RD}{M^2 - 1}$$

Table 4-16. Definitions for Equations 4-11 and 4-12

Parameter	Description	Explanation
T_T	Time to trip	Time that the 51 function will take to time out and trip.
D	Time dial setting	Time dial setting for the 51 function.
M	Multiple of pickup	Measured current in multiples of pickup. The timing algorithm has a dynamic range of 0 to 40 times pickup.
A	Coefficient specific to selected curve	Affects the effective range of the time dial.
B	Coefficient specific to selected curve	Affects a constant term in the timing equation. Has greatest effect on curve shape at high multiples of tap.

Parameter	Description	Explanation
C	Coefficient specific to selected curve	Affects the multiple of PU where the curve would approach infinity if allowed to continue below pickup. Has greatest effect on curve shape near pickup.
N	Exponent specific to selected curve	Affects how inverse the characteristics are. Has greatest effect on curve shape at low to medium multiples of tap.
K	Constant	Characteristic minimum delay term.
T_R	Time to reset	Relevant if 51 function is set for integrating reset.
R	Coefficient specific to selected curve	Affects the speed of reset when integrating reset is selected.

Setting Programmable Curves

Curve coefficients are entered using BESTCOMS. Alternately, curve coefficients can be entered using the SP-CURVE ASCII (Settings Protection-programmable curve) command. Table 4-17 lists the programmable curve settings.

Table 4-17. Programmable Time Current Characteristic Curve Coefficients

Setting	Range	Increment	Default
A Coefficient	0 to 600	0.0001	0.2663
B Coefficient	0 to 25	0.0001	0.0339
C Coefficient	0.0 to 1.0	0.0001	1.0000
N Coefficient	0.5 to 2.5	0.0001	1.2969
R Coefficient	0 to 30	0.0001	0.5000

Curve coefficients are entered by selecting the *Curve Coefficients* button on the *51* tab in the *Time Overcurrent* screen. (Refer to Figure 4-25.) The Curve Coefficients screen will appear (see Figure 4-27). Enter the calculated values for each constant and select *Done*.

Programmable curve coefficients can be entered regardless of the curve chosen for the protection element. However, the programmable curve will not be enabled until *P* is selected as the curve for the protective element.

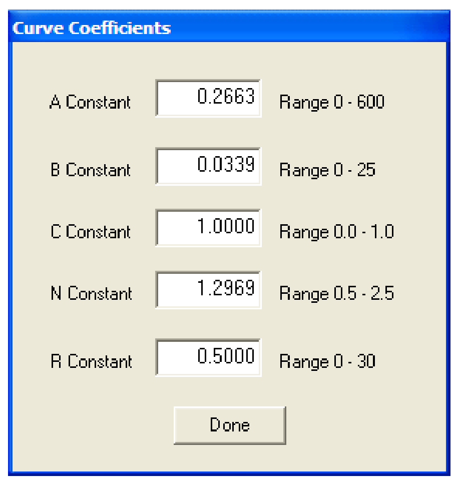

Figure 4-27. Curve Coefficients

46 Curve

The 46 curve is a special curve designed to emulate the I_2t withstand ratings of generators using what is frequently referred to as the generator's K factor. Do not confuse the 46 curve with the 46 element. The 46 curve was designed for use with the 46 function. But, in actuality, the 46 curve may be selected for use with the 51P, 51N, and 51Q protection functions as well (though in actual practice, it is doubted that this will be done very often).

To use the 46 curve, the user should determine the K factor of the generator and the continuous $(I_2)^2t$ rating of the generator (supplied by the manufacturer) and use this to set the time dial and pickup for the 46 curve by the process described in Appendix A, *Time Overcurrent Characteristic Curves*. The K factor is the time the generator can withstand 1 per unit I_2 where 1 pu is the relay setting for nominal current.

Negative-Sequence Overcurrent Protection

For years, protection engineers have enjoyed increased sensitivity to phase-to-ground unbalances with the application of ground relays. Ground relays can be set more sensitively than phase relays because a balanced load has no ground (3_{I0}) current component. The negative-sequence elements can provide similar increased sensitivity to phase-to-phase faults because a balanced load has no negative-sequence (I_2) current component.

Pickup Settings for Negative-Sequence Overcurrent

A typical setting for the negative-sequence elements might be one-half the phase pickup setting in order to achieve equal sensitivity to phase-to-phase faults as three-phase faults. This number comes from the fact that the magnitude of the current for a phase-to-phase fault is √3/2 (87%) of the three-phase fault at the same location. This is illustrated in Figure 4-28.

The phase-to-phase fault is made up of both positive and negative-sequence components as shown in Figure 4-29 or a phase-to-phase fault, the magnitude of the negative-sequence component is 1/ 3 (58%) of the magnitude of the total phase current. When these two factors (√3/2 and 1/√3) are combined, the √3 factors cancel which leaves the one-half factor.

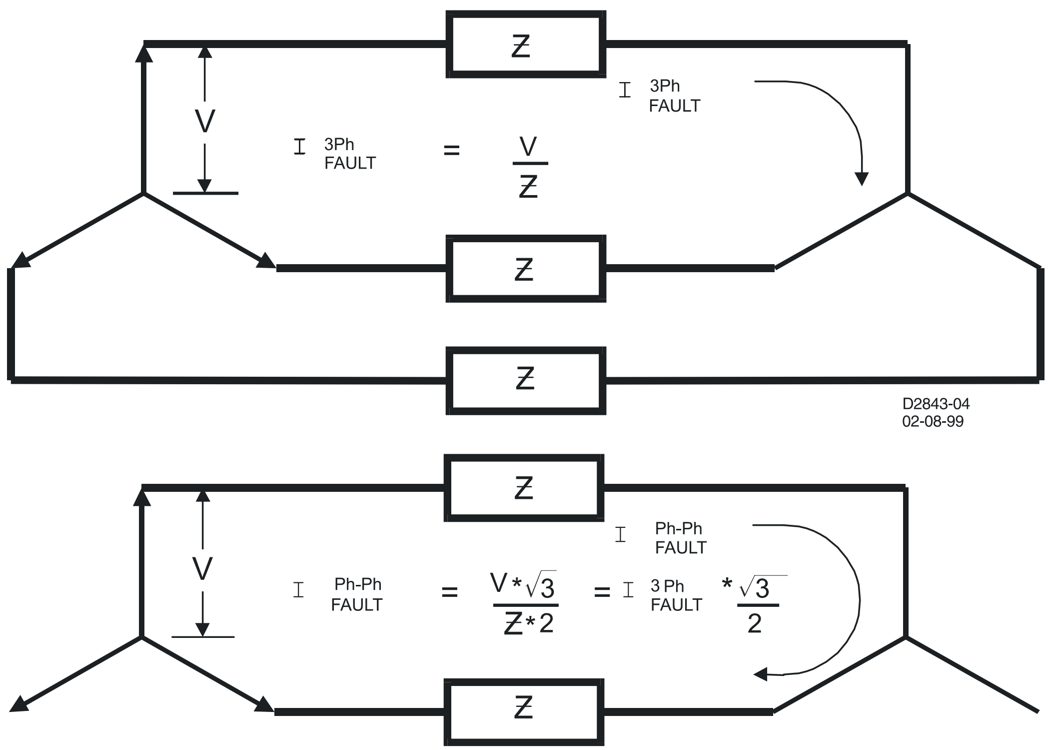

Figure 4-28. Phase-to-Phase Fault Magnitude

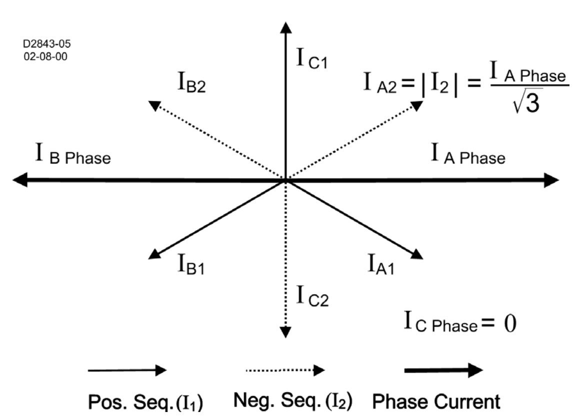

Figure 4-29. Sequence Components for an A-B Fault

Coordination Settings for Negative-Sequence Overcurrent

The 51Q settings should be checked for coordination with phase-only sensing devices such as downstream fuses and reclosers and/or ground relays. To plot the negative-sequence time current characteristics on the same plot for the phase devices, you need to multiply the negative-sequence element pickup value by the correct multiplier. The multiplier is the ratio of phase current to negative-sequence current for the fault type for which you are interested. To plot the negative-sequence time current characteristics on the same plot for the ground devices, you need to multiply the pickup value by the multiplier for phase-to-ground faults (see Table 4-18).

Table 4-18. Fault Type Multipliers

Fault Type	Multiplier
Ph-Ph	m = 1.732
Ph-Ph-G	m > 1.732
Ph-G	m = 3
3-phase	m = infinity

For example, a downstream phase 51 element has a pickup of 150 amperes. The upstream 51Q element has a pickup of 200 amperes. To check the coordination between these two elements for a phase-to-phase fault, the phase overcurrent element would be plotted normally with pickup at 150 amperes. The 51Q element would be shifted to the right by the appropriate factor m. Thus, the characteristic would be plotted on the coordination graph with pickup at: (200 amperes) ∗ 1.732 = 346 amperes.

Generally, for coordination with downstream phase overcurrent devices, phase-to-phase faults are the most critical to consider. All other fault types result in an equal or greater shift of the time current characteristic curve to the right on the plot.

Delta/Wye Transformer Application

Often, the phase relays on the delta side of a delta/wye transformer must provide backup protection for faults on the wye side. For faults not involving ground, this is not a problem since the phase relays will see 1.0 per unit fault current for three-phase faults and 2/√3 (1.15) per unit fault current for phase-to-phase faults. However, for faults involving ground, the sensitivity is reduced because the zero-sequence components are trapped in the delta not seen by the delta-side phase relays. The phase relays will see only 1/√3 (0.577) per unit current for phase-to-ground faults.

Negative-sequence overcurrent protection is immune to the effect caused by the zero-sequence trap and 30 degrees phase shift provided by the delta/wye transformer. For a phase-to-ground fault, the magnitude of the negative-sequence components is 1/3 the magnitude of the total fault current. On a per unit basis, this is true for the fault current on the delta side of the transformer as well. (The previous statement specifies per unit since the actual magnitudes will be adjusted by the inverse of the voltage ratio of the delta/wye transformer.) Thus, backup protection for phase-to-ground faults on the wye side of the transformer can be obtained by using negative-sequence overcurrent protection on the delta side with the pickup sensitivity set at 1/3 per unit of the magnitude of the phase-to-ground fault for which you wish to have backup protection.

Voltage Protection

BE1-CDS240 voltage protection includes elements for overexcitation, phase undervoltage, phase overvoltage, negative-sequence overvoltage, and over/underfrequency.

24 - Volts per Hertz Overexcitation Protection

Overexcitation occurs when a generator or transformer magnetic core becomes saturated. When this happens, stray flux is induced in non-laminated components, causing overheating. The BE1-CDS-240 detects overexcitation conditions with a volts/hertz element that consists of one alarm setting, one integrating time characteristic with selectable exponents (3 sets of time curves), and two definite-time characteristics. This allows the user to individually select an inverse-time characteristic, a composite characteristic with inverse-time, and one or two definite-time elements, or a dual-level, definite-time element. The volts/hertz element has two outputs: *Pickup* and *Trip* as shown in Figure 4-30.

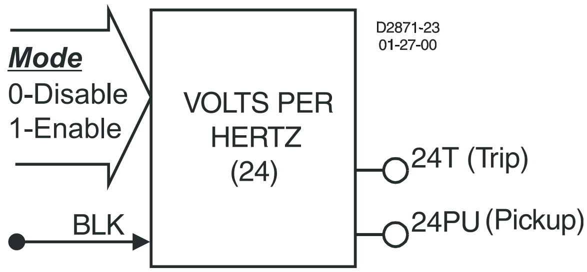

Figure 4-30. Volts per Hertz Overexcitation Logic Block

The integrating time characteristic closely approximates the heating characteristic of the protected equipment as overexcitation increases. A linear reset characteristic provides for the decreasing (cooling) condition.

The 24 element is enabled or disabled by the *Mode* input. Two modes are available. Selecting Mode 0 disables protection; Mode 1 enables the 24 element.

The block (*BLK*) input is used to disable protection. A BESTlogic expression defines how the *BLK* input functions. When this expression is TRUE, the element is disabled by forcing the outputs to logic 0 and resetting the timers. This feature functions in a similar way to the torque control contact of an electromechanical relay.

Theory of Operation for Volts per Hertz Overexcitation

V/Hz protection responds to the magnitude of voltage versus frequency where the measured voltage is phase-phase and includes the phase with the frequency measurement element. If monitored V/Hz is above a pickup setting, the pickup bit is asserted and integrating and/or definite time timers start timing towards trip. The trip output becomes TRUE when the first timer times out (integrating or definite time characteristic). If monitored V/Hz is above both the integrating and definite time pickup thresholds, the definite time delay has priority over the integrating time characteristic.

The pickup settings determine the V/Hz pickup level. The measured V/Hz is always calculated as the measured voltage divided by the sensed system frequency. The measured phase depends on the sensing voltage setting, SG-VTP. The 24 function monitors VAB for both 3-wire and 4-wire connections. Thus, setting is in VPP/Hz for VT connection = 3W, 4W, AB, BC, CA and VPN/Hz for VT connection = AN, BN, CN. For more information, refer to Section 3, *Input and Output Functions*.

Nominal voltage for the BE1-CDS-240 is defined as a phase to neutral quantity. (Refer to Section 3, *Input and Output Functions*, for details). Nominal V/Hz depends on the sensing voltage (VT) connection, nominal voltage, and nominal frequency settings. Nominal V/Hz is calculated as the nominal voltage divided by nominal frequency. For VT connections equal to 3W, 4W, AB, BC, CA, the nominal voltage (phase-neutral value) must be converted to a phase-phase value by multiplying by the square root of 3. No additional conversion is required for VT connections equal to AN, BN, or CN.

For 3W, 4W, AB, BC, or CA phase to phase sensing connections:

$$\text{V/Hz}_{\text{Measured}} = \frac{\text{Measured } V_{\text{Phase-Phase}}}{\text{Measured Frequency}} \qquad \text{V/Hz}_{\text{Nominal}} = \frac{V_{\text{Nominal}} * \sqrt{3}}{\text{Nominal Frequency}}$$

For AN, BN, or CN phase to neutral sensing connections:

$$\text{V/Hz}_{\text{Measured}} = \frac{\text{Measured } V_{\text{Phase-Neutral}}}{\text{Measured Frequency}} \qquad \text{V/Hz}_{\text{Nominal}} = \frac{V_{\text{Nominal}}}{\text{Nominal Frequency}}$$

Equations 4-13 and 4-14 represent the trip time and reset time for a constant V/Hz level. Normally, the V/Hz pickup is set to a value greater than the V/Hz nominal. This ensures that V/Hz measured divided by V/Hz nominal is always greater than 1.000 throughout the pickup range. If the pickup is set less than nominal, then measured values above pickup and below nominal will result in the maximum time delay. The maximum time delay is determined by Equation 4-13 with (V/Hz measured / V/Hz nominal) set equal to 1.001. The overall inverse time delay range is limited to 1,000 seconds maximum and 0.2 seconds minimum.

$$T_T = \frac{D_T}{\left[\frac{V/Hz_{Measured}}{V/Hz_{Nominal}} - 1\right]^n}$$

Equation 4-14. Time to Trip

$$T_R = D_R * \frac{E_T}{FST} * 100$$

Equation 4-15. Time to Reset

where:

T_T = Time to trip
T_R = Time to reset
D_T = Time dial trip
D_R = Time dial, reset
E_T = Elapsed time
n = Curve exponent (0.5, 1, 2)
FST = Full scale trip time (T_T)
E_T/FST = Fraction of total travel toward trip that integration had progressed to. (After a trip, this value will be equal to one.)

When the measured V/Hz rises above a pickup threshold, the pickup element becomes TRUE and an integrating or definite time timer starts. If the V/Hz remains above the pickup threshold and the integration continues for the required time interval as defined by the equations shown above and the set time dial, the trip output becomes TRUE. But if the measured V/Hz condition falls below the pickup setting and integrating reset is chosen, the integrating trip timer will ramp down towards reset at a linear rate based on the reset time dial setting. See Appendix B, *Overexcitation (24) Inverse Time Curves*, for details on each of the available time curves.

If the target is enabled for the 24 element, the target reporting function will record a target when the trip output is TRUE and the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting*, for more information about target reporting.

BESTlogic Settings for Volts Per Hertz Overexcitation

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-31 illustrates the BESTCOMS screen used to select BESTlogic settings for the Overexcitation (24) element. To open the *BESTlogic Function Element* screen for *Overexcitation (24),* select *Voltage Protection* from the *Screens* pull-down menu and select the *24* tab. Then, select the *BESTlogic* button. Alternately, settings may be made using SL-24 ASCII command.

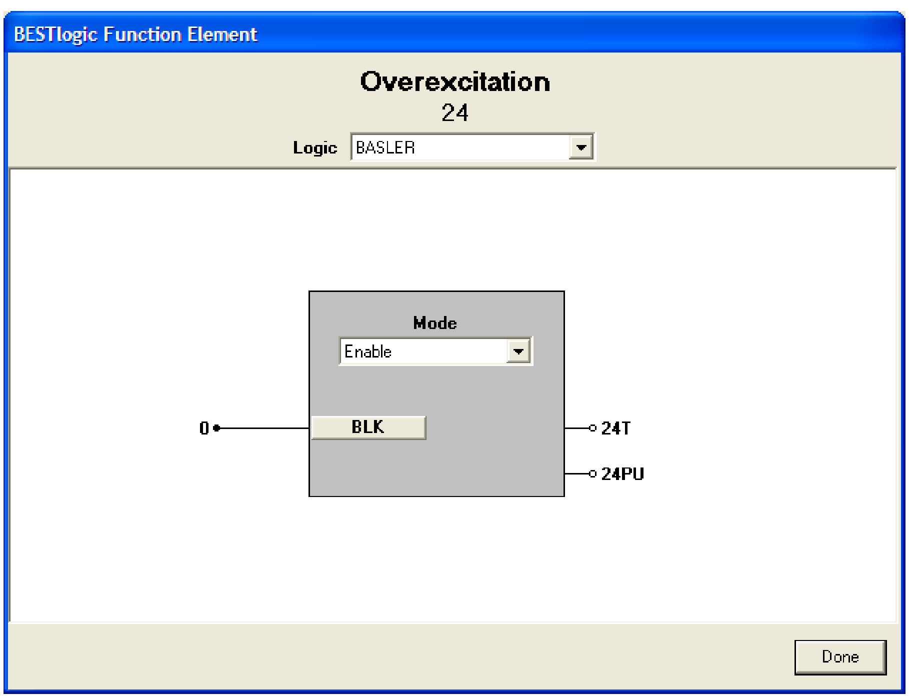

Figure 4-31. BESTlogic Function Element Screen, 24

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the BESTlogic function by selecting its mode of operation from the *Mode* pull-down menu. To connect the function/elements inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, See Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-19 lists the BESTlogic settings for Volts per Hertz Overexcitation.

Table 4-19. BESTlogic Settings for Volts per Hertz Overexcitation

Function	Range/Purpose	Default
Mode	0 = Disable 1 = Enable	0
BLK	Logic expression that disables the function when TRUE.	0

Operating Settings for Volts per Hertz Overexcitation

Operating settings for the 24 function consist of a pickup setting, a trip time dial, and a reset time dial. A pickup of 0 disables the element. The unit of measure is secondary VPP/Hz or VPN/Hz and depends on the SG-VTP setting. For more information, refer to Section 3, *Input and Output Functions, Power System Inputs*. Operating settings are made using BESTCOMS. Figure 4-32 illustrates the BESTCOMS screen used to select operational settings for the *Volts per Hertz* element. To open the screen, select *Voltage Protection* from the *Screens* pull-down menu and select the *24* Tab. Alternately, settings can be made using the S<g>-24 and S<g>-24D commands or at the optional front panel HMI using Screen 5.#.5.1, \PROT\SG#\24\24.

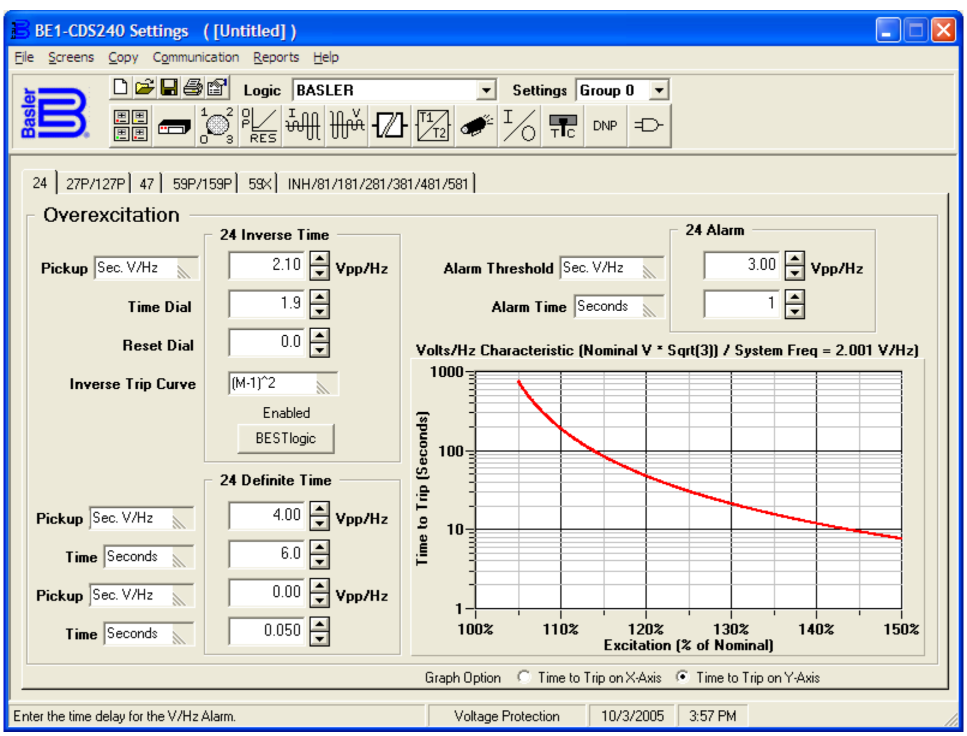

Figure 4-32. Voltage Protection Screen, 24 Tab

Table 4-20 lists the operating settings for Volts per Hertz Overexcitation.

Table 4-20. Operating Settings for Volts per Hertz Overexcitation

Setting	Range	Increment	Unit of Measure	Default
Integrating Pickup	0.5 to 6	0.1	Sec. V/Hz	0
Trip Time Dial	0 to 9.9	0.1	N/A	0
Reset Time Dial	0 to 9.9	0.1	N/A	0
Inverse Trip Curve	0.5, 1.0, 2.0	N/A	N/A	(M-1)^2
Definite Time Pickup #1	0.5 to 6	0.1	Sec. V/Hz	0
Definite Time Delay #1	0.050 to 600	3 digit resolution	Seconds	50 ms
Definite Time Pickup #2	0.5 to 6	0.1	Sec. V/Hz	0
Definite Time Delay #2	0.050 to 600	3 digit resolution	Seconds	50 ms

Programmable Alarm for Volts per Hertz Overexcitation

A separate V/Hz alarm threshold and user adjustable time delay are included for indicating when overexcitation is occurring so that the operator can take corrective action before the 24 function trips. If the V/Hz level exceeds the alarm setting, a programmable alarm bit is set. See Section 6, *Reporting and Alarms*, for more information. Settings for the alarm are made using BESTCOMS (Figure 4-25). Alternately, settings can be made with the SA-24 ASCII command. Table 4-21 lists the programmable alarm settings for Volts per Hertz Overexcitation. V/Hz alarm settings cannot be set through the optional HMI.

Table 4-21. Programmable Alarm Settings for Volts per Hertz Overexcitation

Setting	Range	Increment	Unit of Measure	Default
Alarm Level	0.5 to 6	0.1	Sec. V/Hz	0
Alarm Time Delay	0.050 to 600	3 digit resolution	Seconds	0

Settings Example for Volts per Hertz Overexcitation

V/Hz tripping elements are used to de-energize a generator or transformer that is experiencing an overexcitation condition. Therefore, the manufacturer's overexcitation limit curves are required to establish optimum protection. Figures 4-33 and 4-34 show examples of a transformer and generator limit curve along with the optimum composite protection characteristic.

NOTE

Actual damage curves must be obtained from the equipment manufacturer for particular equipment to be protected.

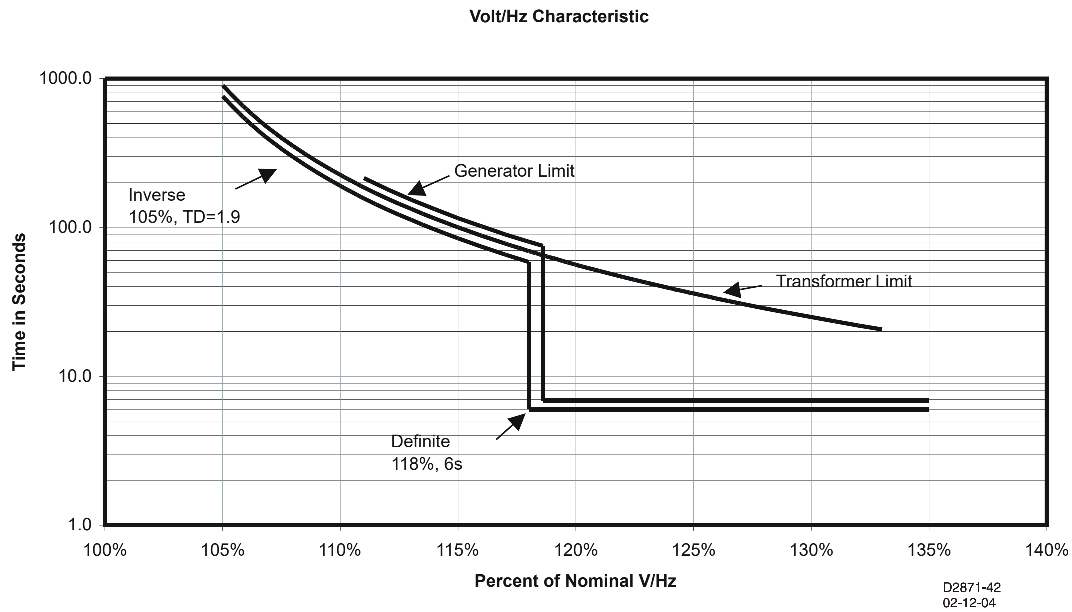

Figure 4-33. Time Shown on Vertical Axis

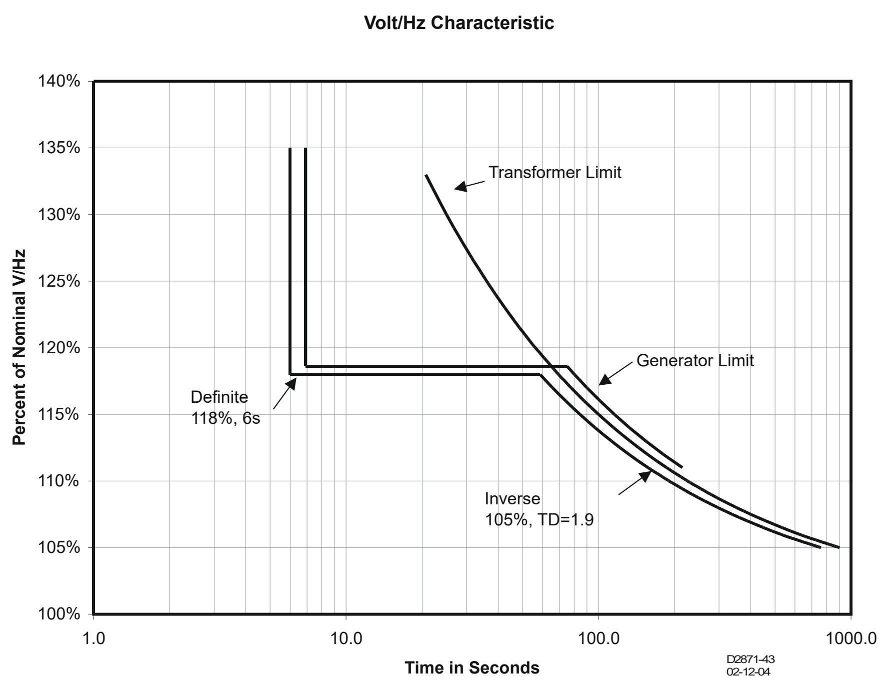

Figure 4-34. Time Shown on Horizontal Axis

Assuming a Vnom of 69.3 volts phase-neutral, 1 pu volts/hertz = (69.3 * √3) / 60 = 2.00. Using IEEE/C37.102, "*Guide for AC Generator Protection*" as a guide for setting overexcitation protection, the following example demonstrates how to set the BE1-CDS240 to provide a composite V/Hz characteristic for protection of a generator and a step-up transformer:

- Alarm = 105% @ 1 second time delay; V/Hz = 2 * 1.05 = 2.10
- Inverse time pickup = 105%; Time Dial = 1.9; Inverse Trip Curve = (M-1)^2; V/Hz = 2 * 1.05 = 2.10
- Definite Time #1 = 118% @ 6 seconds time delay; V/Hz = 1.18 * 2.0 = 2.36

In BESTCOMS, the 24 graphing capability can be used to verify the composite shape as shown in Figure 4-35. Secondary V/Hz is shown.

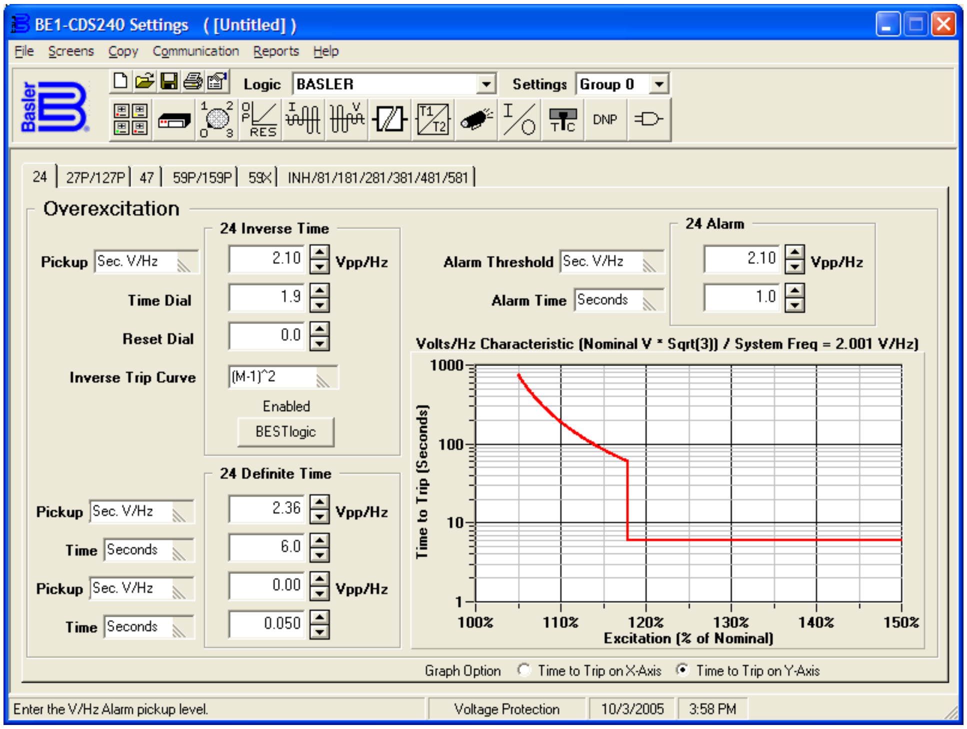

Figure 4-35. Voltage Protection Screen, Overexcitation (24) Tab

The reset rate is determined by the reset dial setting. A setting of 0.0 enables reset to be instantaneous. Using the inverse squared characteristic, assume a trip time dial setting 2.0 and a pickup multiple of 1.2. The total time to trip will be 50 seconds. If this exists for 30 seconds before being corrected (60% elapsed time), what would the total reset time be for a reset dial setting of 5? Based on the reset equation (Equation 4-15), the calculation will be:

$$T_R = D_R * \frac{E_T}{FST} * 100 \qquad T_R = 5.0 * \frac{30}{50} * 100 = 300 \text{ seconds}$$

Equation 4-16. Time to Reset

If the overexcitation condition returns prior to total reset (i.e., less than 300 seconds), timing resumes from that point at the inverse square rate. For example, if this condition recurs after 150 seconds or 50% of the total reset time, then trip time from the second event will start at 30% instead of 0%, therefore tripping in 70% or the original trip time or 35 seconds. Figure 4-36 illustrates the inverse time delay and reset time.

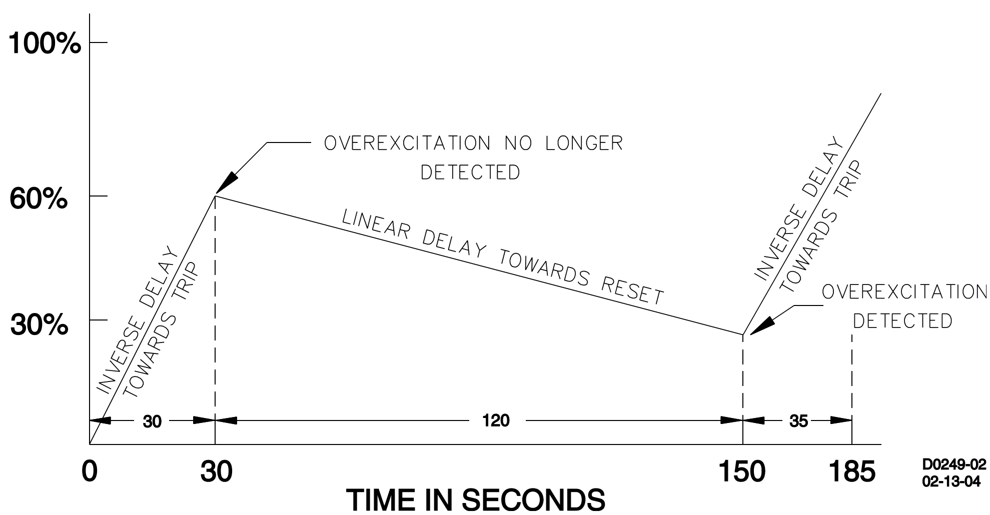

Figure 4-36. Inverse Time Delay and Reset Time

Retrieving Volts per Hertz Overexcitation Status from the Relay

The status of each logic variable can be determined through the ASCII command interface using the RG-STAT (report general-status) command. See Section 6, *Reporting and Alarms, General Status Reporting,* for more information. The status can also be determined using BESTCOMS *Metering* screen.

27P/59P - Phase Undervoltage/Overvoltage Protection

Figure 4-37 illustrates the Phase Undervoltage/Overvoltage Logic Blocks. The 127P phase undervoltage element and the 159P phase overvoltage element are identical in configuration.

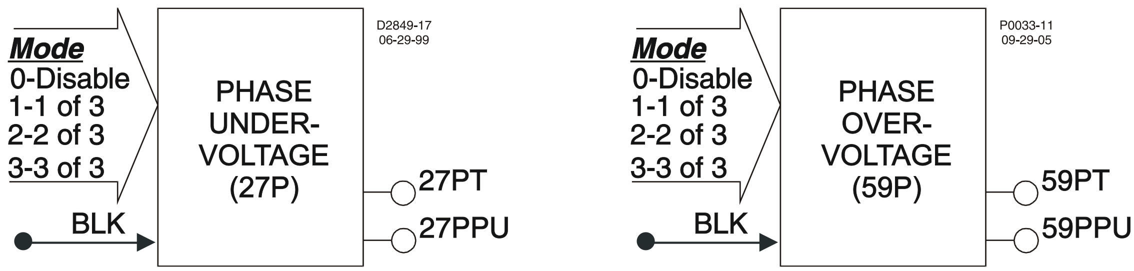

Figure 4-37. Phase Undervoltage/Overvoltage Logic Blocks

Each element has two logic outputs: *27PT* (Trip) and *27PPU* (Pickup). When the monitored voltage decreases below the undervoltage pickup setting (27P) or increases above the overvoltage pickup setting (59P), the pickup output becomes TRUE and the element starts timing toward a trip. The trip output becomes TRUE when the element timer times out. The *BLK* (block) input is used to disable protection. A BESTlogic expression defines how the *BLK* input functions. When this expression is TRUE, the element is disabled by forcing the outputs to logic 0 and resetting the timer. This feature functions in a similar way to the torque control contact of an electromechanical relay.

An element is enabled or disabled by the *Mode* input. Any one of four modes is possible for the phase undervoltage and phase overvoltage elements. Selecting Mode 0 disables protection. Mode 1 activates protection when one of the three phases of voltage decreases below the pickup setting (27P) or increases above the pickup setting (59P). Mode 2 requires two of the three phases of voltage to be beyond the pickup setting. Mode 3 requires all three phases of voltage to be beyond the pickup setting. More information about logic mode selections is provided in the *BESTlogic Settings for Phase Undervoltage and Overvoltage* in this section.

The phase undervoltage and overvoltage protective functions each include a timer and three independent comparators, one for each phase. The 27P/59P functions can be set to monitor VPP or VPN. This is determined by the 27/59 mode parameter of the phase VT connections setting. For more information on the VTP setup for PP or PN voltage response, see Section 3, *Input and Output Functions, Power System Inputs, Voltage Measurement*.

If the 60FL element trip logic is TRUE, and V block is enabled for phase blocking (P), all functions that use the phase voltage are blocked. For more information on the 60FL function, see the paragraphs later in this section.

If the target is enabled for the element, the target reporting function will record a target for all phases that are picked up when the protective function trip output is TRUE and the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting*, for more information about target reporting.

When undervoltage inhibit is selected, undervoltage sensing is disabled for any phase that falls below the inhibit threshold. Undervoltage inhibiting is disabled when the threshold is set to zero. Undervoltage inhibit is used to prevent undesired undervoltage tripping, such as when a loss of supply occurs.

BESTlogic Settings for Phase Undervoltage/Overvoltage

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-38 illustrates the BESTCOMS screen used to select BESTlogic settings for the Under and Overvoltage elements. To open the screen, select *Voltage Protection* from the *Screens* pull-down menu, and select the *27P/127P* or *59P/159P* tab. alternately, settings may be made using the SL-27P and SL-59P ASCII commands.

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme

must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the element by selecting its mode of operation from the *Mode* pull-down menu. To connect the elements inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

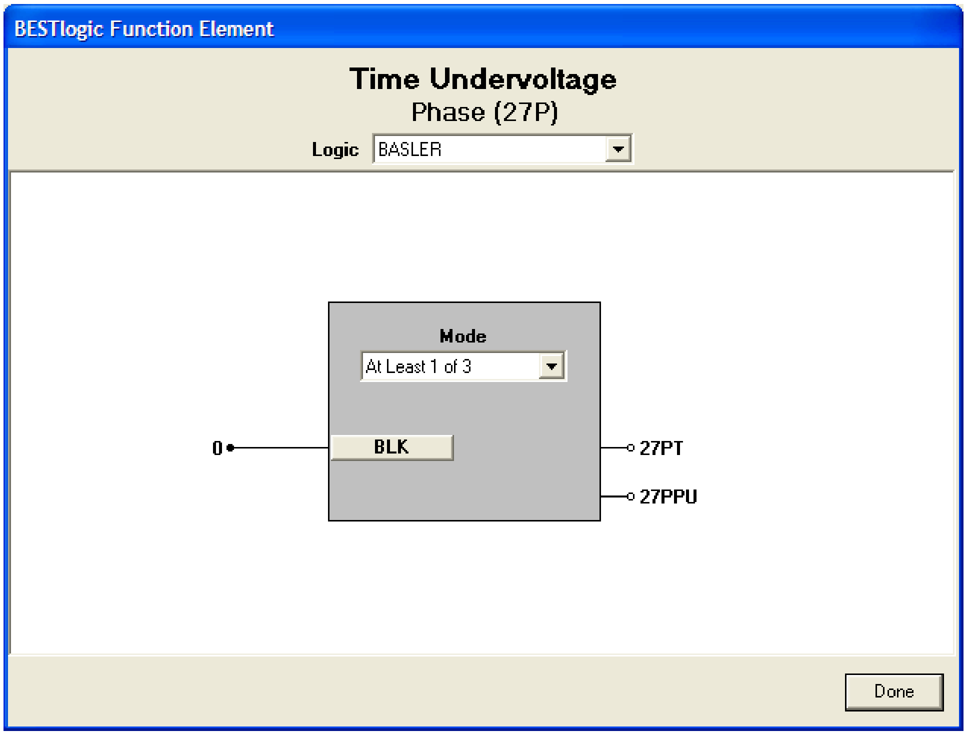

Figure 4-38. BESTlogic Function Element Screen, Phase (27P)

Table 4-22 summarizes the BESTlogic settings for Phase Undervoltage/Overvoltage.

Table 4-22. BESTlogic settings for Phase Undervoltage/Overvoltage

Function	Range/Purpose		Default
Mode	0 =	Disabled	0
	1 =	Undervoltage (27) or overvoltage (59) on one (or more) phases causes pickup.	
	2 =	Undervoltage (27) or overvoltage (59) on two (or more) phases causes pickup.	
	3 =	Undervoltage or overvoltage on all three phases causes pickup.	
BLK	Logic expression that disables function when TRUE.		0

Example 1. Make the following BESTlogic settings to the 27P element. Refer to Figure 4-38.

Mode: At least 1of 3 phases

BLK: 0

Operating Settings for Phase Undervoltage/Overvoltage

Operating settings for the 27P and 59P functions consist of pickup and time delay values. The pickup value determines the level of voltage required for the element to start timing toward a trip. The time delay value determines the length of time between pickup and trip. Time delays can be set in milliseconds, seconds, or cycles. The default is milliseconds if no unit of measure is specified.

Operating settings are made using BESTCOMS. Figure 4-39 illustrates the BESTCOMS screen used to select operational settings for the undervoltage elements. The 59P/159P overvoltage elements are set in a similar manner. To open the screen, select *Voltage Protection* from the *Screens* pull-down menu and select the *27P/127P* or *59/159P* tab. Alternately, settings may be made using the S<g>-27P and S<g>-59P ASCII command or through the optional HMI using Screens 5.#.6.1 (27P), \PROT\SG#\27, and 5.#.8.1 (59P), \PROT\SG#\59.

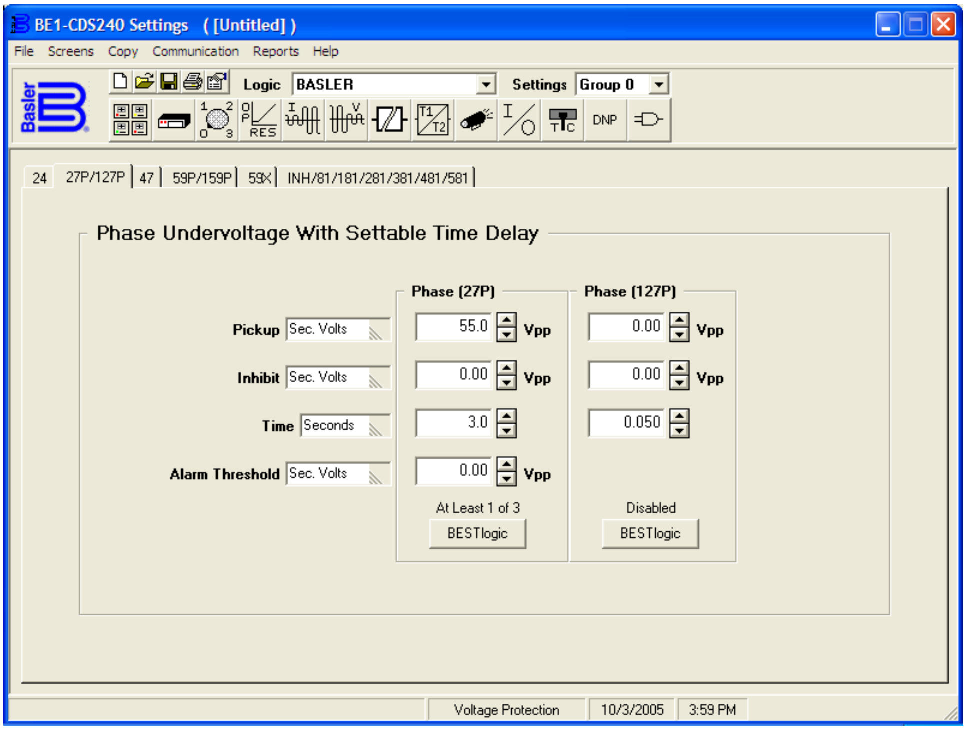

Figure 4-39. Voltage Protection Screen, 27P/127P Tab

Beside the *Logic* pull-down menu is a pull-down menu labeled *Settings.* The Settings menu is used to select the setting group that the elements settings apply to. The default unit of measure for the Pickup, Alarm Threshold, and Inhibit settings is secondary volts. Primary volts (Pri Volts), per unit volts (Per U Volts) and percent volts (% Volts) can also be selected as the *Pickup* setting unit of measure. The unit of measure for the *Time* setting that represents the element's time delay defaults to milliseconds. It is also selectable for seconds, minutes, and cycles.

Operating settings for Phase Undervoltage/Overvoltage are summarized in Table 4-23.

Table 4-23. Operating Settings for Phase Undervoltage/Overvoltage

Setting	Range	Increment	Unit of Measure	Default
Pickup	0 = Disabled 10 to 300	0.1 for 0 to 99.9 1.0 for 100 to 300	Secondary Volts †	0
Inhibit 27 only	0 = Disabled 10 to 300	0.1	Secondary Volts †	0
Time Delay	50 to 999 milliseconds	1	Milliseconds	50 ms
	1 to 600 seconds	0.1 for 1.0 to 9.9	Seconds	
		1.0 for 10 to 600	Seconds	
	3 to 36,000 cycles (60 Hz)	*	Cycles	
	2.5 to 30,000 cycles (50 Hz)			

∗ Time delays less than 10 cycles can be entered to the nearest 0.1 cycles from the front panel HMI. All time delays can be entered to the nearest 0.01 cycles from the ASCII command interface. Time delays entered in cycles are converted to milliseconds or seconds. Increment precision after conversion is limited to that appropriate for each of those units of measure.

† Unit of measure is secondary VPP or secondary VPN depending on the VTP connection settings.

Time delay settings entered in cycles are converted to seconds or milliseconds (per the nominal frequency setting stored in EEPROM) before being stored. See Section 3, *Input and Output Functions, Power System Inputs*, *Voltage Measurement,* for more information about this setting. If the nominal frequency setting is being changed from the default (60 hertz) and time delay settings are being set in cycles, the frequency setting should be entered and saved before making any time delay settings changes.

Example 1. Make the following operating settings to the 27P element. Refer to Figure 4-39.

Pickup: 55 secondary volts

Time: 3 seconds

Retrieving Phase Undervoltage/Overvoltage Status from the Relay

The status of each logic variable can be determined through the ASCII command interface using the RG-STAT (report general-status) command. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information. The status can also be determined using BESTCOMS *Metering* screen.

59X - Auxiliary Overvoltage Protection

Figure 4-40 illustrates the inputs and outputs of the auxiliary overvoltage element. Element operation is described in the following paragraphs.

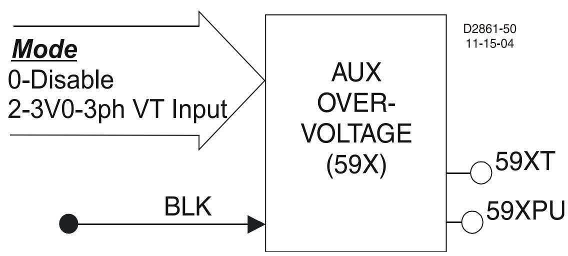

Figure 4-40. Auxiliary Overvoltage Logic Block

The 59X auxiliary element has two outputs: *59XPU* (pickup) and *59XT* (trip). When the monitored voltage increases above the pickup setting, the pickup output becomes TRUE and the element starts timing toward a trip. The trip output becomes TRUE when the element timer times out.

The *BLK* (block) input is used to disable protection. A BESTlogic expression defines how the *BLK* input functions. When this expression is TRUE, the element is disabled by forcing the outputs to logic 0 and resetting the timer. This feature functions in a similar way to the torque control contact of an electromechanical relay.

The 59X element is enabled or disabled by the Mode input. Two modes are available. Selecting Mode 0 disables protection. Mode 2 enables the element as described in this section under *BESTlogic Settings for the Auxiliary Overvoltage Element*. The pickup setting determines the voltage pickup level of the element. The time delay setting controls how long it takes the trip output to become TRUE after the pickup output becomes TRUE. When the monitored voltage increases above the pickup threshold, the pickup output becomes TRUE and the timer starts. If the voltage remains above the pickup threshold for the duration of the time delay setting, the trip output becomes TRUE. If the voltage decreases below the 59X dropout ratio of 98 percent, the timer is reset to zero.

If the 60FL element trip logic is TRUE and V block is enabled for 3VO blocking (N), the 59X function will be blocked if they are set to Mode 2. For more information on the 60FL function, see the paragraphs later in this section.

If the target is enabled for the 59X element, the target reporting function will record a target when the trip output is TRUE and the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting*, for more information about target

BESTlogic Settings for Auxiliary Overvoltage

BESTlogic settings are made from the *BESTlogic Function Element* Screen in BESTCOMS. Figure 4-41 illustrates the BESTCOMS screen used to select BESTlogic settings for the Overvoltage element. To open the *BESTlogic Function Element* Screen for the Time Overvoltage element, select *Voltage Protection* from the *Screens* pull-down menu. Then select the 59X tab. Alternately, settings may be made using SL-59X ASCII command.

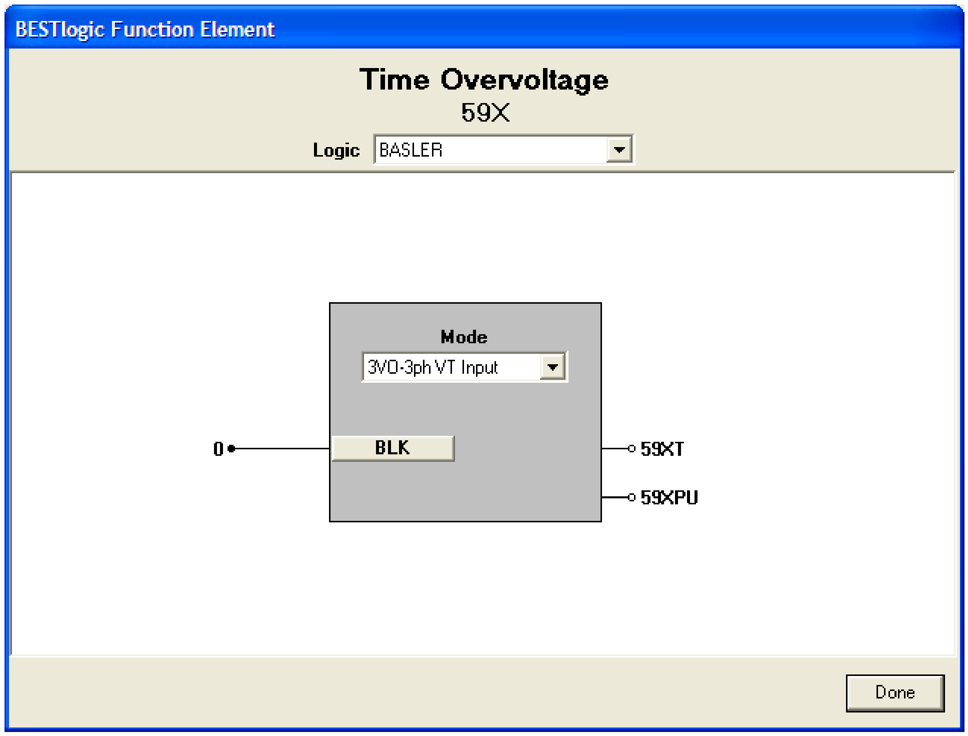

Figure 4-41. BESTlogic Function Element Screen, 59X

At the top center of the *BESTlogic Function Element* Screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the overvoltage function by selecting its mode of operation from the *Mode* pull-down menu. To connect the elements inputs, select the button for the corresponding input in the *BESTlogic Function Element* Screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-24 summarizes the BESTlogic settings for Auxiliary Overvoltage.

Table 4-24. BESTlogic Settings for Auxiliary Overvoltage

Function	Range/Purpose	Default
Mode	0 = Disabled 2 = 3V0-3-phase VT Input	0
BLK	Logic expression that disables function when TRUE.	0

Note: To use Mode 2, the VTP connection must be 4-wire.

Example 1. Make the following settings to the 59X element. Refer to Figure 4-41.
Mode: 3V0 3-phase Vx Input
BLK: 0

Operating Settings for Auxiliary Overvoltage

Operating settings for the 59X function consists of pickup and time delay values. The pickup value determines the level of voltage required for the element to start timing toward a trip. The unit of measure is secondary volts (PP or PN). The time delay value determines the length of time between pickup and trip. Time delays can be set in milliseconds, seconds, or cycles. The default is milliseconds if no unit of measure is specified.

Operating settings are made using BESTCOMS. Figure 4-42 illustrates the BESTCOMS screen used to select operational settings for the Auxiliary Overvoltage element. To open the *Voltage Protection* screen for the Overvoltage element, select *Voltage Protection* from the *Screens* pull-down menu. Then select the 59X tab. Alternately, settings may be made using the S<g>-59X ASCII command or through the optional HMI Screen 5.#.8.1, \PROT\SG#\59.

Beside the *Logic* pull-down menu is a pull-down menu labeled *Settings*. The settings menu is used to select the setting group that the elements settings apply to.

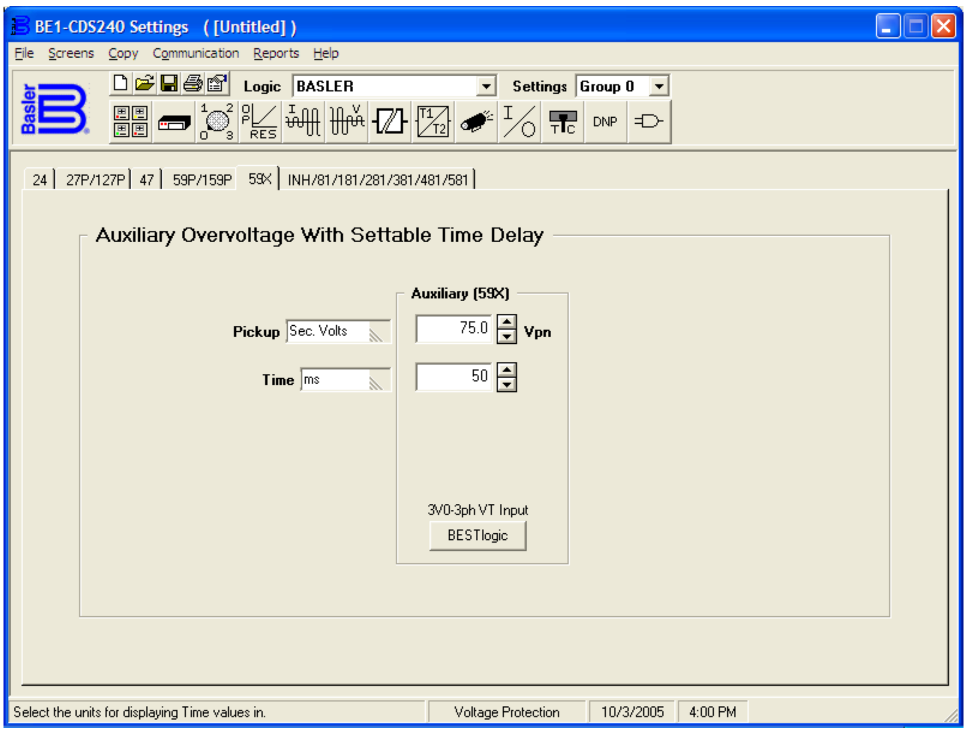

Figure 4-42. Voltage Protection Screen, 59X Tab

Table 4-25 summarizes the operating settings for Auxiliary Overvoltage.

Table 4-25. Operating Settings for Auxiliary Overvoltage

Setting	Range	Increment	Unit of Measure	Default
Pickup	0 = Disabled 1 to 150	0.1 for 0 to 99.9 1.0 for 100 to 150	Secondary Volts	0
Time Delay	50 to 999 milliseconds	1	Milliseconds	50 ms
	1 to 600 seconds	0.1 for 1.0 to 9.9	Seconds	
		1.0 for 10 to 600	Seconds	
	3 to 36,000 cycles (60 Hz)	*	Cycles	
	2.5 to 30,000 cycles (50 Hz)			

∗ Time delays less than 10 cycles can be entered to the nearest 0.1 cycles from the front panel HMI. All time delays can be entered to the nearest 0.01 cycles from the ASCII command interface. Time delays entered in cycles are converted to milliseconds or seconds. Increment precision after conversion is limited to that appropriate for each of those units of measure.

Example 1. Make the following changes to the 59X element. Refer to Figure 4-42.

Pickup: 75 secondary volts

Time: 50 ms

Retrieving Auxiliary Overvoltage Status from the Relay

The status of each logic variable can be determined through the ASCII command interface using the RG-STAT (report general-status) command. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information. The status can also be determined using BESTCOMS *Metering* screen.

47 - Negative-Sequence Overvoltage Protection

Figure 4-43 illustrates the inputs and outputs of the negative-sequence overvoltage element. Element operation is described in the following paragraphs. Negative-sequence overvoltage protection is not available if VTP connection is single-phase.

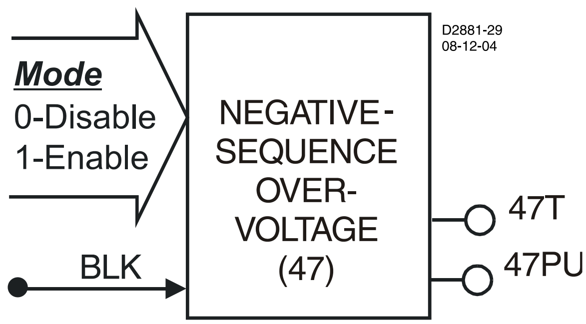

Figure 4-43. Negative-Sequence Overvoltage Logic Block

The negative-sequence overvoltage element has two outputs: *47PU* (pickup) and *47T* (trip). When the monitored negative-sequence voltage increases above the pickup setting, the pickup output becomes TRUE and the element starts timing toward a trip. The trip output becomes TRUE when the element timer times out.

The *BLK* (block) input is used to disable protection. A BESTlogic expression defines how the *BLK* input functions. When this expression is TRUE, the element is disabled by forcing the outputs to logic 0 and resetting the timer. This feature functions in a similar way to the torque control contact of an electromechanical relay.

The 47 element is enabled or disabled by the *Mode* input. Two modes are available. Selecting Mode 0 disables protection. Mode 1 enables the 47 element. More information about logic mode selections is provided in the *BESTlogic Settings for Negative-Sequence Overvoltage* paragraphs.

The pickup setting determines the voltage pickup level of the element. Voltage pickup is based on PN. The time delay setting controls how long it takes the trip output to become TRUE after the pickup output becomes TRUE. When the monitored voltage increases above the pickup threshold, the pickup output (47PU) becomes TRUE and the timer starts. If the voltage remains above the pickup threshold for the duration of the time delay setting, the trip output (47T) becomes TRUE. If the voltage decreases below the dropout ratio of 98 percent, the timer is reset to zero.

If the 60FL element trip logic is TRUE and V block is enabled for negative-sequence blocking <Q>, all functions that use the negative-sequence voltage (V_2) are blocked. For more information on the 60FL function, see the paragraphs later in this section.

If the target is enabled for the 47 element, the target reporting function will record a target when the trip output is TRUE and the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting*, for more information about target reporting.

BESTlogic Settings for Negative-Sequence Overvoltage

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-44 illustrates the BESTCOMS screen used to select BESTlogic settings for the negative-sequence overvoltage function. To open the screen, select *Voltage Protection* from the *Screens* pull-down menu and then select the *47* Tab. Then select the *BESTlogic* button at the bottom of the screen. Alternately, settings may be made using the SL-47 ASCII command.

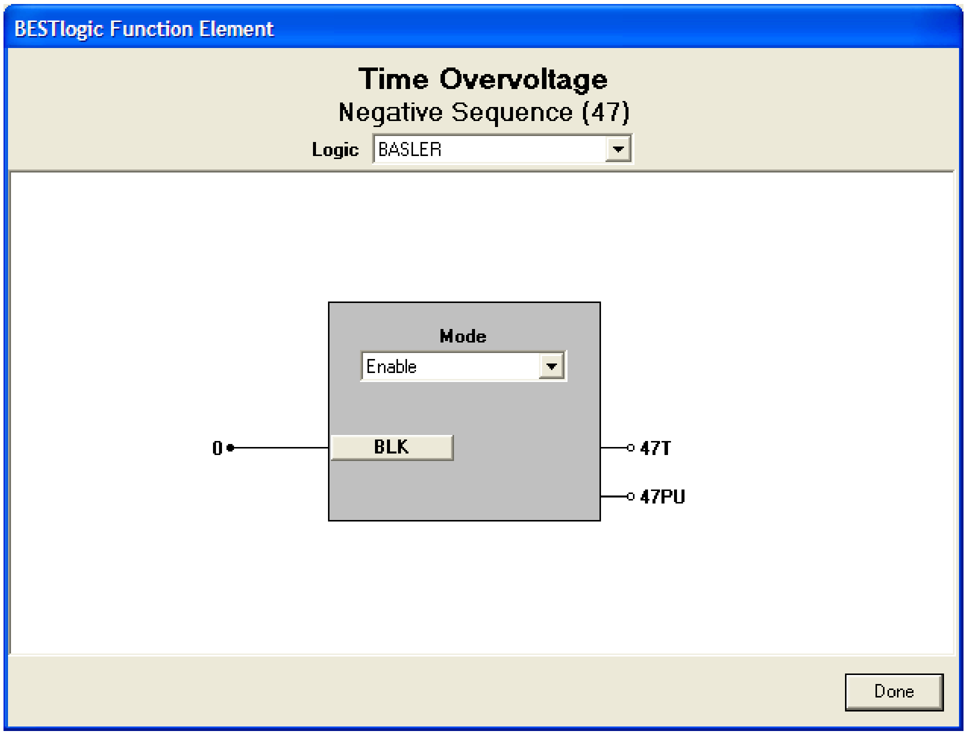

Figure 4-44. BESTlogic Function Element Screen, Negative Sequence (47)

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the negative-sequence overvoltage function by selecting its mode of operation from the *Mode* pull-down menu. To connect the elements inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-26 summarizes the BESTlogic settings for Negative-Sequence Overvoltage.

Table 4-26. BESTlogic Settings for Negative-Sequence Overvoltage

Function	Range/Purpose	Default
Mode	0 = Disabled 1 = Enabled	1
BLK	Logic expression that disables function when TRUE. A setting of 0 disables blocking.	0

Example 1. Make the following BESTlogic settings to the 47 element. Refer to Figure 4-44.

Mode: Enable

BLK: 0

Operating Settings for Negative-Sequence Overvoltage

Operating settings are made using BESTCOMS. Figure 4-45 illustrates the BESTCOMS screen used to select operational settings for the negative-sequence overvoltage element. To open the screen select *Voltage Protection* from the *Screens* pull-down menu and then select the *47* tab. Alternately, settings maybe made using the S<g>-47 ASCII command or through the optional HMI interface using Screen 5.#.7.1, \PROT\SG#\47\47.

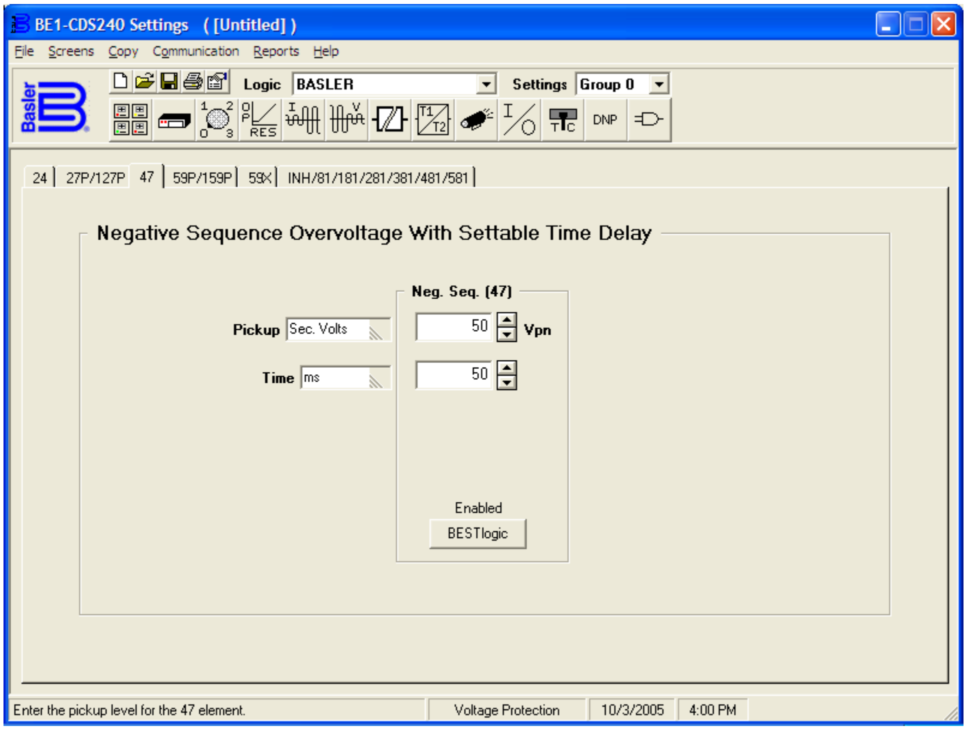

Figure 4-45. Voltage Protection Screen, 47 Tab

Beside the *Logic* pull-down menu is a pull-down menu labeled *Settings*. The Settings menu is used to select the setting group that the elements settings apply to.

The default unit of measure for the *Pickup* setting is secondary volts. Primary volts (Pri Volts), per unit volts (Per U Volts), and percent volts (% Volts) can also be selected as the pickup setting unit of measure. The unit of measure for the *Time* setting that represents the element's time delay defaults to milliseconds. It is also selectable for seconds, minutes, and cycles.

Table 4-27 summarizes operating settings for Negative-Sequence Overvoltage.

Table 4-27. Operating Settings for Negative-Sequence Overvoltage

Setting	Range	Increment	Unit of Measure	Default
Pickup	0 = Disabled 10 to 300	0.1 for 0 to 99.9 1.0 for 100 to 300	Secondary Volts	0
Time Delay	50 to 999 milliseconds	1	Milliseconds	50 ms
	1 to 600 seconds	0.1 for 0.1 to 9.9	Seconds	
		1.0 for 10 to 600	Seconds	
	3 to 36,000 cycles (60 Hz)	∗	Cycles	
	2.5 to 30,000 cycles (50 Hz)			

∗ Time delays less than 10 cycles can be entered to the nearest 0.1 cycles from the front panel HMI. All time delays can be entered to the nearest 0.01 cycles from the ASCII command interface. Time delays entered in cycles are converted to milliseconds or seconds. Increment precision after conversion is limited to that appropriate for each of those units of measure.

Example 1. Make the following operational settings to the 47 element. Refer to Figure 4-45.

Pickup: 50 Vpn secondary volts

Time: 50 ms

Retrieving Negative-Sequence Overvoltage Status from the Relay

The status of each logic variable can be determined through the ASCII command interface using the RG-STAT (report general-status) command. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information. The status can also be determined using BESTCOMS *Metering* screen.

Frequency Protection

81 - Over/Underfrequency Protection

BE1-CDS240 frequency protection consists of six independent elements that can be programmed for underfrequency or overfrequency protection. Each element has an adjustable frequency setpoint and time delay. The 81 elements share a common undervoltage inhibit setting. Power system frequency is measured on the A phase voltage input for four-wire or single-phase connections or the AB voltage input when in three-wire mode. Power system frequency is measured on the optional auxiliary voltage input as well. When the applied voltage is greater than 10 volts, the BE1-CDS240 measures the frequency.

Frequency element designations are 81, 181, 281, 381, 481, and 581. Each of the six elements has identical inputs, outputs, and setting provisions. Figure 4-46 illustrates the inputs and output of a frequency element. A trip output (x81T) is provided on each element. The trip output becomes TRUE when the monitored frequency decreases below (81U) or increases above (81O) the pickup setting and the element timer times out.

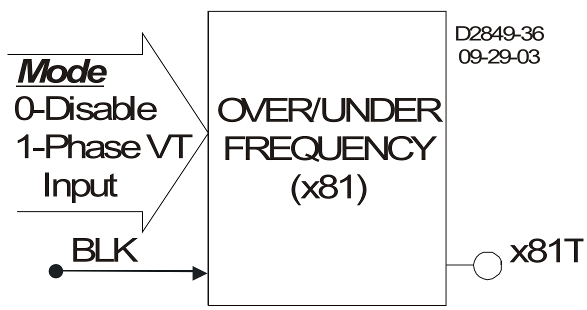

Figure 4-46. Over/Underfrequency Protection Logic Block

The *BLK* (block) input is used to disable protection. A BESTlogic expression is used to define how the BLK input functions. When this expression is TRUE, the element is disabled by forcing the outputs to logic 0 and resetting the timer. This feature functions in a similar way to the torque control contact of an electromechanical relay.

An element is enabled or disabled by the *Mode* input. Two mode options are possible. *Mode 0* disables protection and *Mode 1* enables the element to monitor the frequency on VTP input. Security of your load-shedding scheme can be enhanced by monitoring two independent VT circuits. See Section 8, *Application,* for more information. More information about logic mode selections is provided in the following *BESTlogic Settings for Underfrequency and Overfrequency Elements* paragraphs. Pickup settings define the frequency setpoint and time delay, and program the element for underfrequency or overfrequency protection. The frequency setpoint defines the value of frequency that will initiate action by an element. The time delay setting determines how long it takes the trip output to become TRUE once the measured frequency reaches the frequency setpoint. If three consecutive cycles of the measured frequency have either decreased (81U) below or increased (81O) above the pickup threshold, and the timer has timed out, then the 81T will trip. If the timer has not timed out and the frequency remains in the pickup range for the remainder of the time delay, the 81T will trip. If the monitored voltage decreases below the user-defined setpoint, frequency protection is inhibited.

If the target is enabled for the element, the target reporting function will record a target for the appropriate phase when the protective function trip output is TRUE *and* the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting,* for more information about target reporting.

BESTlogic Settings for Over/Underfrequency

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-47 illustrates the BESTCOMS screen used to select BESTlogic settings for the Over/Underfrequency element. To open the *BESTlogic Function Element* screen for Over/Underfrequency element, select *Voltage Protection* from the *Screens* pull-down menu and select the *INH/81/181/281/381/481/581* tab. Then select the *BESTlogic* button for the element to be programmed. Alternately, settings may be made using the SL-<x>81 ASCII command.

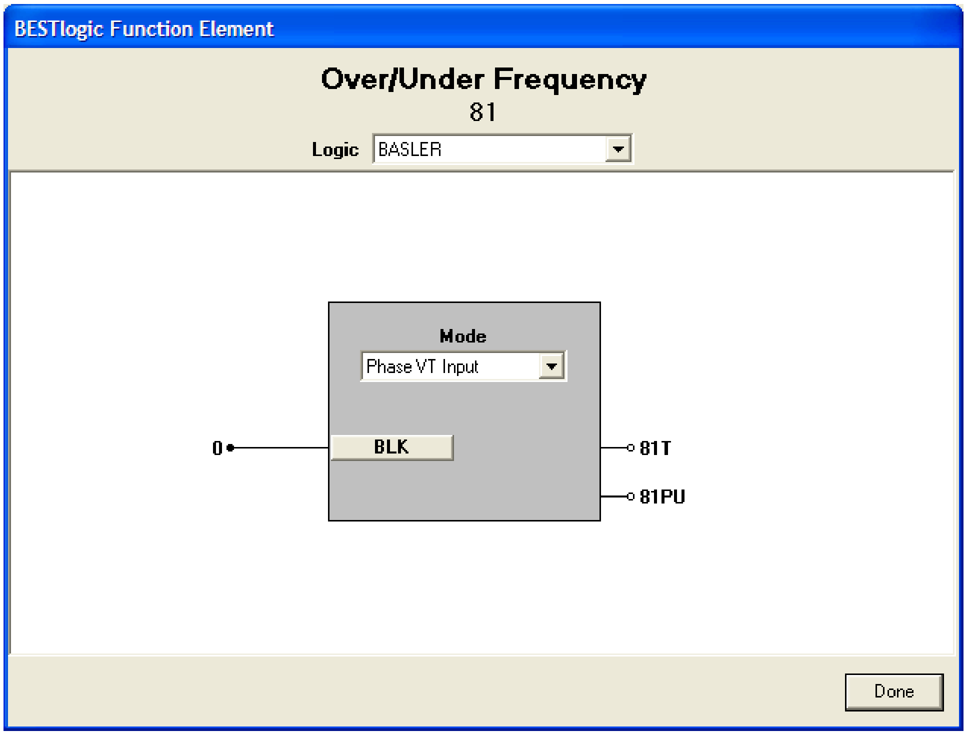

Figure 4-47. BESTlogic Function Element Screen, 81

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*. Enable the Over/Underfrequency function by selecting its mode of operation from the *Mode* pull-down menu. To connect the elements inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

BESTlogic settings for Over/Underfrequency are summarized in Table 4-28.

Table 4-28. BESTlogic Settings for Over/Underfrequency

Function	**Range/Purpose**	**Default**
Mode	0 = Disabled 1 = Enabled on VP input	0
BLK	Logic expression that disables function when TRUE.	0

Example 1. Make the following BESTlogic settings to the 81 element. Refer to Figure 4-47.

Mode: Phase VT Input
BLK: 0

Operating Settings for Over/Underfrequency

Operating settings for the 81 elements consist of pickup values, time delay values, and a mode setting that defines whether an element provides under or over frequency protection and is selectable from a pull-down menu under each element tab. The pickup value determines the value of frequency required for the element to start timing toward a trip. The time delay value determines the length of time between reaching the pickup value and tripping. Time delays can be set in milliseconds, seconds, or cycles. The default is milliseconds if no unit of measure is specified. Minimum timing resolution is two cycles. A time delay setting of zero makes the element instantaneous with no intentional time delay.

Operating settings are made using BESTCOMS. Figure 4-48 illustrates the BESTCOMS screen used to select operational settings for the Over/Underfrequency element. To open the *BESTlogic Function Element* screen for Over/Underfrequency element, select *Voltage Protection* from the *Screens* pull-down menu and select the *INH/81/181/281/381/481/581* tab. Alternately, settings may be made using the S<g>-<x>81 ASCII command or the optional HMI interface using Screens 5.#.10.1 and 5.#.10.2, \PROT\SG#\81\SETTINGS.

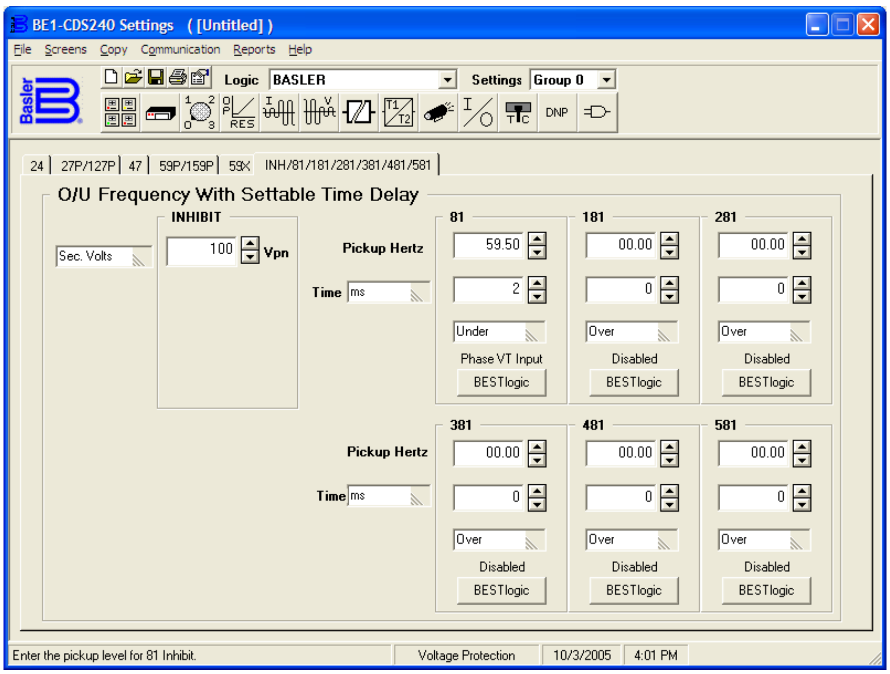

Figure 4-48. Voltage Protection Screen, INH/81/181/281/381/481/581 Tab

Beside the *Logic* pull-down menu is a pull-down menu labeled *Settings*. The Settings menu is used to select the setting group that the element's settings apply to.

Over/Underfrequency protection can be inhibited when the monitored voltage decreases below a user-defined level. The undervoltage inhibit level is set through BESTCOMS. Alternately, it can be set using the S<g>-<x>81INH command where x equals nothing or one through five. Settings can also be made using the optional HMI Screen 5.#.10.3, \PROT\SG#\81\SETTINGS. The voltage inhibit setting unit of measure depends upon the VTP and VTX connection settings. For 4-wire or PN connections, it is Sec VPN. For 3-wire or PP connections, it is Sec. VPP.

Table 4-29 summarizes the operating settings for Over/Underfrequency.

Table 4-29. Operating Settings for Over/Underfrequency

Setting	Range	Increment	Unit of Measure	Default
Pickup	40 to 70, 0 = Disabled	0.01	Hertz	0
Time Delay	0 to 999 milliseconds	1	Milliseconds	0

Setting	Range		Increment	Unit of Measure	Default
	0.0 to 600 seconds		0.1 for 0.1 to 9.9	Seconds	
			1.0 for 10 to 600	Seconds	
	0 to 36,000 cycles (60 Hz)		∗	Cycles	
	0 to 30,000 cycles (50 Hz)				
Mode	O U	= Overfrequency = Underfrequency	n/a	N/A	0
Voltage Inhibit Level	15 to 150 0 = Disabled (functions enabled for all voltage levels)		0.1 (for 0.1 to 99.9) 1.0 (for 100 to 150)	Secondary Volts †	40.0

∗ Time delays less than 10 cycles can be entered to the nearest 0.1 cycles from the front panel HMI. All time delays can be entered to the nearest 0.01 cycles from the ASCII command interface. Time delays entered in cycles are converted to milliseconds or seconds. Increment precision after conversion is limited to that appropriate for each of those units of measure.

† Phase-to-phase and phase-to-neutral settings depend on the VTP and VTX connection settings.

The default unit of measure for the voltage and negative-sequence inhibit setting is secondary volts. Primary volt (Pri Volt), per unit volts (Per U Volts), and percent volts (% Volts) can also be selected as the pickup setting unit of measure. Over/underfrequency inhibit is in hertz. The unit of measure for the *Time* setting that represents the element's time delay defaults to milliseconds. It is also selectable for seconds, minutes, and cycles.

Example 1. Make the following settings to the 81 element and to the inhibit function. See Figure 4-48.

Pickup Hertz: 59.5
Time: 2 ms
Mode: Underfrequency
Voltage INHIBIT: 100 Vpn secondary volts

Retrieving Over/Underfrequency Status from the Relay

The status of each logic variable can be determined through the ASCII command interface using the RG-STAT (report general-status) command. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information. The status can also be determined using BESTCOMS *Metering* screen.

Breaker Failure Protection

50BF - Breaker Failure Protection

BE1-CDS240 relays provide four independent breaker failure protection functions. Each current circuit has an associated breaker failure function. For example, Current Circuit 1 is internally connected to 50BF; Current Circuit 2 is internally connected to 150 BF and so on. This section discuses 50BF but applies to all BF functions. Figure 4-49 shows the breaker failure function block which has two outputs, *BFRT (1, 2, 3, 4)* (Breaker Failure Retrip) and BFT *(1, 2, 3, 4)* (Breaker Failure trip) which is true after the breaker failure *Delay Timer* has timed out. The *BFIALM* (1, 2, 3, 4) (Breaker failure initiate alarm) occurs if the *Control Timer* has expired (closing the window of breaker failure opportunity), and there is no *BLK* (Block input) and the BFI50 (internal protection element) is still calling for a trip.

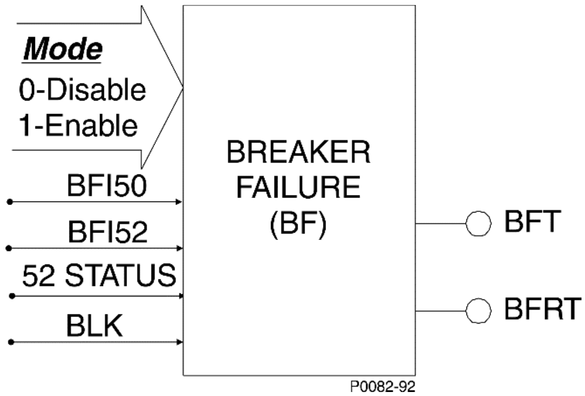

Figure 4-49. Breaker Failure Logic Block

A BESTlogic expression defines how the *BLK* (Block) input functions. When this expression is TRUE, the element is disabled by forcing the outputs to logic 0 and resetting the timer to zero. For example, this may be an input wired to a test switch such that breaker failure protection is disabled when the primary protective elements are being tested to prevent inadvertent backup tripping during testing.

The breaker failure *Delay Timer* is stopped by the fast-dropout current detector function. See Section 3, *Input and Output Functions, Power System Inputs, Current Measurement,* for more details on this function. The fast-dropout current detector is designed to directly determine when the current in the poles of the breaker has been interrupted without having to wait for the fault current samples to clear the one-cycle filter time used by the normal current measurement function. This function has less than one cycle dropout time. The *Delay Timer* can also be stopped by the *BLK* (Block) logic input being asserted.

Upon sensing *BFI50* transition from 0 to 1 state, a *Control Timer* seals in the *BFI50* signal for the duration of the *Control Timer* setting. If the *Control Timer* expires and the *BFI50* signal is still present, a *BFIALM* (Breaker Failure Initiate Alarm) signal will occur. The *Control Timer* serves the purpose to improve security by presenting a window of opportunity for the breaker failure element to operate. It improves dependability by sealing in the initiate to prevent stopping breaker failure timing if the tripping relay drops out prematurely. A *Control Timer* setting of zero shall disable the control timer seal in function allowing the *Control Timer* to follow the *BFI50* input.

Phase and neutral fault detectors are provided to monitor current. At least one of these four fault detectors must be picked up to start the breaker failure *Delay Timer*.

The current detector logic is TRUE if the current has been interrupted and is used to stop the BF timer. The I = 0 algorithm looks at the sample data directly and does not rely upon the 1 cycle phasor estimation calculation. It rejects dc tail-off by looking for the characteristic exponential decay. Current shall be declared interrupted when the current in all three phases is below 10% nominal or if the current is decaying exponentially. Only the three phase currents shall be monitored by this function.

Logic to start the breaker failure timing via the *BFI52* input is provided with breaker status supervision. Both the *52 STATUS* and the *BFI52* have to be TRUE for a *BFI52* to cause a trip condition. A breaker status logic input monitors the breaker state.

The breaker failure timer is initiated by the either the *BFI52* or the *BFI50*. When both signals are in the zero state the breaker failure *Delay Timer* will be stopped. When the breaker failure *Delay Timer* is actively timing, the *BFRT* (Breaker Failure Retrip) output shall be TRUE. When the breaker failure *Delay Timer* times out, the *BFT* output shall be TRUE. A block input is provided to disable the function and reset the timers to zero.

If the target is enabled for the function block, the target reporting function will record a target when the protective function trip output is TRUE and the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms*, *Fault Reporting,* for more details on the target reporting.

An alarm variable is provided in the programmable alarms function that can be used to indicate an alarm condition when the breaker failure initiate is held longer than the control time. See Section 6, *Reporting and Alarms*, *Alarms Function,* for more details on the alarm reporting function.

BESTlogic Settings for Breaker Failure

BESTlogic settings are made from the *BESTlogic Function Element* Screen in BESTCOMS. Figure 4-50 illustrates the BESTCOMS screen used to select BESTlogic settings for the breaker failure element. To open *BESTlogic Function Element* screen for the breaker failure element, select *Overcurrent* from the

Screens pull-down menu. Then select the button labeled *BESTlogic*. Alternately, settings may be made using the SL-50BF ASCII command.

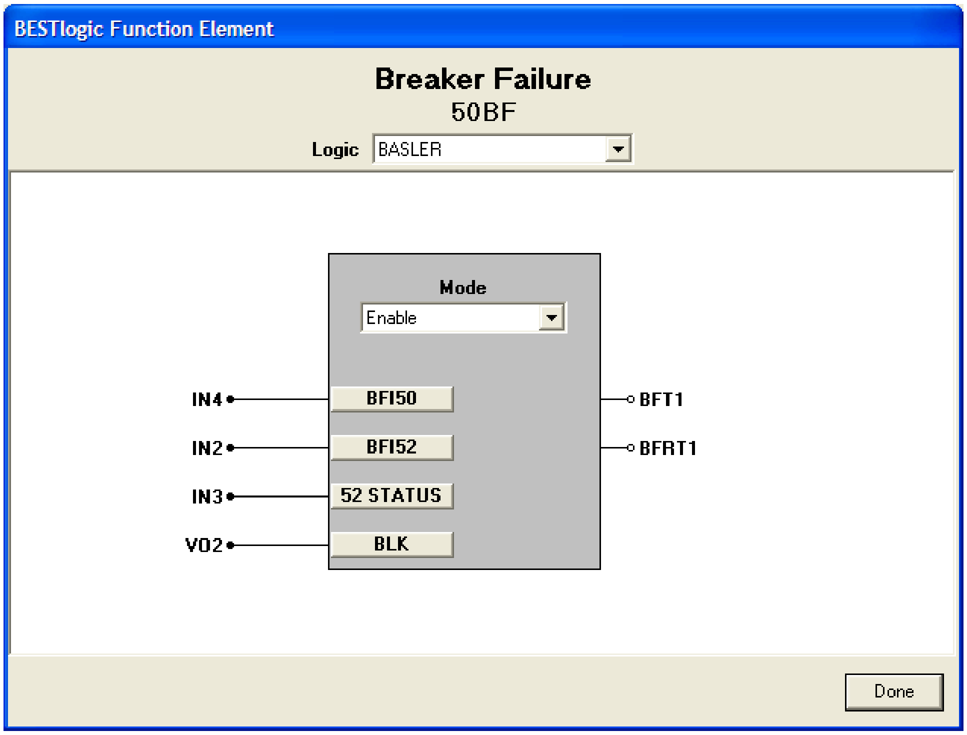

Figure 4-50. BESTlogic Function Element Screen, 50BF

At the top center of the *BESTlogic Function Element* Screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the breaker failure function by selecting its mode of operation from the *Mode* pull-down menu. To connect the elements inputs, select the button for the corresponding input in the *BESTlogic Function Element* Screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* Screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-30 summarizes the BESTlogic settings for Breaker Failure.

Table 4-30. BESTlogic Settings for Breaker Failure

Function	Range/Purpose	Default
Mode	0 = Disable, 1 = Enable	0
BFI50	Logic expression that starts the breaker failure timer when TRUE.	0
BFI52	Logic expression that starts the breaker failure timer when TRUE.	0
52 STATUS	Monitors the breaker state.	0
BLK	Logic expression that disables function when TRUE.	0

Example 1. Make the following changes to the Breaker Failure element. Refer to Figure 4-50.

Mode: Enable

BFI50: IN4

BFI52: IN2
52 STATUS: IN3
BLK: VO2

Operating Settings for Breaker Failure

Operating settings are made using BESTCOMS. Figure 4-51 illustrates the BESTCOMS screen used to select operational settings for the breaker failure element. To open *BESTlogic Function Element* screen for the breaker failure element, select *Breaker Failure* from the *Screens* pull-down menu. Alternately, settings may be made using the S0-x50BF (where x = blank, 1, 2, or 3) ASCII command or through the optional HMI interface using Screens 5.#.11.1 through 5.#.11.4, \PROT\SG#\BF\x50BF (where x = blank, 1, 2, or 3).

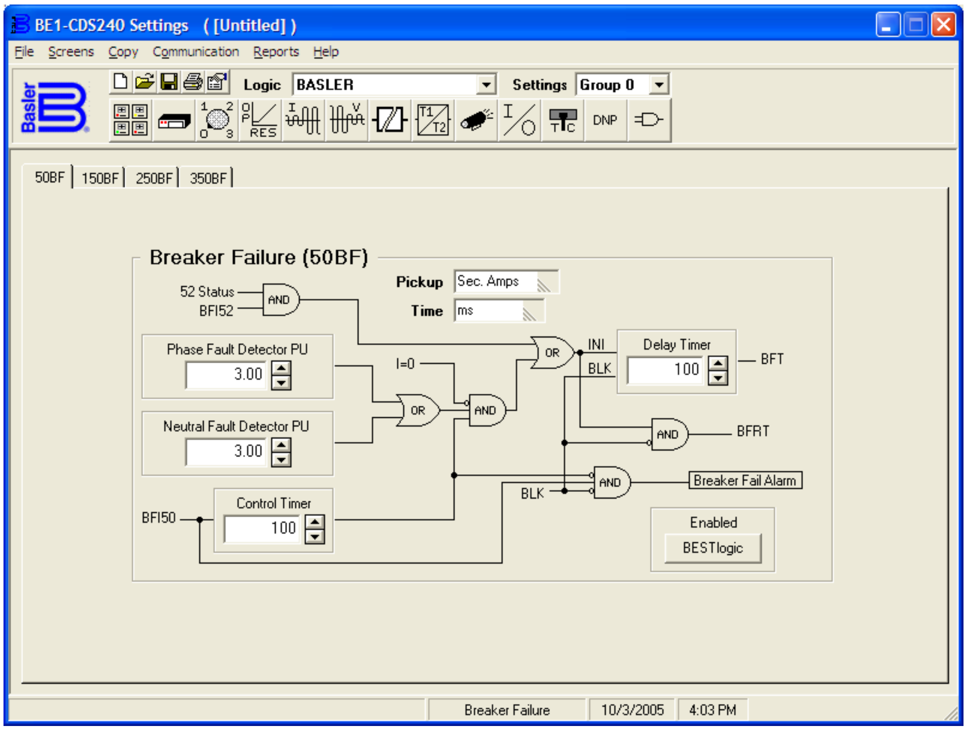

Figure 4-51. Breaker Failure Screen, 50BF Tab

Beside the *Logic* pull-down menu is a pull-down menu labeled *Settings*. The Settings menu is used to select the setting group that the elements settings apply to.

The default unit of measure for the *Pickup* setting is secondary amps. The unit of measure for the *Time* setting that represents the element's time delay defaults to milliseconds. It is also selectable for seconds, minutes, and cycles.

Table 4-31 summarizes the operating settings for Breaker Failure.

Table 4-31. Operating Settings for Breaker Failure

Setting	Range	Increment	Unit of Measure	Default
Pickup	Sec. Amps, Pri. Amps, Per. U. Amps, % Amps	N/A	N/A	Sec. Amps
Time	Milliseconds, Seconds, Minutes, Cycles	N/A	N/A	Milliseconds
Phase Fault Detector PU	5A CT: 0.5 A to 10.00 A 1A CT: 0.1 A to 2.00 A	0.01 A	(See Pickup)	0.00

Setting	Range	Increment	Unit of Measure	Default
Neutral Fault Detector PU	5A CT: 0.5 A to 10.00 A 1A CT: 0.1 A to 2.00 A	0.01 A	(See Pickup)	0.00
Delay Timer	0 = Disabled	N/A	N/A	0
	50 to 999 ms	1 m	Milliseconds	
	0.05 to 0.999 seconds	0.1 sec	Seconds	
	0 to 59.96 (60 Hz) or 0 to 49.97 (50 Hz)	∗	Cycles	
Control Timer	0 = Disabled	N/A	N/A	0
	50 to 999 ms	1 m	Milliseconds	
	0.05 to 0.999 seconds	0.1 sec	Seconds	
	0 to 59.94 (60 Hz) or 0 to 49.95 (50 Hz)	∗	Cycles	

∗ Time delays less than 10 cycles can be entered to the nearest 0.1 cycles from the front panel HMI. All time delays can be entered to the nearest 0.01 cycles from the ASCII command interface. Time delays entered in cycles are converted to milliseconds or seconds. Increment precision after conversion is limited to that appropriate for each of those units of measure.

Example 1. Make the following operational settings to the breaker failure element. See Figure 4-51.

Pickup:	secondary amps
Time:	ms
Phase Fault Detector PU:	3.00
Neutral Fault Detector PU:	3.00
Control Timer:	100
Delay Timer:	100

Retrieving Breaker Failure Status from the Relay

The status of each logic variable can be determined from the ASCII command interface using the RG-STAT (report general-status) or the RL (report logic) commands. Status can also be determined using BESTCOMS *Metering* screen. See Section 6, *Reporting and Alarms, General Status Reporting,* for more information.

Logic Timers

62 - General Purpose Logic Timers

BE1-CDS240 relays provide four general-purpose logic timers, which are extremely versatile. Each can be set for one of five modes of operation to emulate virtually any type of timer. Each function block has one output (62, 162, 262, or 362) that is asserted when the timing criteria has been met according to the BESTlogic mode setting. Figure 4-52 shows the 62 function block as an example. Each mode of operation is described in detail in the following paragraphs.

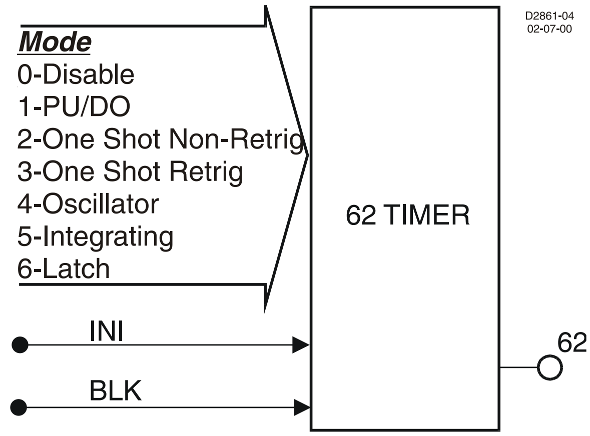

Figure 4-52. General Purpose Logic Timers Logic Block

An *INI* (initiate) logic input is provided to start the timing sequence.

A *BLK* (block) logic input is provided to block operation of the timer. When this expression is TRUE, the function is disabled.

Each timer has a *T1* time setting and a *T2* time setting. The functioning of these settings is dependent upon the type of timer as specified by the mode setting in BESTlogic.

If the target is enabled for the function block, the target reporting function will record a target when the timer output is TRUE and the fault recording function trip logic expression is TRUE. See Section 6, *Reporting and Alarms, Fault Reporting*, for more details on the target reporting function.

Mode 1, PU/DO (Pickup/Dropout Timer)

The output will change to logic TRUE if the *INITIATE* input expression is TRUE for the duration of PICKUP time delay setting T1. See Figure 4-53. If the initiate expression toggles to FALSE before time T1, the T1 timer is reset. Once the output of the timer toggles to TRUE, the *INITIATE* input expression must be FALSE for the duration of DROPOUT time delay setting T2. If the *INITIATE* input expression toggles to TRUE before time T2, the output stays TRUE and the T2 timer is reset.

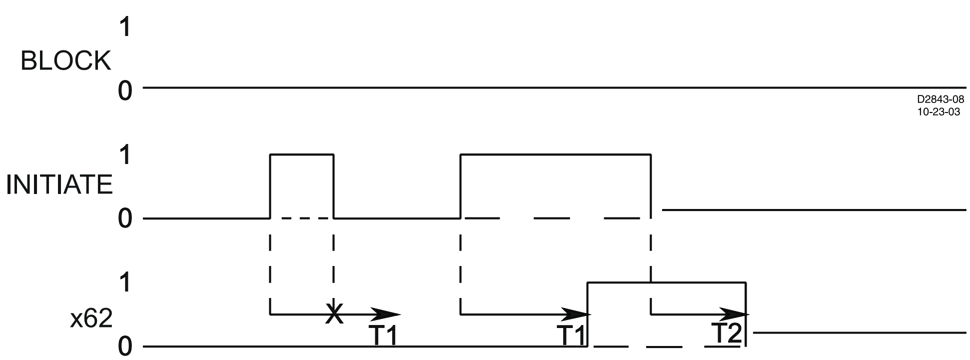

Figure 4-53. Mode 1, PU/DO (Pickup/Dropout Timer)

Mode 2, One-Shot Nonretriggerable Timer

The one-shot nonretriggerable timer starts its timing sequence when the *INITIATE* input expression changes from FALSE to TRUE. See Figure 4-54. The timer will time for DELAY time T1 and then the output will toggle to TRUE for DURATION time T2. Additional initiate input expression changes of state are ignored until the timing sequence has been completed. If the duration time (T2) is set to 0, this timer will not function. The timer will return to FALSE if the BLOCK input becomes TRUE.

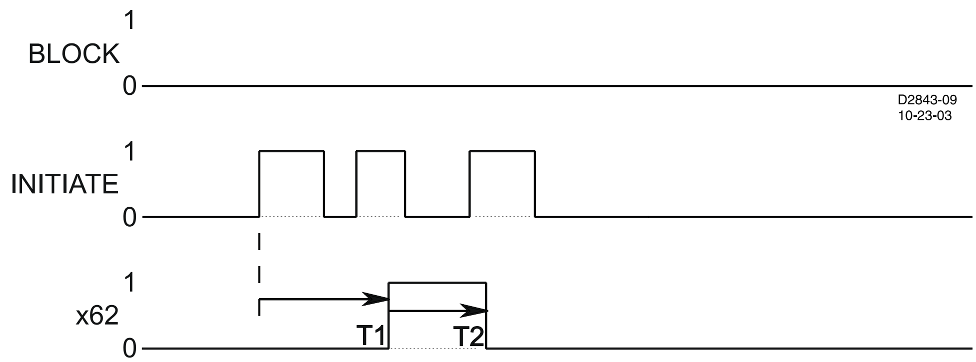

Figure 4-54. Mode 2, One-Shot Nonretriggerable Timer

Mode 3, One-Shot Retriggerable Timer

This mode of operation is similar to the one shot nonretriggerable mode, except that if a new FALSE-to-TRUE transition occurs on the *INITIATE* input expression, the output is forced to logic FALSE and the timing sequence is restarted. See Figure 4-55.

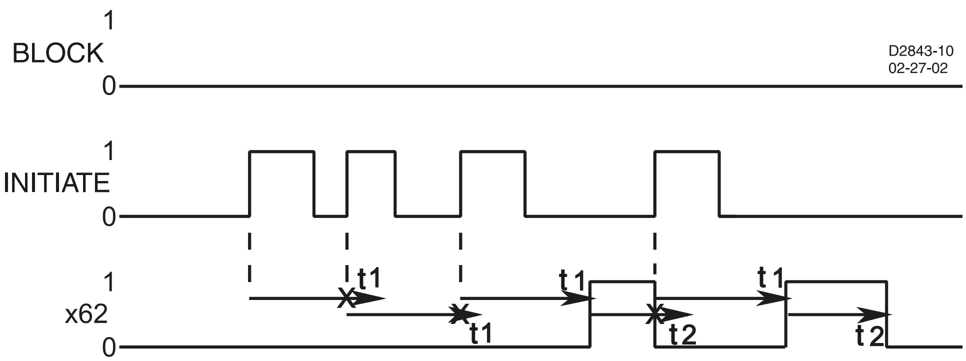

Figure 4-55. Mode 3, One Shot Retriggerable Timer

Mode 4, Oscillator

In this mode, the *INITIATE* input is ignored. See Figure 4-56. If the *BLOCK* input is FALSE, the output, x62, oscillates with an ON time of T1 and an OFF time of T2. When the *BLOCK* input is held TRUE, the oscillator stops and the output is held OFF.

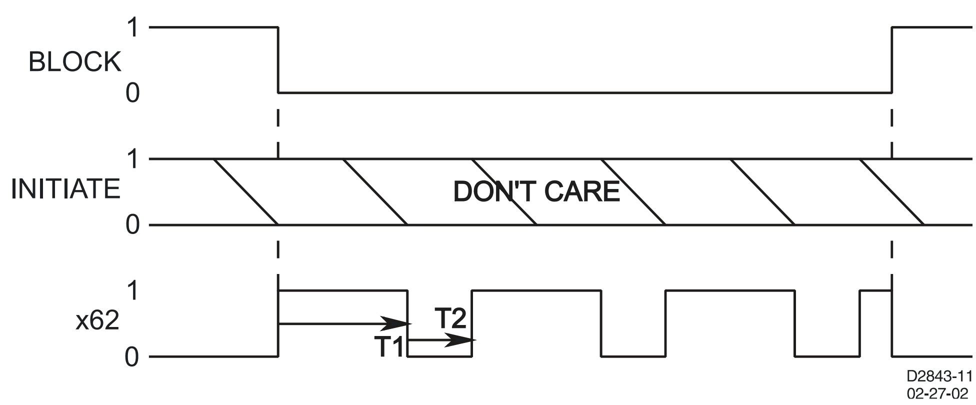

Figure 4-56. Mode 4, Oscillator

Mode 5, Integrating Timer

An integrating timer is similar to a pickup/dropout timer except that the PICKUP time T1 defines the rate that the timer integrates toward timing out and setting the output to TRUE. Conversely, the RESET time T2 defines the rate that the timer integrates toward dropout and resetting the output to FALSE. PICKUP time T1 defines the time delay for the output to change to TRUE if the initiate input becomes TRUE and stays

TRUE. RESET time T2 defines the time delay for the output to change to FALSE if it is presently TRUE and the initiate input becomes FALSE and stays FALSE.

In the example shown in Figure 4-57, RESET time T2 is set to half of the PICKUP time T1 setting. The initiate input expression becomes TRUE and the timer starts integrating toward pickup. Prior to timing out, the initiate expression toggles to FALSE and the timer starts resetting at twice the rate as it was integrating toward time out. It stays FALSE long enough for the integrating timer to reset completely but then toggles back to TRUE and stays TRUE for the entire duration of time T1. At that point, the output of the timer is toggled to TRUE. Then later, the initiate expression becomes FALSE and stays FALSE for the duration of RESET time T2. At that point, the output of the timer is toggled to FALSE.

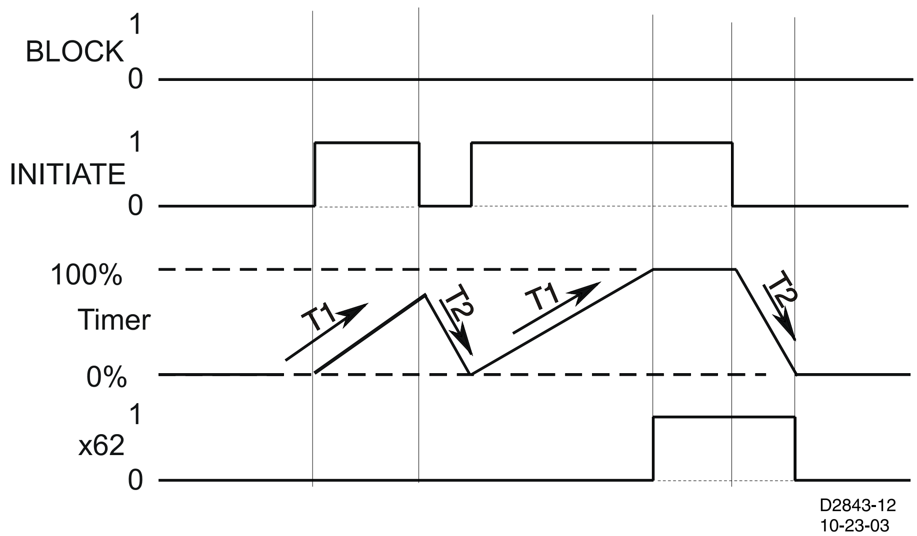

Figure 4-57. Mode 5, Integrating Timer

This type of timer is useful in applications where a monitored signal may be hovering at its threshold between on and off. For example, it is desired to take some action when current is above a certain level for a certain period. A 50T function could be used to monitor the current level. Thus, if the current level is near the threshold so that the *INITIATE* input toggles between TRUE and FALSE from time to time, the function will still time out as long as the time that it is TRUE is longer than the time that it is FALSE. With a simple pickup/dropout timer, the timing function would reset to zero and start over each time the initiate expression became FALSE.

Mode 6, Latch

A one shot timer starts its timing sequence when the *INITIATE* input expression changes from FALSE to TRUE. The timer will time for DELAY time T1 and then the output will latch TRUE. Additional *INITIATE* input expression changes of state are ignored. Time (T2) is ignored. Refer to Figure 4-58.

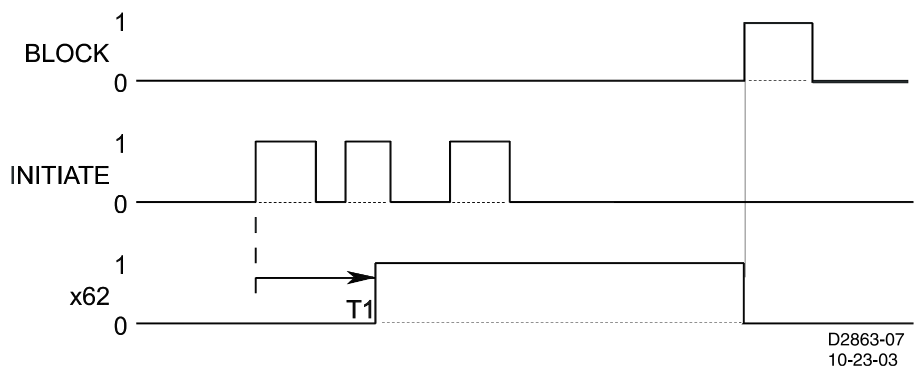

Figure 4-58. Mode 6, Latch

BESTlogic Settings for General Purpose Logic Timers

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-59 illustrates the BESTCOMS screen used to select BESTlogic settings for the *Logic Timer* elements. To open the *BESTlogic Function Element* screen for *Logic Timer*, select *Logic Timers* from the *Screens* pull-down menu. Alternately, settings may be made using the SL-x62 ASCII command.

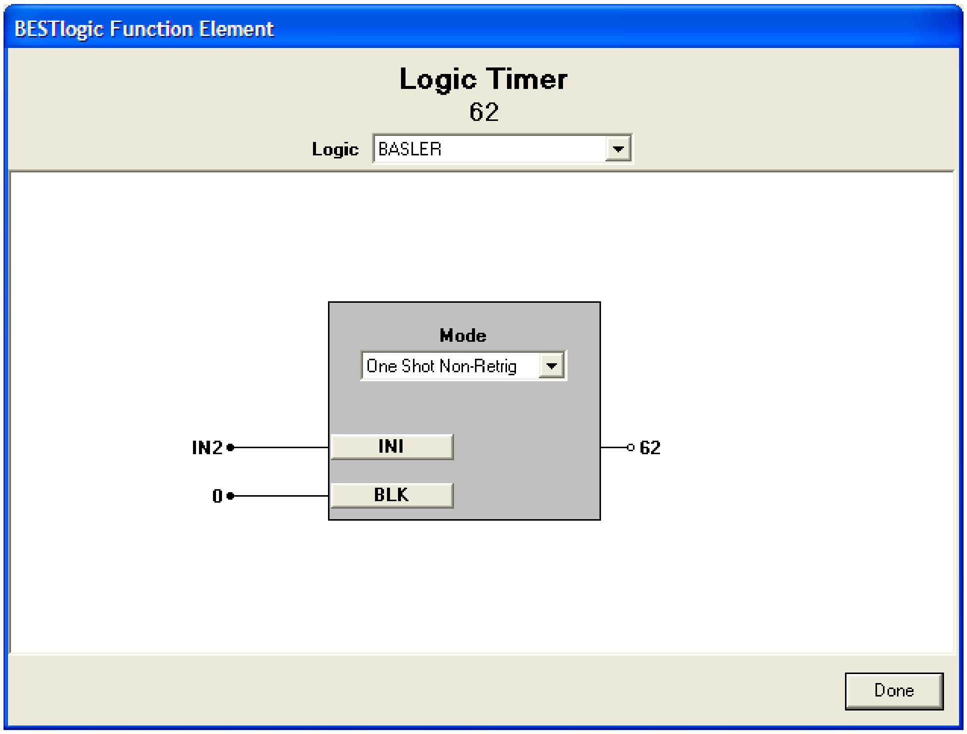

Figure 4-59. BESTlogic Function Element Screen, 62

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. User or custom logic must be selected on this menu in order to allow changes to the mode and inputs of the element. Enable the *Logic Timer* function by selecting its mode of operation from the *Mode* pull-down menu.

To connect the element's inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

Table 4-32 summarizes the BESTlogic settings for General Purpose Logic Timers.

Table 4-32. BESTlogic Settings for General Purpose Logic Timers

Function	Range/Purpose		Default
Logic Mode	0 = Disabled 1 = PU/DO 2 = One Shot Non-Retrig 3 = One Shot Retrig	4 = Oscillator 5 = Integrating 6 = Latch	0
INITIATE	Logic expression that initiates timing sequence.		0
BLOCK	Logic expression that disables function when TRUE.		0

Example 1. Make the following settings to the 62 Logic Timer. Figure 4-59 illustrates these settings.

Logic: User
Mode: One Shot Non-Retriggerable
INITIATE: IN2
BLOCK: 0

Operating Settings for General Purpose Logic Timers

Operating settings are made using BESTCOMS. Figure 4-60 illustrates the BESTCOMS screen used to select operational settings for the Logic Timer elements. To open the *Logic Timers* screen, select *Logic Timers* from the *Screens* pull-down menu. Alternately, settings may be made using the S<g>-x62 ASCII command or through the optional HMI interface using Screen 5.#.9.1, \PROT\SG#\62\SETTINGS.

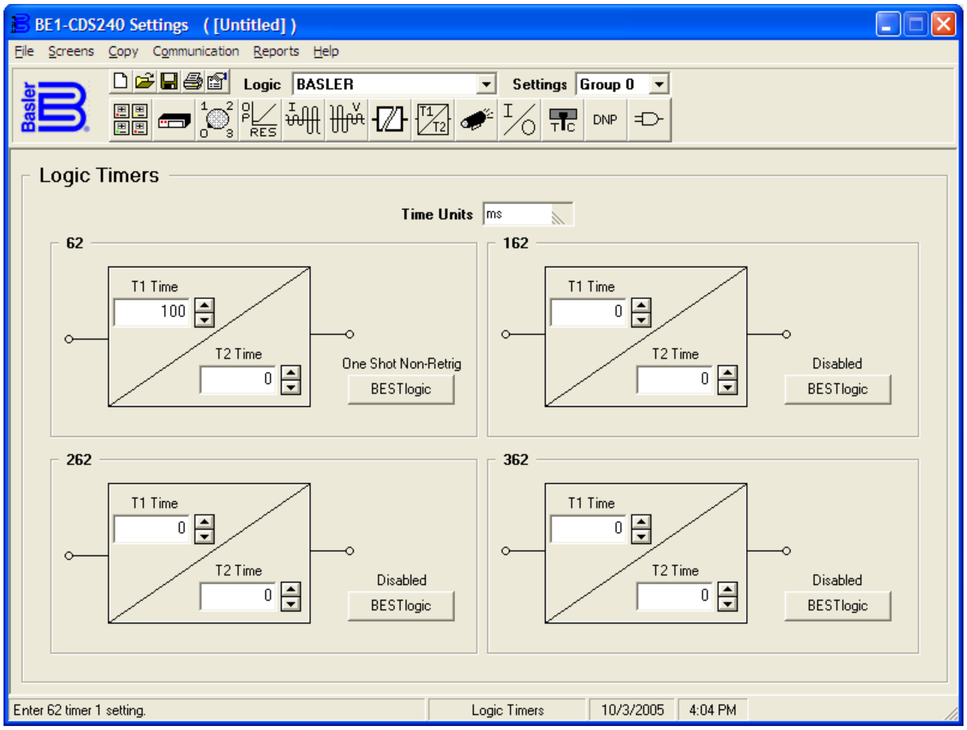

Figure 4-60. Logic Timers Screen

At the top left of the screen is a pull-down menu labeled *Logic*. This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. User or custom logic *must* be selected on this menu in order to allow changes to be made to the mode and inputs of the element.

Beneath the *Logic* pull-down menu is a pull-down menu labeled *Settings*. The Settings menu is used to select the setting group that the element's settings apply to. See Section 7, *BESTlogic Programmable Logic, Logic Schemes*.

Using the pull-down menus and buttons, make the application appropriate settings to the Logic Timer elements.

Table 4-33 summarizes the operating settings for General Purpose Logic Timers.

Table 4-33. Operating Settings for General Purpose Logic Timers

Setting	Range	Increment	Unit of Measure	Default
T1 Time, T2 Time	0 to 999 ms	1	Milliseconds	0
	0.1 to 9999 sec.	0.1 for 0.1 to 9.9 sec.	Seconds	
		1.0 for 10 to 9999 sec.		
	0 to 599,940 (60 Hz) 0 to 499,950 (50Hz)	*	Cycles	

∗ Time delays less than 10 cycles can be entered to the nearest 0.1 cycles through the HMI. All time delays can be entered to the nearest 0.01 cycles from the ASCII command interface. Time delays entered in cycles are converted to milliseconds or seconds. Increment precision after conversion is limited to that appropriate for each of those units of measure.

Example 1. Make the following operating settings to the 62 element. Figure 4-60 illustrates these settings.

Time units: ms
T1 Time: 100
T2 Time: 0

Retrieving General Purpose Logic Timers Status from the Relay

The status of each logic variable can be determined from the ASCII command interface by using the RG-STAT (report general-status) or the RL (report logic) commands. Status can also be determined using BESTCOMS *Metering* screen. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information.

Voltage Transformer Fuse Loss Detection

60FL - Fuse Loss Detection

BE1-CDS240 relays have one 60FL element that can be used to detect fuse loss or loss of potential in a three-phase system. The 60FL element is illustrated in Figure 4-61. When the element logic becomes TRUE, the 60FL logic output becomes TRUE. A logic diagram is shown in Figure 4-62. Logic parameters are shown in Table 4-34.

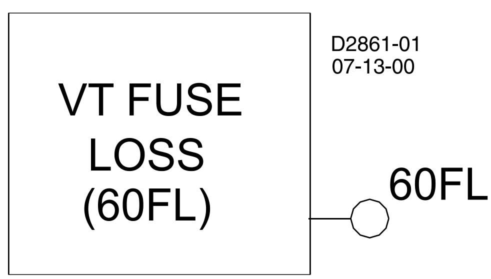

Figure 4-61. Fuse Loss Detection Logic Block

Trip Logic: 60FL Trip = (A * B * C * D * G) + (E * F * B * G) (See Table 4-34.)

Reset Logic: 60FL Reset = H * /K */L (See Table 4-34.)

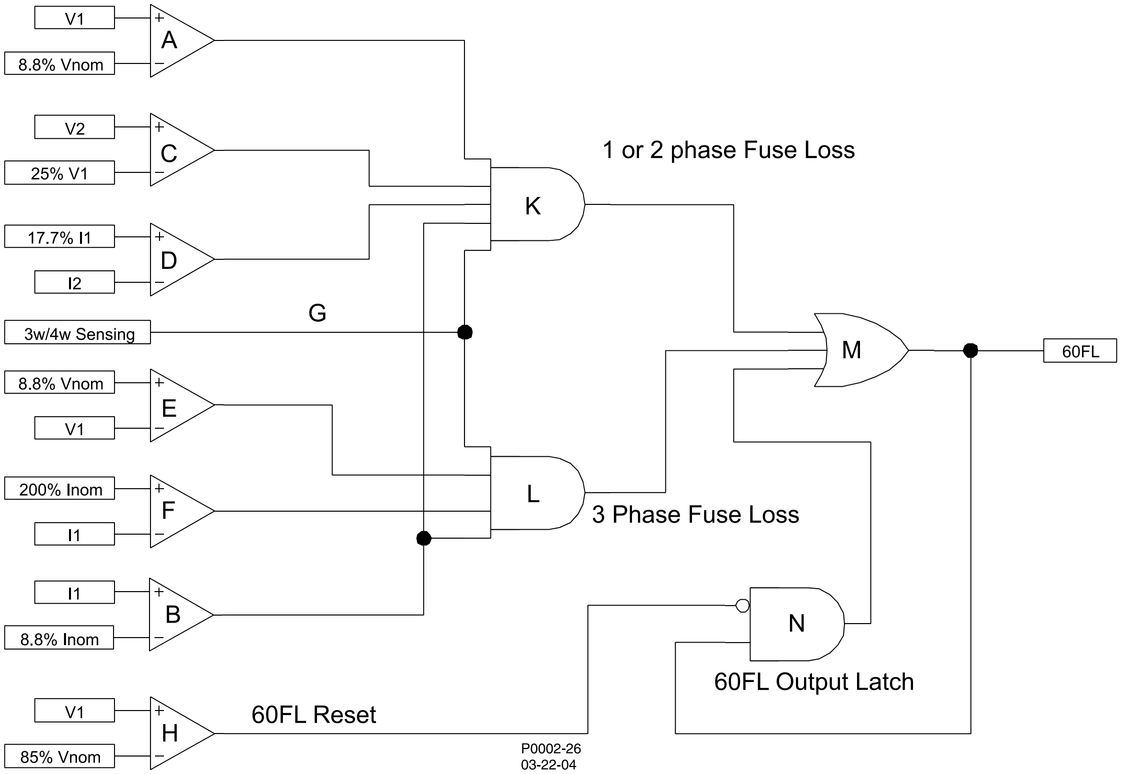

Figure 4-62. 60FL Element Logic

Table 4-34. 60FL Logic Parameters

Input	TRUE Condition
A	Positive-sequence volts greater than 8.8% of the nominal voltage; Detects minimum voltage is applied.
B	Positive-sequence amps greater than 8.8% of the nominal current; Detects minimum current is applied.
C	Negative-sequence volts greater than 25% of the pos-seq volts; Detects loss of 1 or 2 phase voltages.
D	Negative-sequence amps less than 17.7% of the pos-seq amps; Detects a normal current condition.
E	Positive-sequence volts less than 8.8% of the nominal voltage; Detects loss of 3-phase voltage.
F	Positive-sequence amps less than 200% of the nominal current; Detects a normal load current condition.
G	Three-wire or four-wire sensing selected.
H	Positive-sequence volts greater than 85% of nominal voltage; Detects a restored voltage condition.
K	(A * B * C * D * G); Detects when either one or two phases are lost.
L	(E * F * B * G); Detects when all three phases are lost.
M, N	Latches the 60FL output until the reset criteria are met.

Fuse Loss Detection Blocking Settings

The 60FL logic bit is always enabled regardless of the SP-60FL setting. User selectable block settings determine how certain (not all) current and voltage protective functions operate when a fuse loss condition exists (see Table 4-35). The I Block setting (51/27R) assumes that the voltage is VNOM when 60FL is TRUE because the voltage measurement is not present or is unreliable. If the input voltage is nominal, then voltage restraint and control have no effect. The V Block settings (P, N, and Q) determine which voltage functions are blocked when the 60FL logic is TRUE.

Settings are made using BESTCOMS. Figure 4-63 illustrates the BESTCOMS screen used to select blocking settings for the 60FL element. Select *Reporting and Alarms* from the *Screens* pull-down menu and select the *VT Monitor* tab. Alternately, settings may be made using the SP-60FL ASCII command. See Section 11, *ASCII Command Interface, Command Summary, Protection Setting Commands,* for more information.

Table 4-35. 60FL Element Blocking Settings

Mode Input	Setting	Explanation	Default
I Block	DIS	When I Block is disabled, current tripping level is determined by the sensing voltage level (51/27R operates normally).	ENA
	ENA	When I Block is enabled and the 60FL logic is TRUE (voltage sensing is lost), the current tripping level is controlled by the 51P function and the 27R function is inhibited. When I Block is enabled and the 60FL logic is FALSE, the current tripping level is controlled by the 51/27R function.	
V Block	DIS	Phase (P), Neutral (N), and Negative-Sequence (Q) voltage functions are not automatically blocked when 60FL logic is TRUE.	PNQ
	P	All functions that use phase voltage are blocked when the 60FL logic is TRUE. (27P/127P and 59P/159P)	
	N	All functions that use 3-phase residual voltage ($3V_0$) measurements are blocked when the 60FL logic is TRUE. (59X - Mode 2)	
	Q	All functions that use the negative-sequence voltage (V_2) measurement are blocked when the 60FL logic is TRUE. (47)	

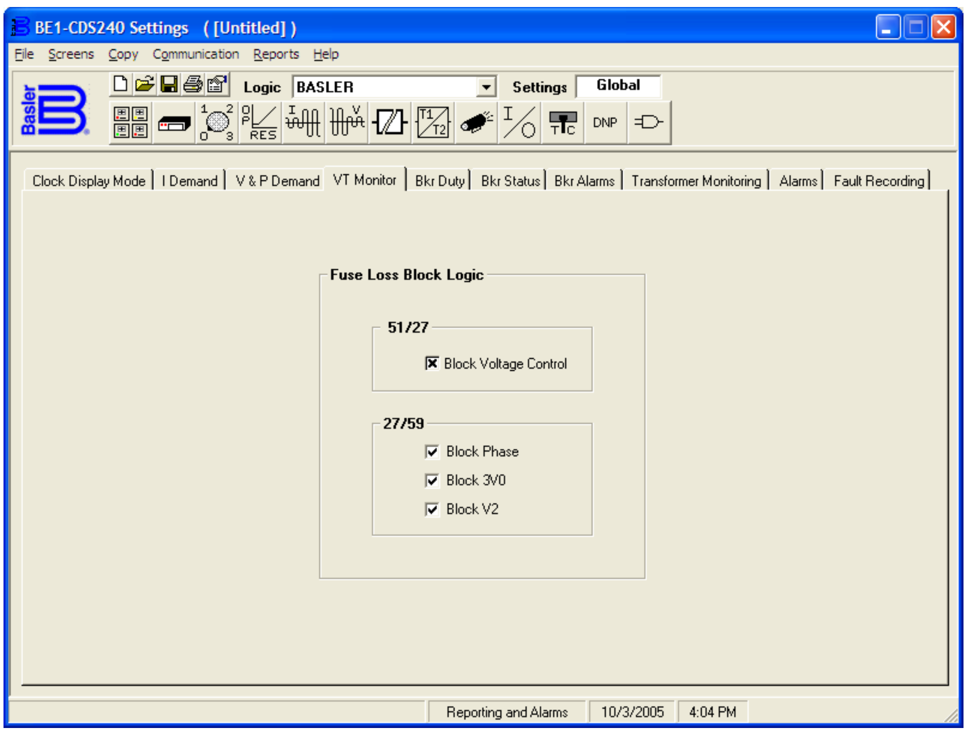

Figure 4-63. Reporting and Alarms Screen, VT Monitor Tab

The directional tests are also supervised by the loss of potential function 60FL. If the 60FL bit is TRUE, then voltage sensing was loss or is unreliable. Under this condition positive, negative, and zero-sequence directional tests are disabled and their bits are cleared. There is no user setting to enable or disabled this supervision. Current polarization is not affected by the 60FL since it does not rely on voltage sensing. Similarly, zero-sequence voltage polarization can only be performed if 3P4W sensing is selected. The following qualifiers are applied to the voltage polarized ground direction element based on the user selected input quantity:

V0IN inputs:

Test: 60FL=FALSE & 3P4W=TRUE & (IN > minimum) & (IN > I1*8%) & (V0 > minimum)

V0IG inputs:

Test: 60FL=FALSE & 3P4W=TRUE & (IG > minimum) & (V0 > minimum)

VXIN inputs:

Test: (IG > minimum) & (IN > I1*8%) & (VX > minimum)

VXIG inputs:

Test: (IG > minimum) & (VX > minimum)

I Block and V Block settings are made using the SP-60FL command.

The 60FL element detects fuse loss and loss of potential by using voltage and current thresholds that are expressed as a percentage of the nominal voltage and current values. See Section 3, *Input and Output Functions*, for information on changing the nominal voltage and current values using the SG-NOM command.

Retrieving Fuse Loss Detection Status from the Relay

The status of the logic variable can be determined through the ASCII command interface using the RG-STAT (report general-status) command. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information. The status can also be determined using BESTCOMS *Metering* screen.

Virtual Switches

43 - Virtual Selector Switches

The BE1-CDS240 Current Differential System has eight virtual selector switches that can provide manual control, locally and remotely, without using physical switches and/or interposing relays. Each virtual switch can be set for one of three modes of operation to emulate virtually any type of binary (two position) switch. An example would be an application that requires a ground cutoff switch. The traditional approach might be to install a switch on the panel and wire the output to a contact sensing input on the relay or in series with the ground trip output of the relay. Instead, a virtual switch can be used to reduce costs with the added benefit of being able to operate the switch both locally through the HMI and remotely from a substation computer or through a modem connection to a remote operator's console.

The state of the switches can be controlled from the optional HMI or ASCII command interface. Control actions can be set by the BESTlogic mode setting. When set for *On/Off/Pulse*, each switch can be controlled to open (logic 0), close (logic 1), or pulse such that the output toggles from its current state to the opposite state and then returns. Additional modes allow the switch operation to be restricted. In *On/Off*, the switch emulates a two-position selector switch, and only open and close commands are accepted. In *Off/Momentary On*, a momentary close, spring-return switch is emulated and only the pulse command is accepted. Because switch status information is saved in nonvolatile memory, the relay powers up with the switches in the same state as when the relay was powered down.

Each virtual selector switch element (see Figure 4-64) has one output: *43, 143, 243, 343, 443, 543, 643,* and *743*. The output is TRUE when the switch is in the closed state; the output is FALSE when the switch is the open state. Since both the output and the inverse of the output of these switches can be used as many times as desired in your programmable logic, they can emulate a switch with as many normally open and normally closed decks as desired.

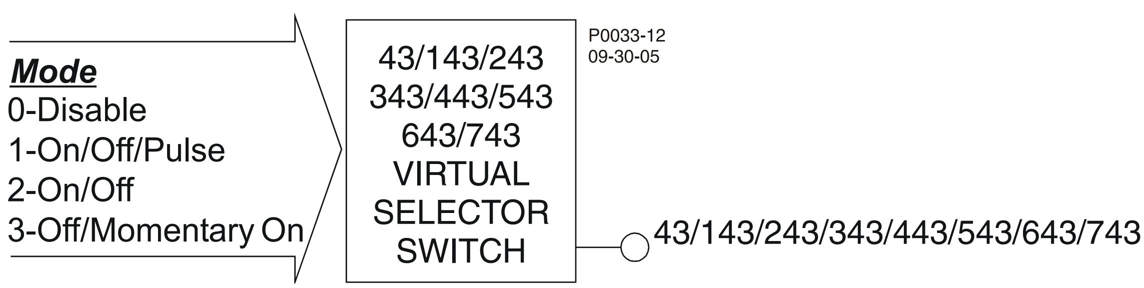

Figure 4-64. Virtual Selector Switches Logic Block

User specified labels could be assigned to each virtual switch and to both states of each switch. In the previous ground cutoff switch example, you might enable one of the switches in BESTlogic as Mode 2, ON/OFF and connect the output of that switch to the blocking input of the 59x protection element. This would disable the ground overvoltage protection when the switch is closed (logic 1) and enable it when the switch is open (logic 0). For the application, you might set the switch label to be 59N_CUTOFF (10 character maximum). The closed position on the switch might be labeled DISABLD (7 character maximum) and the open position might be labeled NORMAL. Section 7, *BESTlogic Programmable Logic*, has more details about setting user programmable names for programmable logic variables.

BESTlogic Settings for Virtual Selector Switches

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-65 illustrates the BESTCOMS screen used to select BESTlogic settings for the *Virtual Switch* element. To open the *BESTlogic Function Element* screen for the *Virtual Switch* element, select *Virtual Switches* from the *Screens* pull-down menu. Then select the *BESTlogic* button for the virtual switch to be edited. Alternately, settings may be made using SL-x43 ASCII command (where x = blank, 1, 2, 3, 4, 5, 6, or 7).

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic.* This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the Virtual Switch function by selecting its mode of operation from the *Mode* pull-down menu. Select *Done* when the settings have been completely edited.

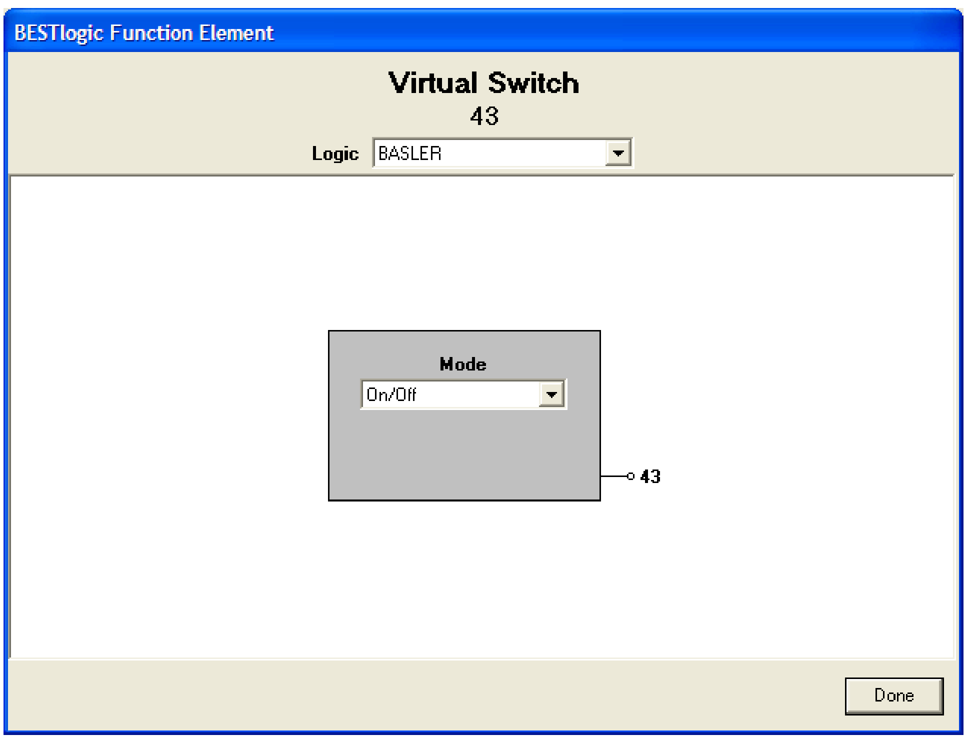

Figure 4-65. BESTlogic Function Element Screen, 43

Table 4-36 summarizes the BESTlogic settings for Virtual Selector Switches. These settings enable the x43 element by selecting the mode of operation. There are no logic inputs.

Table 4-36. BESTlogic Settings for Virtual Selector Switches

Function	Range/Purpose		Default
Mode	0 = Disabled 1 = On/Off/Pulse	2 = On/Off 3 = Off/Momentary On	0

Example 1. Make the following BESTlogic settings to the Virtual Switch function. See Figure 4-65.

Mode: On/Off

Select Before Operate Control of Virtual Selector Switches

The state of each virtual selector switch can be controlled at the optional HMI using Screens 2.1.1 through 2.1.8, \CTRL\43\x43 (where x = blank, 1, 2, 3, 4, 5, 6, or 7). Control is also possible through the ASCII command interface by using the select-before-operate commands CS-x43 (control select-virtual switch) and CO-x43 (operate select-virtual switch). A state change takes place immediately without having to execute an *Exit - Save* settings command. The state of the switches cannot be controlled using BESTCOMS. BESCOMS can only be used to set the logic mode or name labels (Figure 4-66) for the x43 virtual selector switches.

CS/CO-x43 Command

Purpose: Select and operate the virtual selector switches.

Syntax: CS/CO-<x>43[=<Action>]

Comments: x = no entry for 43 or 1 for 143. Action = 0 to open the switch, 1 to close the switch, P to pulse the switch to the opposite state for 200 milliseconds and then automatically return to starting state.

The virtual switch control commands require the use of select-before-operate logic. First, the command must be selected using the CS-x43 command. After the select command is entered, there is a 30 second window during which the CO-x43 control command will be accepted. The control selected and the operation selected must match exactly or the operate command will be blocked. If the operate command is blocked, an error message is output.

CS/CO-x43 Command Examples:

Example 1. Read the status of Virtual Switch 43.

>CO-43

`0`

Example 2. Momentarily toggle the state of Switch 543 to closed.

>CS-543=P

`543=P SELECTED`

>CO-543=P

`543=P EXECUTED`

Example 3. An example of an operate command not matching the select command.

>CO-243=1

`ERROR:NO SELECT` (**Note:** Must enter "CS-243=1" first to select.)

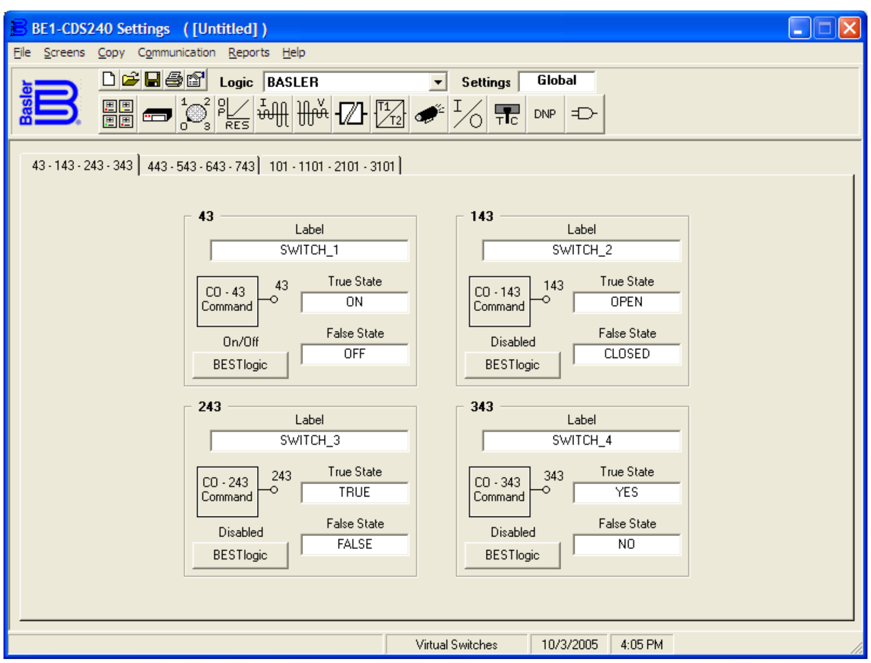

Figure 4-66. Virtual Switches Screen, 43 – 143 – 243 – 343 Tab

Retrieving Virtual Selector Switches Status from the Relay

The state of each virtual selector switch can be determined from the optional HMI Screen 1.4.3, \STAT\OPER\43. This information is also available through the ASCII command interface by using the RG-STAT command and on BESTCOMS *Metering* screen. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information.

HMI Screens 2.1.1 through 2.1.8 provide switch control and can also display the current status of their respective switches. ASCII command CO-x43 returns the state of each virtual selector switch in a read-only mode. See the previous Example 1.

101 - Virtual Breaker Control Switches

Virtual breaker control switches (shown in Figure 4-67) provide manual control of a circuit breaker or switch without using physical switches and/or interposing relays. Both local and remote control is possible. A virtual switch can be used instead of a physical switch to reduce costs with the added benefit that the virtual switch can be operated both locally from the HMI and remotely from a substation computer or modem connection to an operator's console. The BE1-CDS240 relays provide four Virtual Breaker Control Switches (101, 1101, 2101, and 3101).

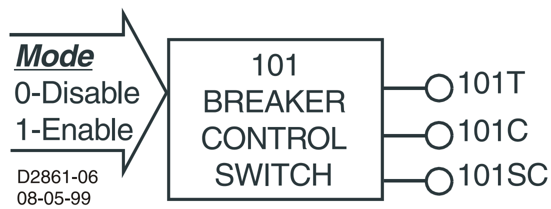

Figure 4-67. Virtual Breaker Control Switch Logic Block

The virtual breaker control switch emulates a typical breaker control switch with a momentary close, spring return, trip contact (output 101T), a momentary close, spring return, close contact (output 101C), and a slip contact (output 101SC). The slip contact output retains the status of the last control action. That is, it is FALSE (open) in the after-trip state and TRUE (closed) in the after-close state. Figure 4-68 shows the state of the 101SC logic output with respect to the state of the 101T and 101C outputs.

When the virtual control switch is controlled to trip, the 101T output pulses TRUE (closed) for approximately 200 milliseconds and the 101SC output goes FALSE (open). When the virtual control switch is controlled to close, the 101SC output pulses TRUE (closed). The status of the slip contact output is saved to nonvolatile memory so that the relay will power up with the contact in the same state as when the relay was powered down.

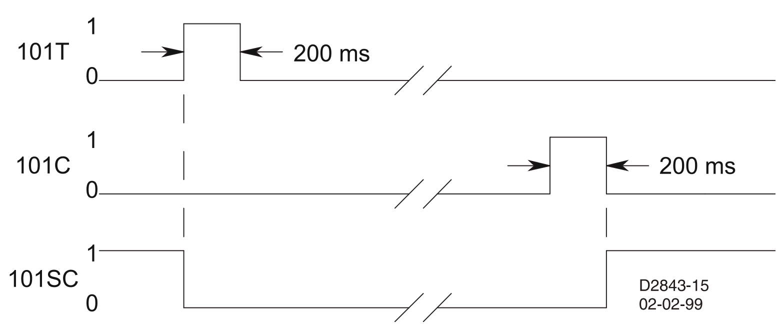

Figure 4-68. Virtual Breaker Control Switch State Diagram

BESTlogic Settings for Virtual Breaker Control Switches

BESTlogic settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 4-69 illustrates the BESTCOMS screen used to select BESTlogic settings for the 101 V*irtual Breaker Control Switch* element. To open the *BESTlogic Function Element* screen for the 101 *Virtual Breaker Control Switch* element, select *Virtual Switches* from the *Screens* pull-down menu. Then select the *101 – 1101 – 2101 – 3101* tab. Next, select the *BESTlogic* button for the Virtual Breaker Control Switch to be edited. Alternately, settings may be made using the SL-x101 ASCII command (where x = blank, 1, 2, or 3).

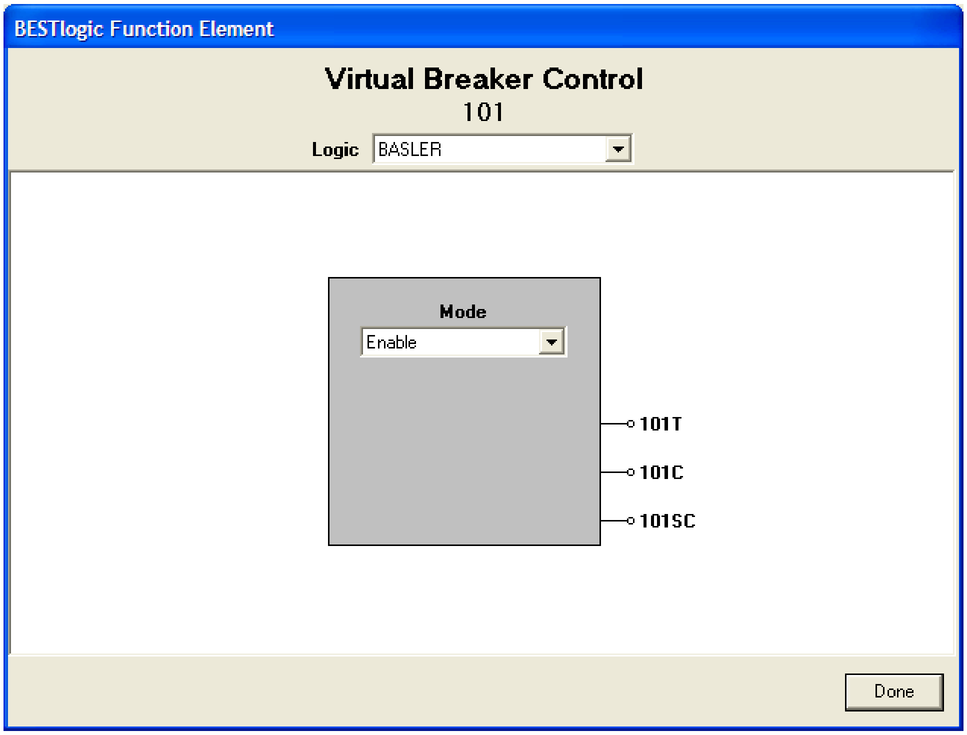

Figure 4-69. BESTlogic Function Element Screen, 101

At the top center of the *BESTlogic Function Element* screen is a pull-down menu labeled *Logic.* This menu allows viewing of the BESTlogic settings for each preprogrammed logic scheme. A custom logic scheme must be created and selected in the *Logic* pull-down menu at the top of the screen before BESTlogic settings can be changed. See Section 7, *BESTlogic Programmable Logic*.

Enable the *101 Virtual Breaker Control* function by selecting its mode of operation from the *Mode* pull-down menu. Select *Done* when the settings have been completely edited.

Table 4-37 summarizes the BESTlogic settings for Virtual Breaker Control Switches.

Table 4-37. BESTlogic Settings for Virtual Breaker Control Switches

Function	Range/Purpose	Default
Mode	0 = Disable, 1 = Enable	0

Select Before Operate Control of Virtual Breaker Control Switches

The state of the virtual breaker control switches can be controlled at the optional HMI through Screens 2.2.1 through 2.2.4, \CTRL\BKR\BKR_x (where x = 1 for 101, 2 for 1101, 3 for 2101, or 4 for 3101). Control is also possible through the ASCII command interface by using the select-before-operate commands CS-x101 (control select-virtual control switch) and CO-x101 (control operate-virtual control switch). Control is not possible using BESTCOMS. A state change takes place immediately without having to execute an *Exit - Save* settings command.

CS/CO-x101 Command

Purpose: Select and operate the virtual control switch.
Syntax: CS/CO-<x>101[=<Action>]
Comments: Action = T to pulse the 101T output; C to pulse the 101C output

The virtual switch control commands require the use of select-before-operate logic. First, the command must be selected using the CS-x101 command. After the select command is entered, there is a 30 second window during which the CO-x101 control command will be accepted. The control selected and the operation selected must match exactly or the operate command will be blocked. If the operate command is blocked and error message is output.

CS/CO-x101 Command Examples:

Example 1. Read the status of the 2101 virtual control switch.

```
>CO-2101
C
```

The returned setting indicates that the switch is in the after-close state.

Example 2. Trip the breaker by closing the trip output of the 1101 virtual control switch.

```
>CS-1101=T
1101=T SELECTED
>CO-1101=T
1101=T EXECUTED
```

Retrieving Virtual Breaker Control Switch Status from the Relay

The virtual breaker control switch state (after-trip or after-close) can be determined through the ASCII command interface by using the RG-STAT (reports general-status) command or on BESTCOMS *Metering* screen. See Section 6, *Reporting and Alarms, General Status Reporting*, for more information.

HMI Screens 2.2.1 through 2.2.4 provide switch control and displays the status of the virtual control switches (after-trip or after-close). As the previous Example 1 demonstrated, the state of each virtual selector switch can be determined using the CO-2101 command in a read-only mode.

SECTION 5 • METERING

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SECTION 5 • METERING

Introduction

The BE1-CDS240 Current Differential System measures the voltage and current inputs, displays those values in real time, records those values every one-half second, and calculates other quantities from the measured inputs.

Metering Functions

The CDS-240 metering functions include voltage, current, frequency, power factor, apparent power, reactive power, and true power. Metered values are viewed through any communication port using serial commands, using the BESTCOMS™ *Metering* screen, or at the front panel HMI. Metering functions are summarized in the following paragraphs and in Table 5-1. For assistance with navigating the HMI metering screens, refer to Section 10, *Human-Machine Interface*. For more information on power, VA, and var calculations, refer to Section 3, *Input and Output Functions, Power System Inputs, Power Measurement*. Energy measurement is covered in Section 6, *Reporting and Alarms*.

Auto Ranging

The BE1-CDS240 automatically scales metered values. Table 5-1 illustrates the ranges for each value metered.

Table 5-1. Auto Ranging Scales for Metered Values

Metered Value	Unit Display Ranges			
	Whole Units	**Kilo Units**	**Mega Units**	**Giga Units**
Current	0 A to 9,999 A	10 kA to 9,999 kA	10 MA	N/A
Voltage	0 V to 9,999 V	10 kV to 9,999 kV	N/A	N/A
Apparent Power	N/A	0 kVA to 000 kVA	1 MVA to 999 MVA	1 GVA to 1000 GVA
Reactive Power	N/A	0 kvar to 999 kvar	1 Mvar to 999 Mvar	1 Gvar to 1000 Gvar
True Power	N/A	0 kW to 999 kW	1 MW to 999 MW	1 GW to 1000 GW
Frequency	10 to 75 Hz	N/A	N/A	N/A

BESTCOMS™ Metering Screen

Metered values are viewed through the BESTCOMS *Metering* screen (see Figure 5-1). To open the *Metering* screen, select *Metering* from the *Reports* pull-down menu. To begin viewing metered values, select the *Start Polling* button in the bottom right of the screen.

Alternately, metering can be performed using the ASCII command interface or HMI using screens \METER\VOLT, \METER\CRNT, \METER\DIFF, \METER\POWER, and \METER\FREQ.

Refer to Table 5-2 for a list of ASCII commands and HMI screens used for metering.

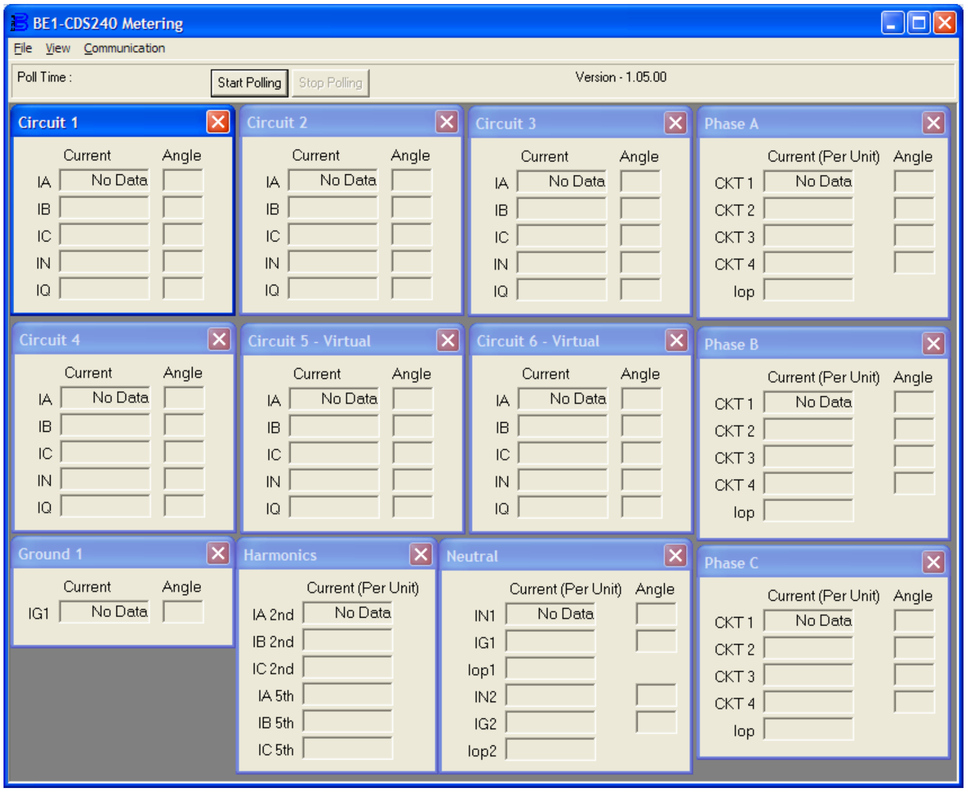

Figure 5-1. Metering - Circuits 1 - 6, Ground, Differential, and Harmonics

Other metering views can be selected from the *View* pull-down menu. These alternate views are shown in Figures 5-2 through 5-4.

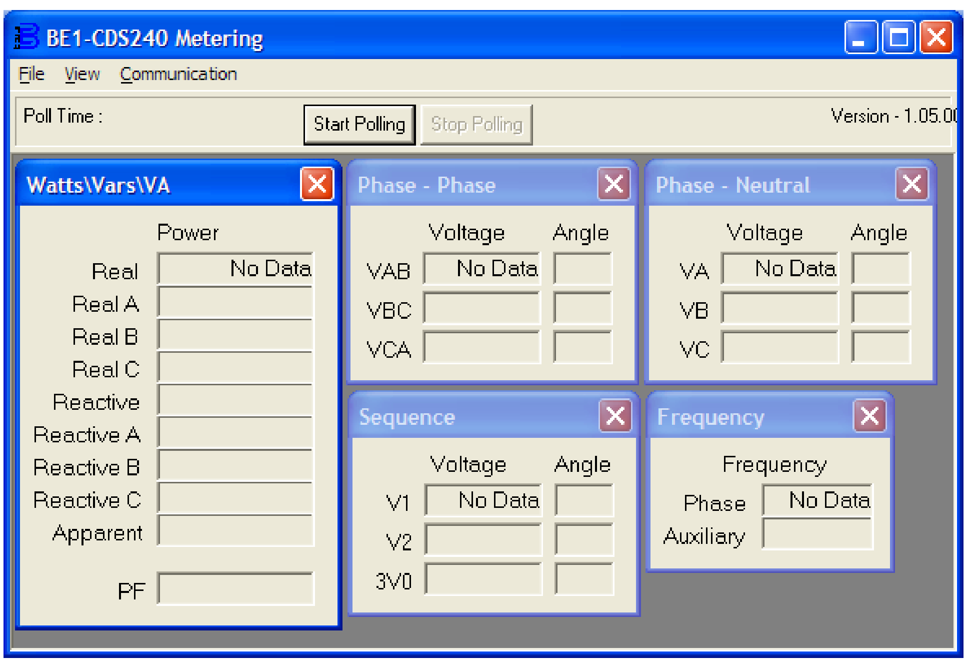

Figure 5-2. Metering - Watts/Vars/VA, Phase-Phase Voltage, Phase-Neutral Voltage, Sequence Voltage, and Frequency

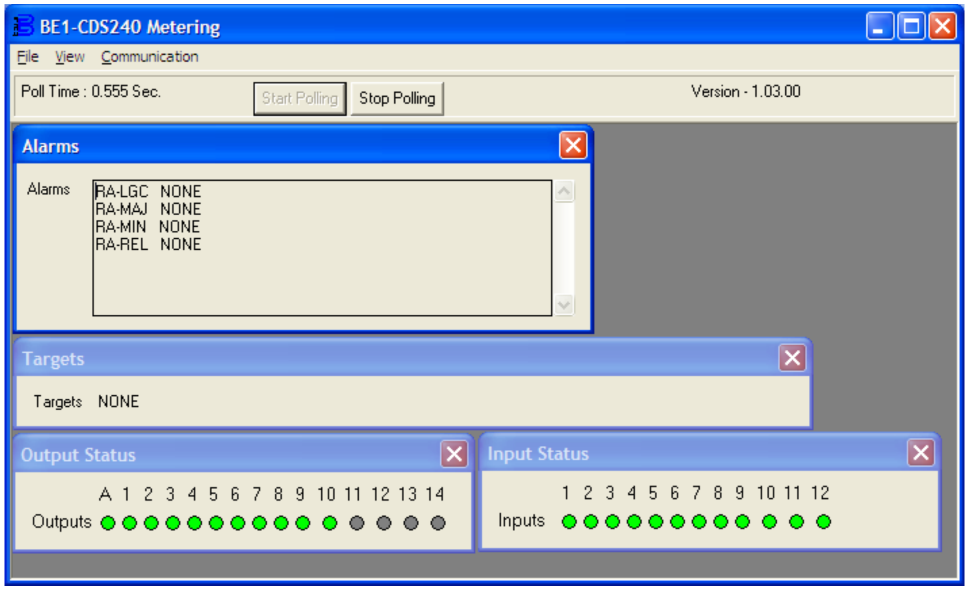

Figure 5-3. Metering - Alarms, Targets, Output Status, and Input Status

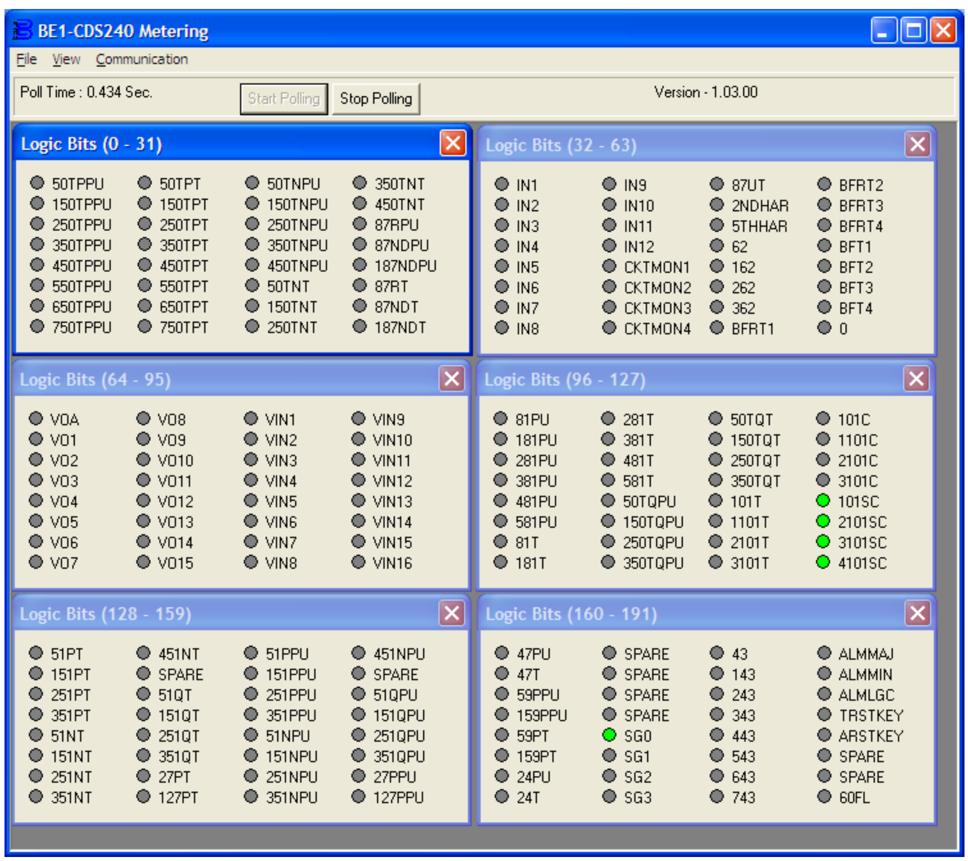

Figure 5-4. Metering - Logic Bits Views

Table 5-2. ASCII Command and HMI Metering Cross-Reference

Metering Function	ASCII Command	HMI Screen
All metered values	M	\METER
Fast metered values	M-FAST	N/A
Voltage, all values	M-V	\METER\VOLT
Voltage, A-phase	M-VA	\METER\VOLT\V_PH
Voltage, B-phase	M-VB	\METER\VOLT\V_PH
Voltage, C-phase	M-VC	\METER\VOLT\V_PH
Voltage, A-phase to B-phase	M-VAB	\METER\VOLT\V_LL
Voltage, B-phase to C-phase	M-VBC	\METER\VOLT\V_LL
Voltage, A-phase to C-phase	M-VAC	\METER\VOLT\V_LL
Voltage, Positive-Sequence	M-V1	\METER\VOLT\V_SEQ
Voltage, Negative-Sequence	M-V2	\METER\VOLT\V_SEQ
Voltage, Zero-Sequence	M-3V0	\METER\VOLT\V_SEQ
Power, True	M-WATT	\METER\POWER\WATTS
Power, True, A-phase	M-WATTA	\METER\POWER\WATTS
Power, True, B-phase	M-WATTB	\METER\POWER\WATTS
Power, True, C-phase	M-WATTC	\METER\POWER\WATTS
Power, True, Three-phase	M-WATT3	\METER\POWER\POWER
Power, Reactive	M-VAR	\METER\POWER\VARS
Power, Reactive, A-phase	M-VARA	\METER\POWER\VARS
Power, Reactive, B-phase	M-VARB	\METER\POWER\VARS
Power, Reactive, C-phase	M-VARC	\METER\POWER\VARS
Power, Reactive, Three-phase	M-VAR3	\METER\POWER\POWER
Power, Apparent (VA)	M-S	\METER\POWER\POWER
Power Factor	M-PF	\METER\POWER\POWER
Frequency, all values	M-FREQ	\METER\FREQ
Frequency, Phase	M-FREQP	\METER\FREQ
Frequency, Auxiliary Current	M-FREQX	\METER\FREQ
Current, all values	M-I	\METER\CRNT
Current, Circuits 1-6	M1, M2, M3, M4, M5, M6	\METER\CRNT\CT_1-6\I_MEAS and \METER\CRNT\CT_1-6\I_CALC
Current, Circuits 1-6	M1-I, M2-I, M3-I, M4-I, M5-I, M6-I	\METER\CRNT\CT_1-6\I_MEAS
Current, Circuits 1-6, A-phase	M1-IA, M2-IA, M3-IA, M4-IA, M5-IA, M6-IA	\METER\CRNT\CT_1-6\I_MEAS
Current, Circuits 1-6, B-phase	M1-IB, M2-IB, M3-IB, M4-IB, M5-IB, M6-IB	\METER\CRNT\CT_1-6\I_MEAS
Current, Circuits 1-6, C-phase	M1-IC, M2-IC, M3-IC, M4-IC, M5-IC, M6-IC	\METER\CRNT\CT_1-6\I_MEAS
Current, Circuits 1-6, Neutral	M1-IN, M2-IN, M3-IN, M4-IN, M5-IN, M6-IN	\METER\CRNT\CT_1-6\I_CALC

Metering Function	ASCII Command	HMI Screen
Current, Circuits 1-6, Negative-Sequence	M1-IQ, M2-IQ, M3-IQ, M4-IQ, M5-IQ, M6-IQ	\METER\CRNT\CT_1-6\I_CALC
Current, Ground	M-IG	\METER\CRNT\GND
Differential Currents, all values	MD	\METER\DIFF
2nd Harmonics as a % of Iop	MD-2ND	\METER\DIFF\HARM
5th Harmonics as a % of Iop	MD-5TH	\METER\DIFF\HARM
Diff Currents, Comp & Iop, all phases	MD-I	\METER\DIFF\COMP
Diff Currents, Comp & Iop, A-phase	MD-IA	\METER\DIFF\COMP\IA
Diff Currents, Comp, A-phase	MD-IA1COMP	\METER\DIFF\COMP\IA
Diff Currents, Comp, A-phase	MD-IA2COMP	\METER\DIFF\COMP\IA
2nd Harmonics as a % of Iop, A-phase	MD-IA2ND	\METER\DIFF\HARM
Diff Currents, Comp, A-phase	MD-IA3COMP	\METER\DIFF\COMP\IA
Diff Currents, Comp, A-phase	MD-IA4COMP	\METER\DIFF\COMP\IA
5th Harmonics as a % of Iop, A-phase	MD-IA5TH	\METER\DIFF\HARM
Diff Currents, Comp & Iop, B-phase	MD-IB	\METER\DIFF\COMP\IB
Diff Currents, Comp, B-phase	MD-IB1COMP	\METER\DIFF\COMP\IB
Diff Currents, Comp, B-phase	MD-IB2COMP	\METER\DIFF\COMP\IB
2nd Harmonics as a % of Iop, B-phase	MD-IB2ND	\METER\DIFF\HARM
Diff Currents, Comp, B-phase	MD-IB3COMP	\METER\DIFF\COMP\IB
Diff Currents, Comp, B-phase	MD-IB4COMP	\METER\DIFF\COMP\IB
5th Harmonics as a % of Iop, B-phase	MD-IB5TH	\METER\DIFF\HARM
Diff Currents, Comp & Iop, C-phase	MD-IC	\METER\DIFF\COMP\IC
Diff Currents, Comp, C-phase	MD-IC1COMP	\METER\DIFF\COMP\IC
Diff Currents, Comp, C-phase	MD-IC2COMP	\METER\DIFF\COMP\IC
2nd Harmonics as a % of Iop, C-phase	MD-IC2ND	\METER\DIFF\HARM
Diff Currents, Comp, C-phase	MD-IC3COMP	\METER\DIFF\COMP\IC
Diff Currents, Comp, C-phase	MD-IC4COMP	\METER\DIFF\COMP\IC
5th Harmonics as a % of Iop, C-phase	MD-IC5TH	\METER\DIFF\HARM
Diff Currents, Comp, Ground	MD-IG1COMP	\METER\DIFF\COMP\IN
Diff Currents, Comp, Ground	MD-IG2COMP	\METER\DIFF\COMP\IN
Diff Currents, Comp & Iop, all values	MD-IN	\METER\DIFF\COMP\IN
Diff Currents, Comp, Neutral	MD-IN1COMP	\METER\DIFF\COMP\IN
Diff Currents, Comp, Neutral	MD-IN2COMP	\METER\DIFF\COMP\IN
Diff Currents, Iop, Neutral	MD-INOP1	\METER\DIFF\COMP\IN
Diff Currents, Iop, Neutral	MD-INOP2	\METER\DIFF\COMP\IN

Voltage

The BE1-CDS240 meters A-phase voltage, B-phase voltage, C-phase voltage, voltage across phases A and B, phases B and C, and phases A and C. Positive-sequence voltage, negative-sequence voltage, and three-phase zero-sequence (residual) voltage are also metered. The VTP connection determines what is measured.

Current

Metered current includes A-phase current, B-phase current, C-phase current, neutral three-phase zero-sequence current, and ground current. Other metered currents include negative-sequence current and derived neutral current. All current measurements are auto ranging. Current is displayed in amps up to 9,999 A and then switches to kilo at 10.0 kA to 9,999 kA.

Frequency

Frequency is metered over a range of 10 to 75 hertz. If the measured frequency is outside this range, the nominal system frequency will be displayed. Frequency is sensed from A-phase to Neutral for four-wire sensing systems or from A-phase to B-phase for three-wire sensing systems. The frequency of auxiliary voltage VX is also measured.

Power Factor

Three-phase power factor is metered over a range of maximum lagging (–0.00) to unity (1.00) to maximum leading (+0.00).

Apparent Power

Metered apparent power is displayed over a range of –7,500 kilovolt amperes to +7,500 kilovars on five-ampere nominal systems. One-ampere nominal systems meter reactive power over a range of –1,500 kilovars to +1,500 kilovars.

True Power

True power is metered over a range of –7,500 kilowatts to +7,500 kilowatts on five-ampere nominal systems. One-ampere nominal systems meter true power over a range of –1,500 watts to +1,500 watts.

SECTION 6 • REPORTING AND ALARMS

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SECTION 6 • REPORTING AND ALARMS

Introduction

This section describes all available reports from the BE1-CDS240 Current Differential System and how they are set and retrieved. All alarm functions are also described along with how major and minor alarms are programmed (or mapped).

Relay Identifier Information

It is important to attach (label) meaningful names to the relays and the relay reports. To provide this feature, BE1-CDS240 relays have four relay identification fields: Relay ID, Station ID, User Label 1, and User Label 2. These fields are used in the header information lines of the Fault Reports, the Oscillographic Records, and the Sequence of Events Recorder (SER) Reports. Each of these four ID fields may be up to 30 alpha/numeric characters long. Figure 6-1 illustrates the BESTCOMS™ screen used to change these settings. Alternately, settings may be made using the SG-ID ASCII command.

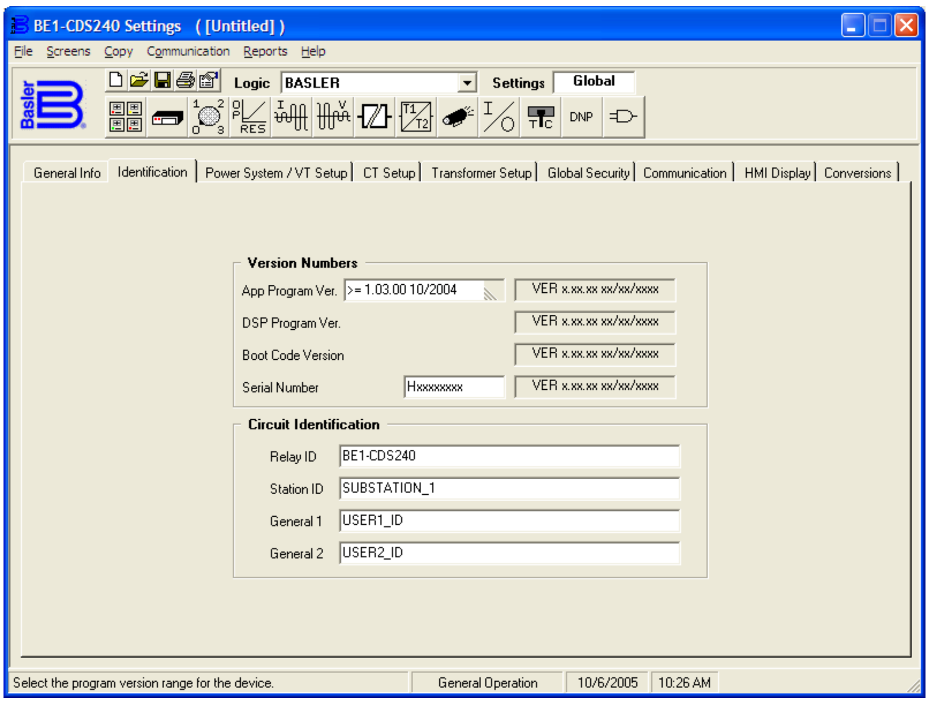

Figure 6-1. General Operation Screen, Identification Tab

To change these, delete the old label from the cell and type the new label. Identification settings are summarized in Table 6-1.

Table 6-1. Circuit Identification Settings

Setting	Parameters	Default
Relay ID	30 characters maximum ∗	BE1-CDS240
Station ID	30 characters maximum ∗	SUBSTATION_1
General 1	30 characters maximum ∗	USER1_ID
General 2	30 characters maximum ∗	USER2_ID

∗ No spaces are allowed in labels; any spaces used in the labels are stripped when the label change is saved. Use the character "_" (Shift + Underscore) to create a break in characters. An example of this is "SUBSTATION_1".

Clock

The BE1-CDS240 provides a real-time clock with capacitor backup that is capable of operating the clock for up to eight hours after power is removed from the relay. The clock is used by the demand reporting function, the fault reporting function, the oscillograph recording function, and the sequence of events recorder function to time-stamp events. The clock function records the year in two-digit format.

Optionally, a backup battery may be installed. The battery will maintain the clock for up to five years. See Section 13, *Testing and Maintenance*, for maintenance of battery.

IRIG-B Port

IRIG time code signal connections are located on the rear panel. When a valid time code signal is detected at the port, it is used to synchronize the clock function. Note that the IRIG time code signal does not contain year information. For this reason, it is necessary to enter the date even when using an IRIG signal. Year information is stored in nonvolatile memory so that when operating power is restored after an outage and the clock is re-synchronized the current year is restored. When the clock rolls over to a new year, the year is automatically incremented in nonvolatile memory. An alarm bit is included in the programmable alarm function for loss of IRIG signal. The alarm point monitors for IRIG signal loss once a valid signal is detected at the IRIG port.

The IRIG input is fully isolated and accepts a demodulated (dc level-shifted) signal. The input signal must be 3.5 volts or higher to be recognized as a valid signal. Maximum input signal level is +10 to –10 volts (20 volt range). Input resistance is nonlinear and rated at 4 kΩ at 3.5 volts.

Setting the Clock Function

Time and date format settings are made using BESTCOMS. Figure 6-2 illustrates the BESTCOMS screen used to select time and date format settings. To open the screen, select *Reporting and Alarms* from the *Screens* pull-down menu. Then select the *Clock Display Mode* tab. Alternately, settings may be made using the SG-CLK ASCII command. Refer to Table 6-2, *Time and Date Format Settings*.

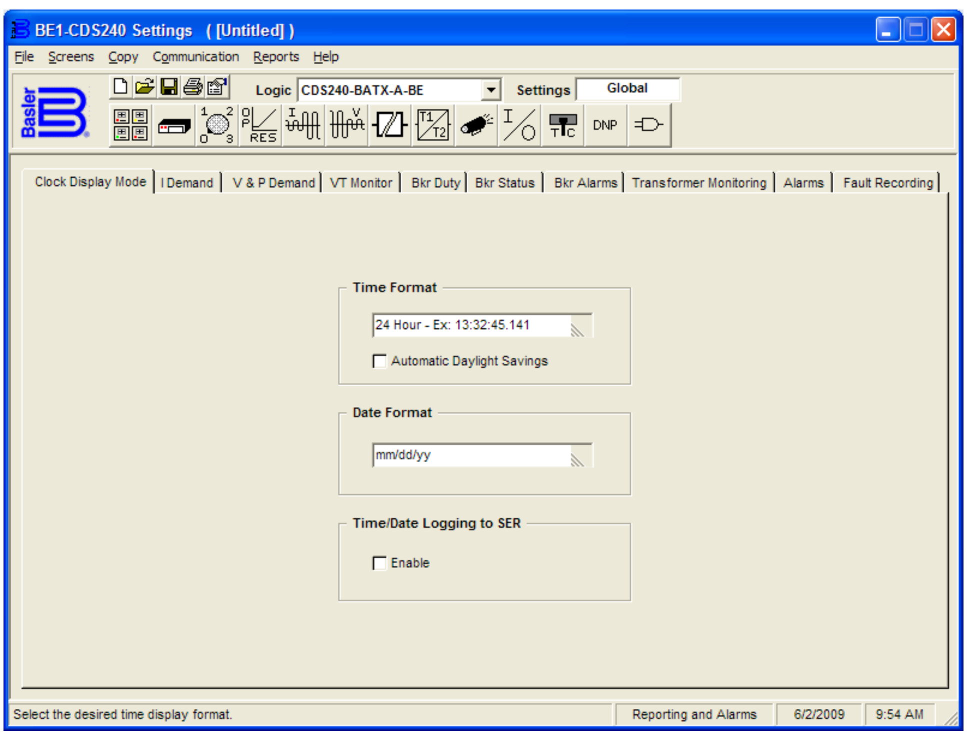

Figure 6-2. Reporting and Alarms Screen, Clock Display Mode Tab

Time and date reporting can be displayed in 12 or 24-hour format. When operating in the 12-hour format, the A.M./P.M. parameter is placed between the minutes and seconds parameters (10:24P23.004 indicates 10:24 in the evening). The default time format is 24 hours. Date reporting format can display the date in mm/dd/yy or dd/mm/yy format. The default date format is mm/dd/yy. The relay clock can also accommodate daylight saving time changes. Automatic daylight saving time adjustments are optional and are disabled by default.

Recording of time or date changes made via Modbus® or DNP is optional and is disabled by default. Recording of time or date changes made via the HMI or the SG-CLK ASCII command is automatic and cannot be disabled.

Table 6-2. Time and Date Format Settings

Parameter	Range	Default
Time Format	12 (12 hour format) 24 (24 hour format)	24
Date Format	m (mm-dd-yy) d (dd-mm-yy)	M
Automatic Daylight Savings	0 (daylight saving time disabled) 1 (daylight saving time enabled)	0
Time/Date Logging to SER	Disabled or Enabled	Disabled

Reading and Setting the Clock

Clock information can be viewed and set at the front panel human-machine interface (HMI) and through the communication ports using ASCII commands or BESTCOMS. Write access to reports is required to set the clock at the HMI and communication ports. An alarm point is provided in the programmable alarms to detect when the relay has powered up and the clock has not been set. Time and date information is read and set at HMI Screen 1.4.6, \STAT\OPER\TIME_DATE, through the communication ports using the RG-DATE and RG-TIME ASCII commands, and through BESTCOMS by selecting the *Communication* pull-down menu and then selecting *Set Date and Time.*

General Status Reporting

BE1-CDS240 relays have extensive capabilities for reporting relay status. This is important for determining the health and status of the system for diagnostics and troubleshooting. Throughout this manual, reference is made to the RG-STAT (report general, status) report and the appropriate HMI screens for determining the status of various functions.

General Status Report

A General Status report is available through the communication ports using the RG-STAT command. This report lists all of the information required to determine the status of the relay. An example of a typical General Status report follows as well as a description of what each line represents. In the explanation of each line, cross-references are made to the corresponding HMI screens that contain that data.

>RG-STAT

```
INPUT(1-12)          STATUS : 000000000000
OUTPUT(A,1-10)       STATUS : 000000000000000
CO-OUT(A,1-10)       STATUS : LLLLLLLLLLLLLL
CO-43 to CO-743      STATUS : 00000000
CO-101(101SC)        STATUS : AFTER CLOSE(1)
CO-1101(1101SC)      STATUS : AFTER CLOSE(1)
CO-2101(2101SC)      STATUS : AFTER CLOSE(1)
CO-3101(3101SC)      STATUS : AFTER CLOSE(1)
CO-GROUP             STATUS : L
ACTIVE LOGIC         STATUS : CDS240-BA87-A-BE
LOGIC VAR(  0- 31)   STATUS : 00000000 00000000 00000000 00000000
LOGIC VAR( 32- 63)   STATUS : 00000000 00000000 00000000 00000000
LOGIC VAR( 64- 95)   STATUS : 00000000 00000000 00000000 00000000
LOGIC VAR( 96-127)   STATUS : 00000000 00000000 00000000 00001111
LOGIC VAR(128-159)   STATUS : 00000000 00000000 00000000 00000000
LOGIC VAR(160-191)   STATUS : 00000000 00001000 00000000 00000000
ACTIVE GROUP         STATUS : 0
BREAKER_LABEL1       STATUS : OFF
BREAKER_LABEL2       STATUS : OFF
BREAKER_LABEL3       STATUS : OFF
BREAKER_LABEL4       STATUS : OFF
DIAG/ALARM           STATUS : 0 RELAY, 0 LOGIC, 0 MAJOR, 0 MINOR
```

Input (1-12)

This line reports the status of contact sensing inputs IN1 through IN12. Input information is available at HMI Screen 1.4.1, \STAT\OPER\INPUT, or with the RG-INPUT ASCII command. "0" indicates a de-energized input and "1" indicates an energized input. See Section 3, *Input and Output Functions,* for more information about contact sensing input operation.

Output (A, 1-10)

Output contact status for OUTA, OUT1 through OUT10 is reported on this line. This information is also available at HMI Screen 1.4.2, \STAT\OPER\OUT, or with the RG-OUTSTAT ASCII command. "0" indicates a de-energized output and "1" indicates an energized output. More information about output contact operation is available in Section 3, *Input and Output Functions*.

CO-OUT (A,1-10)

This line reports the logic override of the output contacts. Logic override status is reported at HMI Screen 2.4, \CTRL\OUT, and through the RG-OUTCNTRL ASCII command. Section 3, *Input and Output Functions,* provides more information about output logic override control.

CO-43 to CO-743

Virtual switch function status is reported on this line. This information is also available at HMI Screen 1.4.3, \STAT\OPER\x43, where x is blank, 1, 2, 3, 4, 5, 6, or 7. The status of the 43 switches is also available from the RG-43STAT ASCII command. See Section 4, *Protection and Control, Virtual Switches,* for more information about this function.

CO-101/1101/2101/3101

These lines report the status of the slip contact outputs of the four virtual breaker control switches. This information is available on HMI Screen 2.2, \CTRL\BKR, or with the RG-101STAT ASCII command. See Section 4, *Protection and Control, Virtual Switches,* for more information about this function.

CO-GROUP

This line reports the status of the logic override of the setting group selection function. This information is available on HMI Screen 2.3, \CTRL\SG, or using the RG-GRPCNTRL ASCII command. See Section 4, *Protection and Control, Setting Groups,* for more information on this function.

Active Logic

This line reports the name of the active logic scheme. The active logic scheme name can also be viewed at HMI Screen 5, \PROT, or with the RG-LOGIC ASCII command. See Section 7, *BESTlogic Programmable Logic, Logic Schemes,* for more information about active logic.

Logic Variables (00-31), (32-63), (64-95), (96-127), (128-159), and (160-191)

These six lines report the status of each of the BESTlogic variable. The output of these lines can be entered into Table 6-3 to determine the status of each logic variable. See Section 7, *BESTlogic Programmable Logic,* for more information about BESTlogic Variables. This information is not available from the HMI. RL (report logic) also reports the BESTlogic logic variables.

Active Group

The active group is indicated on this line. HMI Screen 1.4.4, \STAT\OPER\ACTIVEG, also provides this information. ASCII command RG-GRPACTIVE can also be used to view active group status. See Section 4, *Protection and Control, Setting Groups,* for more information about setting groups.

Breaker Label (1/2/3/4)

These lines report the state of the breakers as defined by the logic expressions SB-LOGIC1/2/3/4. This information is also available on HMI Screen 1.4.5, \STAT\OPER\BKR, or using ASCII command RG-BREAKER. See the paragraphs *Breaker Monitoring,* later in this section for more information about breaker labels.

Diag/Alarm

This line reports the status of each of the following alarm categories: relay, logic, major, and minor. Detailed information on individual alarm points is available on HMI Screen 1.2, \STAT\ALARMS, or using the ASCII command RA. See Section 10, *Human-Machine Interface* and the paragraphs on *Alarms Function* later in this section for more information about the diagnostic and alarm functions.

Other Report General Commands

There are several other RG (report general) commands in addition to those discussed in the previous paragraphs. These include RG-TIME, RG-DATE, RG-TARG, and RG-VER. These are covered in detail in the respective paragraphs in this section. As with many other commands, a combination read command is available to read several items in a group. If the command RG is entered by itself, the relay reports the time, date, target information, and other reports as shown in the following example. The RG-VER command has multiple line outputs and is not read with the RG command.

Table 6-3. Logic Variable Status Report Format

50TPPU	150TPPU	250TPPU	350TPPU	450TPPU	550TPPU	650TPPU	750TPPU	50TPT	150TPT	250TPT	350TPT	450TPT	550TPT	650TPT	750TPT	50TNPU	150TNPU	250TNPU	350TNPU	450TNPU	50TNT	150TNT	250TNT	350TNT	450TNT	87RPU	87NDPU	187NDPU	87RT	87NDT	187NDT
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

IN1	IN2	IN3	IN4	IN5	IN6	IN7	IN8	IN9	IN10	IN11	IN12	CKTMON1	CKTMON2	CKTMON3	CKTMON4	87UT	2NDHARA	2NDHARB	2NDHARC	5THHARA	5THHARB	5THHARC	BFRT1	BFRT2	BFRT3	BFRT4	BFT1	BFT2	BFT3	BFT4	0
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63

VOA	VO1	VO2	VO3	VO4	VO5	VO6	VO7	VO8	VO9	VO10	VO11	VO12	VO13	VO14	VO15	VIN1	VIN2	VIN3	VIN4	VIN5	VIN6	VIN7	VIN8	VIN9	VIN10	VIN11	VIN12	VIN13	VIN14	VIN15	VIN16
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95

81PU	181PU	281PU	381PU	481PU	581PU	81T	181T	281T	381T	481T	581T	50TQPU	150TQPU	250TQPU	350TQPU	50TQT	150TQT	250TQT	350TQT	101T	1101T	2101T	3101T	101C	1101C	2101C	3101C	101SC	1101SC	2101SC	3101SC
96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127

51PT	151PT	251PT	351PT	51NT	151NT	251NT	351NT	451NT	SPARE1	51QT	151QT	251QT	351QT	27PT	127PT	51PPU	151PPU	251PPU	351PPU	51NPU	151NPU	251NPU	351NPU	451NPU	SPARE2	51QPU	151QPU	251QPU	351QPU	27PPU	127PPU
128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159

47PU	47T	59PPU	159PPU	59PT	159PT	24PU	24T	62	162	262	362	SG0	SG1	SG2	SG3	43	143	243	343	443	543	643	743	ALMMAJ	ALMMIN	ALMLGC	TRSTKEY	ARSTKEY	59XPU	59XT	60FL
160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191

Energy Data

Energy information in the form of watthours and varhours is measured and reported by the BE1-IPS100. Both positive and negative values are reported in three-phase, primary units. Watthour and varhour values are calculated per minute as shown in Equation 6-1.

$$\frac{\text{Primary VT Ratio} \times \text{Primary CT Ratio}}{\text{60 minutes}} \times \text{Secondary watts or vars}$$

Equation 6-1. Energy Data Equation

The primary CT ratio can be any of the 4 input current circuits or 2 virtual current circuits. Use *Current Circuit for Power Calculations* to select the current circuit to be used in the power calculation as shown in Figure 14-7, Section 14, *BESTCOMS Software.* Watt and var values are updated every 250 milliseconds and watthour and varhour values are logged once every minute. Energy registers are stored in nonvolatile memory during every update.

Watthour values and varhour values can be read, reset, or changed through the HMI or communication ports. Watthour and varhour values can be accessed at the HMI through Screen 4.6.1. ASCII command RE-KWH (report energy - kilowatthours) gives access to both positive and negative watthour values. A lagging power factor load will report positive watts and positive vars.

ASCII command RE-KVAR (report energy-kilovarhours) gives access to both positive and negative varhour values.

Energy data is also available through the communication ports by using the RE (report energy) command. This read-only command returns both the watt-hours and varhours.

Demand Functions

The demand reporting function continuously calculates demand values for the three-phase currents, three-phase power, three-phase reactive power, neutral current (3-phase residual 3IO), and negative-sequence current. Demand values are recorded with time stamps for Peak Since Reset, Yesterday's Peak, and Today's Peak. Programmable alarm points can be set to alarm if thresholds are exceeded for overload and unbalanced loading conditions.

Demand Calculation and Reporting Function

Thermal Demand Calculation Method

The demand reporting function incorporates an algorithm to digitally simulate a thermal or exponential response. Thermal demand values are computed by an exponential algorithm with the demand interval or response period defined as the time taken by the meter to reach 90 percent of the final value for a step change in the current being measured. The demand interval and monitored CT can be set independently for the phase, neutral, and negative-sequence demand calculations.

Block Demand Calculation Method

The block demand method calculates the average value of the measured current for the time interval set by the demand reporting function. This value remains constant, is stored in registers, and reported for the duration of the following time interval. At the end of the time interval, the calculated average for the previous time interval is again stored in registers and reported for the duration of the following time interval. If you have set a fifteen-minute time interval and block demand calculation, the reported value for fifteen minutes is the average value of the measured current for the previous fifteen minutes.

Sliding Block Demand Calculation Method

Sliding block demand method calculates the average value of the measured current for the time interval set by the demand reporting function. This value is stored in registers and reported for one minute. After one minute has elapsed, the sliding block demand method again calculates the average value of the measured current for the set time interval including the most recent minute. This value is updated each minute.

Each time that the value in the current demand register is updated, it is compared to the values stored in the *Peak Since Reset* and the *Today's Peak* registers. If the new demand value is greater, the new value and time stamp is entered into the appropriate registers. In addition, the demand reporting function keeps an additional set of registers for *Yesterday's Peak.* Each day at midnight, the demand reporting function replaces the values and time stamps stored in *Yesterday's Peak* registers with the values and time stamps from *Today's Peak* registers. It then starts recording new information in *Today's Peak* registers. The demand registers are stored in volatile memory.

The *Today's Peak* and *Yesterday's Peak* registers are read only. The values in the *Peak Since Reset* registers can be reset to zero or preset to a predetermined value. For example, if you are going to switch some loads to take a feeder out of service and you do not want the abnormal loading to affect the values stored in the *Peak Since Reset* registers. You may read these values prior to doing the switching and then reset the registers to these values after the abnormal loading condition has passed.

Setting the Demand Reporting Function

For the demand reporting function to calculate demand, it is necessary to specify the demand interval, calculation method, and which CT to monitor. This is done using BESTCOMS. Figure 6-3 illustrates the BESTCOMS screen used to select demand-reporting settings. To open the screen shown in Figure 6-3, select *Reporting and Alarms,* from the *Screens* pull-down menu. Then select the *I Demand* tab. Alternately, setting may be made using the SG-DI (Read/Program Demand Current settings) and SG-DC (Read/Set Demand Circuit) ASCII commands or the HMI using Screen 6.4.1, \SETUP\DMD\DETAILS.

Demand settings for include columns labeled *Phase, Neutral*, and *Neg.-Sequence*. Each of these columns has settings for *Interval (Minutes), Calculation Method,* and *Current Threshold*. *Current Threshold* display units are selectable from a pull-down menu allowing the selection of *Sec. Amps, Pri. Amps, Per U Amps,* or *% Amps*. The default display unit is *Sec. Amps*. *Calculation Method* can be *Thermal, Block,* or *Sliding Block. Interval (Minutes)* can be set from 0 to 60.

Additionally, *Current Threshold* can be set on Demand Circuits 1 through 6. Choose the demand circuit from the *Demand Circuits* pull-down menu.

Using the pull-down menus and buttons, make the application appropriate current demand settings.

Demand reporting settings are summarized in Table 6-4.

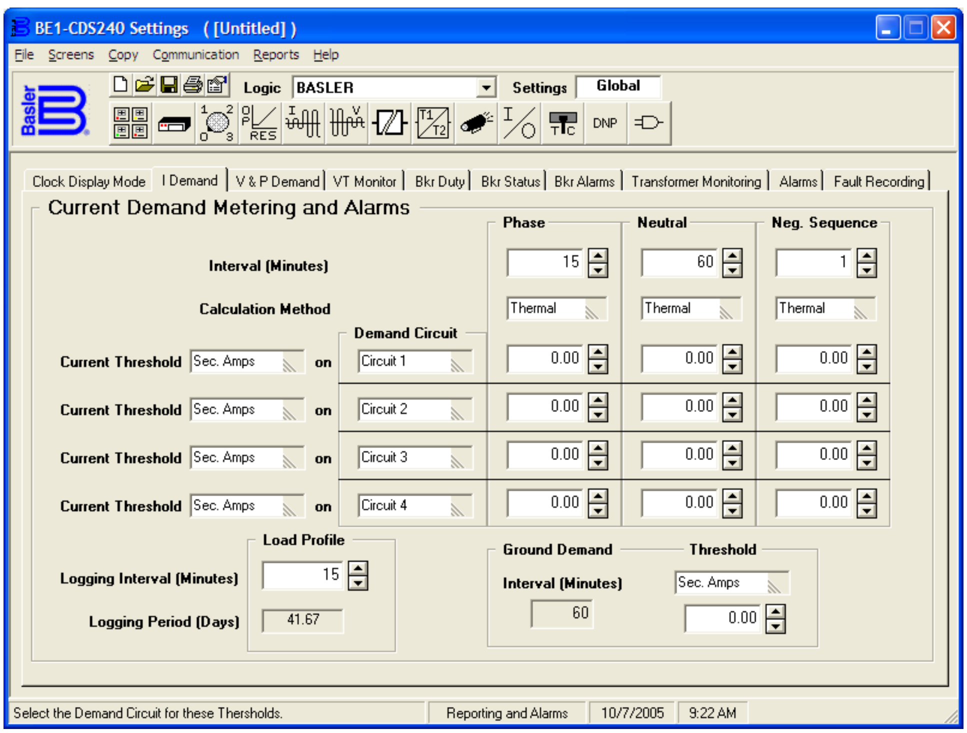

Figure 6-3. Reporting and Alarms Screen, I Demand Tab

Table 6-4. Demand Settings for Current

Setting	Range	Increment	Unit of Measure	Default
Phase Interval (Minutes)	0 to 60	1	Minutes	15
Neutral Interval (Minutes)	0 to 60	1	Minutes	1
Neg.-Sequence Interval (Minutes)	0 to 60	1	Minutes	1
Calculation Method	Thermal (T), Block (B), Sliding Block (S)	N/A	N/A	T
Demand Circuit	1 to 6	N/A	N/A	1, 2, 3, 4

The *Interval (Minutes)* for Phase Voltage, Watt, and Var demands are automatically determined by the *Interval (Minutes)* Phase setting on the *I Demand* tab (Figure 6-3). The *Interval (Minutes)* for Neutral Voltage is automatically determined by the *Interval (Minutes) Neutral* setting on the *I Demand* tab (Figure 6-3).

Retrieving Demand Reporting Information

The values and time stamps in the demand registers are reported in primary amperes. They can be read from both the HMI and the ASCII command interface.

The values and time stamps can be read from HMI menu Screen 4.4, \REPRT\DEMAND. The values in the *Peak Since Reset* registers can be reset by pressing the *Reset* key. The value in the register will be set to zero and then updated on the next processing loop with the currently calculated demand value. No write access is required to do this from the HMI. It is also possible to preset a value into the *Peak Since Reset* demand registers. This can be done by pressing the *Edit* key, changing the preset value using the scrolling pushbutton keys, exiting and then saving the settings. Write access to the *Reports* functional area is required to do this from the HMI.

The values and time stamps in the demand registers can also be read and reset or preset from the ASCII command interface using the RD (report demands) command.

Overload and Unbalance Alarms Function

The programmable alarms function includes alarm points for monitoring phase demand thresholds for overload alarms, and neutral and negative-sequence demand thresholds for unbalanced loading alarms. Each time that the current demand register is updated, the value is compared to the appropriate demand alarm threshold. If the threshold is exceeded, the alarm point is set. See *Alarms Function* in this section for more information on how to use the programmable alarms reporting function.

The Phase, Neutral, and Neg.-Sequence current demand alarm thresholds can be set from the ASCII command interface using the SA-DI command or BESTCOMS (Figure 6-3). The SA-DIG ASCII command is used to set the ground demand alarm threshold, which can also be set with BESTCOMS (Figure 6-3). The Voltage Max and Min Phase/Neutral thresholds are set with the SA-DV ASCII command or with BESTCOMS (Figure 6-4). The Watt Positive and Negative demand thresholds are set with the SA-DWATT ASCII command or with BESTCOMS (Figure 6-4). The SA-DVAR ASCII command is used to set the Var Positive and Negative demand thresholds, which can also be set using BESTCOMS (Figure 6-4). Alternately, HMI Screen \SETUP\DMD\ALARMS, can be used to set all demand alarms.

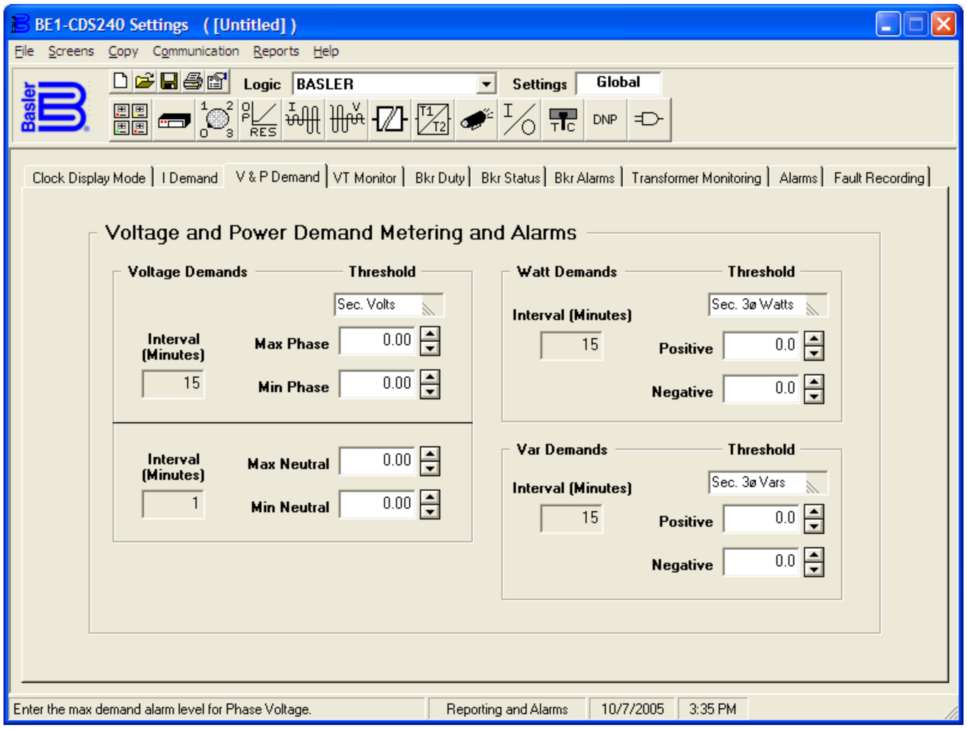

Figure 6-4. Reporting and Alarms Screen, V & P Demand Tab

Table 6-5 provides the specifications for the Demand Alarm Threshold settings. The ASCII commands for setting the Demand Alarm Thresholds are listed in Section 11, *ASCII Command Interface.*

Table 6-5. Demand Alarm Threshold Settings

Demand Alarm Threshold	Range	Increment	Unit of Measure	Default
Phase Current	5A → 0.50 – 16.0 1A → 0.10 – 3.20	0.01 for 0 – 9.99 0.1 for 10.0 – 16.0	Secondary Amps	0
Neutral Current				
Neg.-Sequence Current				
Ground				
Voltage Max/Min Phase	10.0 – 300	0.1 for 10.0 to 99.9 1 for 100 to 300	Secondary Volts	
Voltage Max/Min Neutral	10.0 - 150	0.1 for 10.0 to 99.9 1 for 100 to 150	Secondary Volts	
Watts Positive/Negative	0 – 8500	0.1 for 0 to 99.9 1 for 100 to 8500	Secondary 3Ø Watts	
Vars Positive/Negative			Secondary 3Ø Vars	

Optional Load Profile Recording Function

Load profile recording is an optional selection when the BE1-CDS240 is ordered. The Load Profile, 4000 Point Data Array option (2 or 3 as the third character from the right in the style chart) uses a 4,000-point data array for data storage. Refer to Section 1, *General Information, Model and Style Number Description,* for more information on optional selections. At the specified (programmed) interval, Load Profile takes the data from the demand calculation register and places it in a data array. If the programmed interval is set to 15 minutes, it will take 41 days and 16 hours to generate 4,000 entries. Load profile data is smoothed by the demand calculation function. If you made a step change in primary current, with the demand interval set for fifteen minutes and the load profile recording interval set for one minute, it would take approximately fifteen minutes for the load (step change) to reach 90 percent of the final level. See the previous paragraphs in this section on *Demand Calculation and Reporting Function,* for information on calculation methods.

Setting the Load Profile Recording Function

For the load profile recording function to log data, you must set the demand logging interval. This can be done from the ASCII command interface using the SG-LOG (setting general, logging interval). Table 6-6 lists the settings for the optional load profile recording.

Table 6-6. Load Profile Recording Settings

Function	Range	Increment	Unit of Measure	Default
Demand Log Interval	1 – 60	1	Minutes	15

Retrieving the Load Profile Recording Function

Load profile recorded data is reported by the ASCII command interface using the RD-LOG command. You may request the entire log or only a specific number of entries.

Differential Current Monitoring Function

Differential current monitoring is a diagnostic function designed to aid in the installation and commissioning of transformer banks. This function attempts to identify and prevent false trips due to incorrect polarity, incorrect angle compensation, or mismatch.

During transformer commissioning, it would be particularly useful to analyze the system installation and create a record of the settings and measured currents. The differential current monitoring function can create a differential check record like the sample shown in the following paragraphs. These records are also useful when comparing the present system characteristics to the characteristics at commissioning. A differential record is generated automatically when the ASCII interface command RA-DIFF=TRIG (report alarm-differential, trigger) is issued or when a differential alarm is set. When no alarms are active, you must use the RA-DIFF=TRIG command to obtain a record of the actual operating conditions.

The following differential check record example was developed from a simulated substation and shows that there are no problems in the installation or settings. The first part of the record is the date and time the record was captured and the basic relay identification.

The second part is a record of the CT connections and 87 (differential) settings. These settings may be entered using the S<g>-87 command. Refer to Section 3, *Input and Output Functions,* and Section 4, *Protection and Control, Differential Protection,* for more information on entering settings that develop both the second and third parts of the record. Also, refer to Section 3, *Input and Output Functions,* for information on the CT polarity convention used in both the fourth and fifth parts of the record.

The third part is a record of the compensation factors. It is important to note that the angle compensation cannot be entered manually. The angle compensation is calculated by the relay based on the CT and transformer connections. (See Section 3*, Input and Output Functions, Power system Inputs, Power Measurement, Setting Up the Power System Measurement Functions,* for more information on automatically determining compensation.) Additionally, the tap compensation setting may be entered manually or automatically calculated. (See Section 4, *Protection and Control, Differential Protection,* for more information on auto-tap compensation.)

The fourth part of the record attempts to identify polarity and angle compensation errors by looking at the phase angle differences of compared phases. The differential alarm is set whenever the minimum pickup or the slope ratio exceeds the differential alarm, percent of trip setting. If the differential alarm is set and neither the polarity alarm nor angle compensation alarm is set, a mismatch error is identified indicating that the most likely cause of the alarm is incorrect tap settings. The differential check record needs a specific amount of secondary current to properly measure phase angles. In 5-ampere relays, that amount of current is 150 milliamperes. In one-ampere relays, it is 30 milliamperes. If there is not enough current present to run the algorithm, the message **`I < 150 ma`** (or 30 ma) appears in the appropriate alarm column. Since all phase angles are referenced to A1, no current applied to A1 will cause the **`I < 150 ma`** (or 30 ma) message to appear for all phases.

The fifth part (MEASUREMENTS) displays the measured and calculated currents at the time of the differential record trigger. The relay measures secondary current and develops the tap compensated currents for use by the differential element. Primary current (`MEASURED I PRI`) is calculated simply as the secondary current multiplied by the CT turns ratio. Secondary current (`MEASURED I SEC`) is the current actually measured by the relay. Angle compensated current (`ANGLE COMPENSATED I`) is the measured secondary current with phase compensation applied. Tap compensated current (`TAP COMP I`) is the tap and phase compensated current actually used by the differential function. IOP is the operating current. SLOPE RATIO is the ratio of `IOP` to the restraint current (maximum `TAP COMP I`). The slope ratio is compared against the differential alarm setting. To generate a differential report and set the differential alarm (alarm point number 3), two requirements must be met. One, `IOP` must be above minimum pickup. Two, the slope ratio must exceed the differential alarm. For example, our settings are minimum pickup = 0.20, slope = 40%, and differential alarm setting = 75%. Seventy-five percent of the minimum pickup is 0.75 times 0.2 = 0.15. Operating current must be above 0.15 to satisfy requirement one. When a differential alarm setting of 75% and a slope ratio setting of 40, requirement two is satisfied when the slope ratio exceeds 30% (0.75 times 40 = 30%). See the following paragraphs on *Setting Differential Current Monitoring Alarms* and the associated figure in this section for more information on slope ratios.

A new differential report will not be generated unless the slope ratio drops below the differential alarm setting then increases above the setting. Alternatively, a record can be generated using the RA-DIFF=TRIG ASCII command.

Example 1 is based on the connections of Figure 12-19, an autotransformer with tertiary load. Current transformers are located in double breakers on the transformer H winding side, a single breaker on the X winding and on the leads to the Y winding.

Example 1.

>RA-DIFF

```
CDS240 DIFFERENTIAL CHECK RECORD
STATION ID            : SUBSTATION_1
RELAY ID              : BE1-CDS240
USER1 ID              : USER1_ID
USER2 ID              : USER2_ID
RELAY ADDRESS         : 0
REPORT DATE           : 04/26/03
REPORT TIME           : 10:06:50.060
ACTIVE GROUP          : 0

PHASE 87 SETTINGS      CTR    CT CON   TX CON   GROUNDED   ABC SWAP   DIFF CKT
CT CKT1                400    WYE      WYE      YES        ABC        PRI
CT CKT2                200    WYE      WYE      YES        ABC        SEC
CT CKT3                240    WYE      DAC      NO         ABC        SEC
CT CKT4                400    WYE      WYE      YES        ABC        PRI

MINPU                  0.2 * TAP
SLOPE                  40 %
ALARM                  75 %
URO                     6 * TAP

COMPENSATION           ANGLE   ROTATE   ABC SWAP   Ground  TAP
CT CKT1                DAC     NO       NO         YES     2.00
CT CKT2                DAC     NO       NO         YES     8.00
CT CKT3                WYE     NO       NO          NO     19.2
CT CKT4                DAC     NO       NO         YES     2.00

ALARMS                 PHASE A             PHASE B             PHASE C
DIFFERENTIAL           OK                  OK                  OK
POLARITY               OK                  OK                  OK
ANGLE COMP             OK                  OK                  OK
MISMATCH               OK                  OK                  OK

MEASUREMENTS           PHASE A             PHASE B             PHASE C
MEASURED PRI I
CT CKT1               167.3 @ 0          167.3 @ 240         167.3 @ 120
CT CKT2               200.8 @ 180        200.8 @ 60          200.8 @ 300
CT CKT3               125.5 @ 151        125.5 @ 31          125.5 @ 271
CT CKT4                54.5 @ 180         54.5 @ 60           54.4 @ 300
MEASURED SEC I
CT CKT1                0.42 @ 0           0.42 @ 240          0.42 @ 120
```

```
CT CKT2                1.01 @ 180         1.01 @ 60          1.01 @ 300
CT CKT3                0.52 @ 151         0.52 @ 31          0.52 @ 271
CT CKT4                0.14 @ 180         0.14 @ 60          0.14 @ 300

ANGLE COMPENSATED I
CT CKT1                0.42 @ 330         0.42 @ 210        0.42 @ 90
CT CKT2                1.01 @ 150         1.01 @ 30         1.01 @ 270
CT CKT3                0.52 @ 151         0.52 @ 31         0.52 @ 271
CT CKT4                0.14 @ 150         0.14 @ 30         0.14 @ 270

TAP COMPENSATED I
CT CKT1                0.21 @ 330          0.21 @ 210         0.21 @ 90
CT CKT2                0.13 @ 150          0.13 @ 30          0.13 @ 270
CT CKT3                0.03 @ 151          0.03 @ 31          0.03 @ 271
CT CKT4                0.07 @ 150          0.07 @ 30          0.07 @ 270
I OPERATE              0.01 * TAP          0.01 * TAP         0.01 * TAP
SLOPE RATIO               1 %                 1 %                1 %
```

Setting Differential Current Monitoring Alarms

The differential function continuously monitors the input current in CT Circuits 1, 2, 3, 4, 5, or 6. If a mismatch due to current loading is approaching the trip level, the differential alarm may be activated. This alarm is alarm point number nine in the relay programmable alarms. The alarm point must be mapped to activate an alarm and/or light an LED. For more information on mapping the alarm functions, see *Alarms Function, Major, Minor, and Logic Programmable Alarms* later in this section. The differential alarm is set as a percentage of the percentage restrained differential characteristic. See Figure 6-5 for a graph showing the percentage restrained differential and differential alarm characteristics. To set the differential alarm threshold level, use BESTCOMS (Figure 6-6). Pull down the *Screens* menu and select *Differential Protection.* Select the *Diff Alarm* tab. Alternately, settings can be made using ASCII command SA-DIFF (setting alarm, differential). This setting is not available via the front panel HMI. Table 6-7 summarizes the differential alarm threshold setting.

Table 6-7. Differential Alarm Threshold Setting

Function	Range	Increment	Unit of Measure	Default
Differential Alarm Level	50 – 100	1	Percent (%)	67

Retrieving Differential Current Monitoring Information

To retrieve the differential check record, use the ASCII command RA-DIFF.

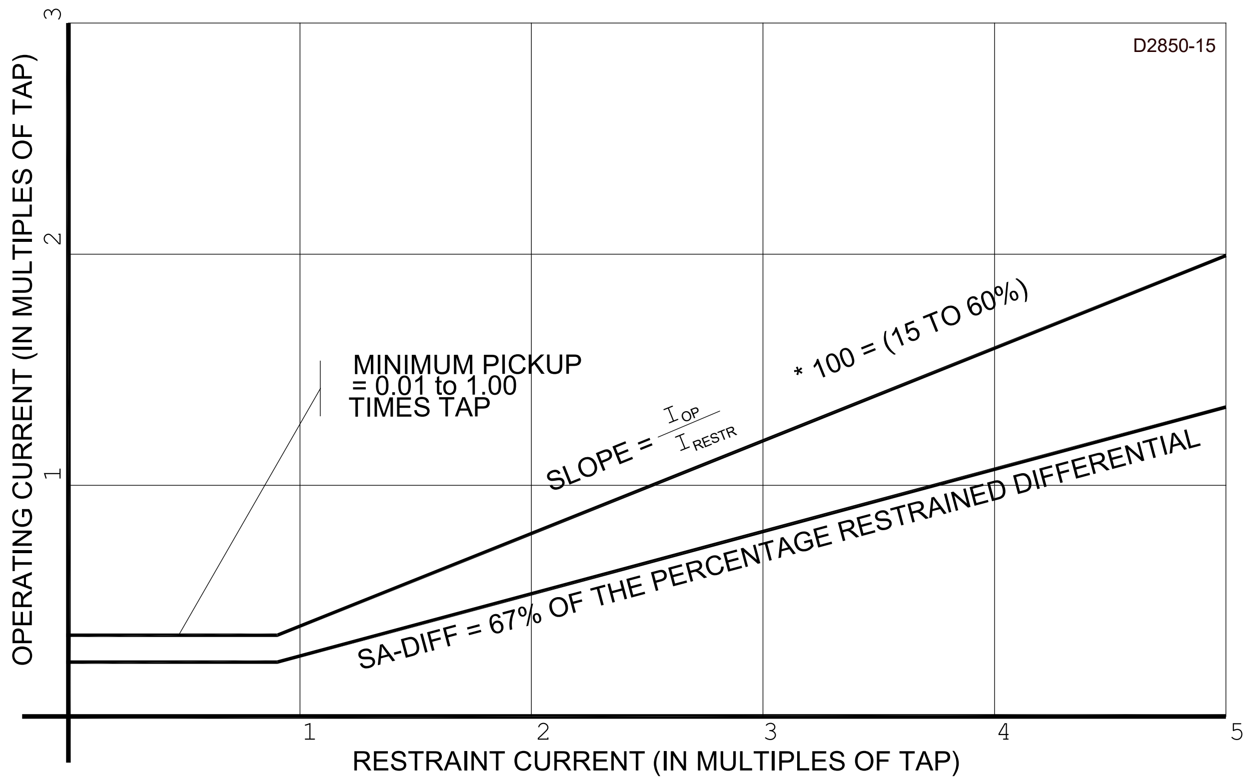

Figure 6-5. Differential Alarm Characteristics

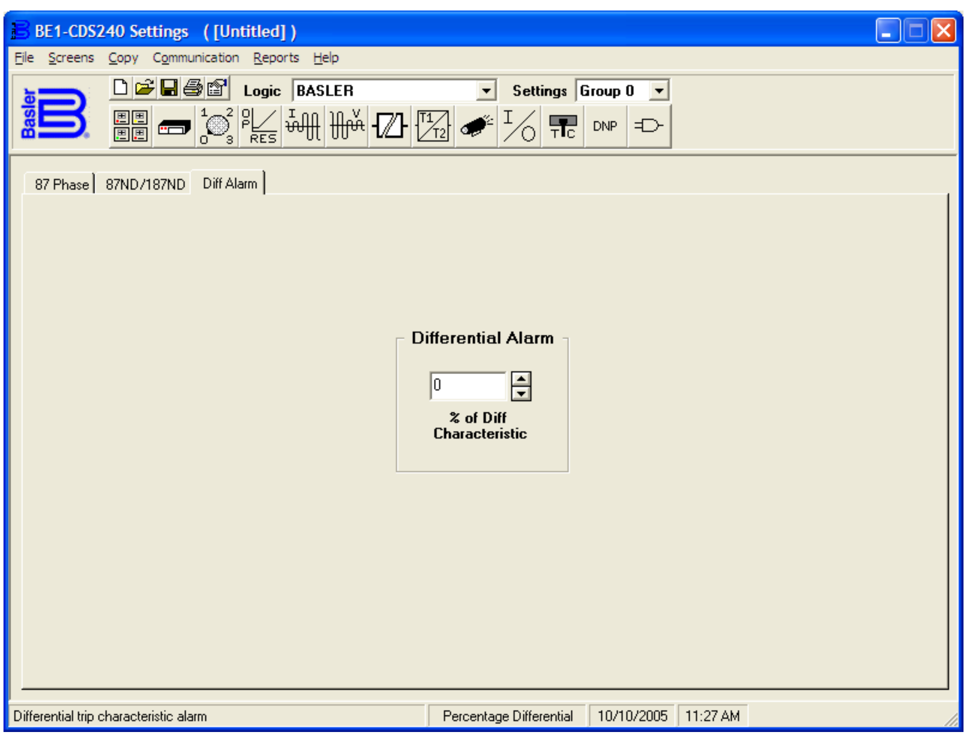

Figure 6-6. Percentage Differential Screen, Diff Alarm Tab

Transformer Monitoring Functions

The transformer monitoring functions provide monitoring and alarms for the transformer to help manage equipment inspection and maintenance expenses. Transformer monitoring functions include through-fault counter reporting and through-fault current duty monitoring. Each of these functions can be set as a programmable alarm. See the paragraphs on *Alarms Function,* later in this section for more information on the use of programmable alarms.

Number of Through Faults Monitoring Function

This function monitors the SG-TRIGGER pickup logic expression. It increments the count in the operations counter register each time that the SG-TRIGGER pickup logic expression is true and returns to false. For more information on this function and the SG-TRIGGER pickup expression, see the illustration and paragraphs later in this section on *Fault Reporting.*

Retrieving Through Fault Operation Counter Information

The current value of the through-fault operations counter register can be read from HMI Screen 4.5.1, \REPRT\XFORM\STATUS. Pressing the *Edit* key allows the user to enter a number into the register to preset it to a value if desired. Write access to the reports functional area must be gained to edit this value at the HMI. The current value of the breaker operations counter can also be read or preset from the ASCII command interface using the RT-TFCNTR (report transformer, through-fault counter) command.

The through fault counter can be monitored to give an alarm when the value exceeds a threshold. See *Transformer Alarms* in this section for more information on this feature.

Transformer Duty Monitoring

The transformer duty monitoring function accumulates the maximum current in each phase of the transformer when a through fault occurs. A through fault is defined as whenever the pickup expression set with the SG-TRIGGER command is true.

Every time the pickup expression in the SG-TRIGGER command is true, the transformer duty monitoring function updates two sets of registers for each phase of the transformer. (Only the CT selected by the transformer duty monitoring function (ST-DUTY) is monitored.) In the accumulated `I*t` Duty registers, the function adds the maximum measured current in primary-ampere seconds. In the accumulated `I2*t` Duty registers, the function adds the maximum measured current squared in primary-ampere seconds. The `t` is calculated from the time the pickup expression is TRUE. The user selects which of the six sets of duty registers are reported and monitored by the function when setting up the mode setting in ST-DUTY.

The value in each set of duty registers is calculated and stored in primary ampere seconds or primary-amperes squared seconds as appropriate. This value is reported, however, as a percent of maximum. The user sets the value that the relay will use for 100% duty (DMAX). The value set for maximum duty is used directly for reporting the accumulated `I*t` Duty registers or `I2*t` Duty registers.

When testing the relay by injecting currents into the relay, the values in the duty registers should be read and recorded prior to the start of testing. Once testing is complete and the relay is returned to service, the registers should be reset to the original pre-test values. A block accumulation logic input may be used when testing so that simulated transformer duty is not added to the duty registers. The BLKTXFMR logic function is an OR logic term (e.g., IN1 or VO7) which blocks the transformer monitoring logic when TRUE (1). BLKTXFMR may be set to zero to disable blocking. When transformer monitoring is blocked (logic expression is equal to 1), transformer through faults are not counted or accumulated. It should be noted that even though a BESTlogic logic expression is used to make this setting, this setting is not included in the section on BESTlogic settings.

Setting the Transformer Duty Monitoring Function

The transformer monitoring function can be set from BESTCOMS (Figure 6-7). Pull down the *Screens* menu and select *Reporting and Alarms.* Select the *Transformer Monitoring* tab. Alternately, settings can be made using the ASCII command ST-DUTY (setting transformer, duty) command or the HMI using Screen 6.6.1, \SETUP\XFRMR\DUTY. This function selects the transformer CT to be monitored that also affects the transformer alarm function (SA-TX). Table 6-8 lists the settings for the transformer duty monitoring function.

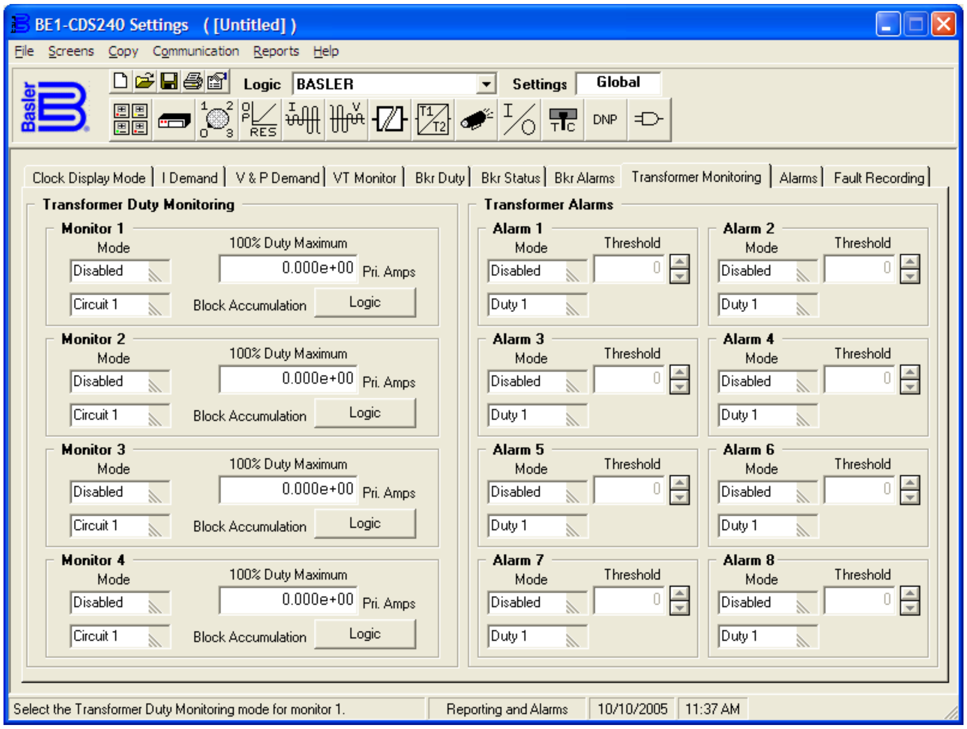

Figure 6-7. Reporting and Alarms Screen, Transformer Monitoring Tab

Table 6-8. Transformer Duty Monitoring Settings

Setting	Range/Purpose		Default
Mode	0 =	Disabled	0
	1 =	Transformer monitoring enabled with duty calculated as $\sum I*t$	
	2 =	Transformer monitoring enabled with duty calculated as $\sum I^2*t$	
	t =	Fault clearing time	
DMAX	Range = 0 to 4.2e+7; Increment = 1; Measured in primary amperes		0.000e+00
Circuit #	1 = Ckt # 1, 2 = Ckt # 2, 3 = Ckt # 3, 4 = Ckt #4, 5 = Ckt # 5, 6 = Ckt #6		1
Block Logic	Logic expression that blocks transformer duty accumulation when TRUE. (This parameter cannot be set through the HMI.)		0

Retrieving Transformer Duty Information

The values currently stored in the accumulated transformer duty registers can be read from HMI Screen 4.5.1, \REPRT\XFORM\DETAILS. Pressing the *Edit* key allows the user to enter a number into the register to preset to a previous value. Write access to the reports functional area is required to edit this value. These values can also be read and set through the ASCII command interface using the RT-DUTY (report transformer, duty) command. It should be noted that when reading and writing to these registers, only the set of registers that is selected to be monitored by the mode setting (accumulated `I*t` or `I2*t`) and the CT setting (CT 1 - 6) is affected. The other set of registers is ignored.

The transformer duty registers can be monitored to give an alarm when the value exceeds a threshold. See *Transformer Alarms,* in this section for more information on this feature.

Transformer Alarms

The programmable alarms function includes three alarm points for checking transformer monitoring functions. Each of these alarm points can be programmed to monitor either of the two transformer monitoring functions (through-fault counter or through-fault duty). That is, you may program an alarm threshold (limit) to monitor each function. Alternately, you may program three different alarm thresholds to monitor one of the monitored functions. The transformer alarms may be programmed using BESTCOMS (Figure 6-7). Pull down the *Screens* menu and select *Reporting and Alarms.* Select the *Transformer*

Monitoring tab. Alternately, settings can be made using the ASCII command SA-TX or using the HMI Screen 6.6.2, \SETUP\XFORM\ALARMS. When [n] in SA-TX[n] is equal to 1, alarm point number one is selected. Likewise for alarm points 2 and 3. When <mode> is set to 0, the transformer alarm function is disabled. When <mode> is set to 1, the transformer alarm function is set for percent duty and the alarm limit threshold is set for a percentage of DMAX which is programmed using the ST-DUTY command. The transformer CT to be monitored is also programmed using the ST-DUTY command. When <mode> is set to 2, the transformer alarm function is set for through faults and the alarm limit threshold is set for the through-fault counter value which when reached would cause an alarm. The transformer CT to be monitored is programmed using the ST-DUTY command. Table 6-9 lists the settings for the transformer programmable alarms function.

Table 6-9. Transformer Programmable Alarms Settings

Setting	Range/Purpose		Default
Mode	0 =	Disabled	0
	1 =	Transformer alarm function enabled and set for percent duty.	
	2 =	Transformer alarm function enabled and set for through faults.	
Alarm Limit (in mode 1)	0 to 100%; Increment = 1; Measured in % of DMAX		0
Alarm Limit (in mode 2)	0 to 99999; Increment = 1; Number of through faults		0

VT Monitor Functions

The VT Monitor reporting function allows the user to enable or disable *Fuse Loss Block Logic*. The *Block Voltage Control* box can be checked (enabled) or unchecked (disabled) for the 51/27 elements. Likewise, *Block Phase, Block 3V0*, and *Block V2* and each be independently checked (enabled) or unchecked (disabled) for the 27 and 59 elements. The default value for all of these logic functions is enabled.

Setting Fuse Loss Block Logic

Fuse Loss Block Logic settings can be made using BESTCOMS. Figure 6-8 illustrates the BESTCOMS screen used to select these reporting settings. To open the screen shown in Figure 6-8, select *Reporting and Alarms*, from the *Screens* pull-down menu. Then select the *VT Monitor* tab. Alternately, settings may be made using the SP-60FL ASCII command.

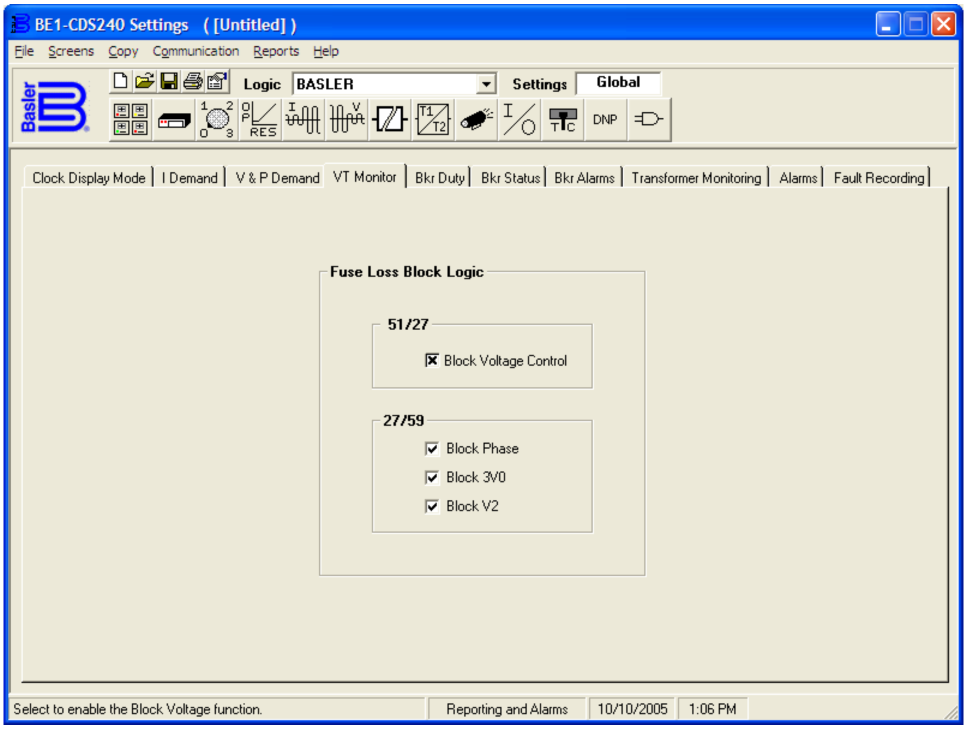

Figure 6-8. Reporting and Alarms Screen, VT Monitor Tab

Breaker Monitoring

Depending on the system scheme, one BE1-CDS240 relay can provide overcurrent protection for more than one circuit breaker. However, breaker-monitoring functions provide extensive monitoring and alarms for only a single circuit breaker. This extensive monitoring helps to manage equipment inspection and maintenance expenses. Breaker monitoring functions include breaker status and operations counter reporting, breaker fault current interruption duty monitoring, and breaker trip speed monitoring. Each of these functions can be programmed as a programmable alarm. See *Alarms Function* in this section for more information on the use of programmable alarms.

Breaker Status Reporting

The breaker status monitoring function monitors the position of the breaker for reporting purposes. It also, counts the opening strokes of the breaker and records them in the breaker operations counter register.

Setting the Breaker Status Reporting Function

Since the relay is completely programmable, it is necessary to program which logic variable is to be monitored for breaker status. This is done with BESTCOMS (Figure 6-9). Alternately, the ASCII command SB-LOGIC (setting breaker, logic) can be used. It should be noted that even though a BESTlogic logic expression is used to make this setting, this setting is not included in the section on BESTlogic settings. We include it here because it is related to breaker monitoring. See Section 7, *BESTlogic Programmable Logic,* for more information on the use of BESTlogic for programming the relay. When you program SB-LOGIC, the breaker name that you set also labels the 101 Virtual Breaker Control Switch. For more information on this switch, refer to Section 4, *Protection And Control, 101 Virtual Breaker Control Switch.*

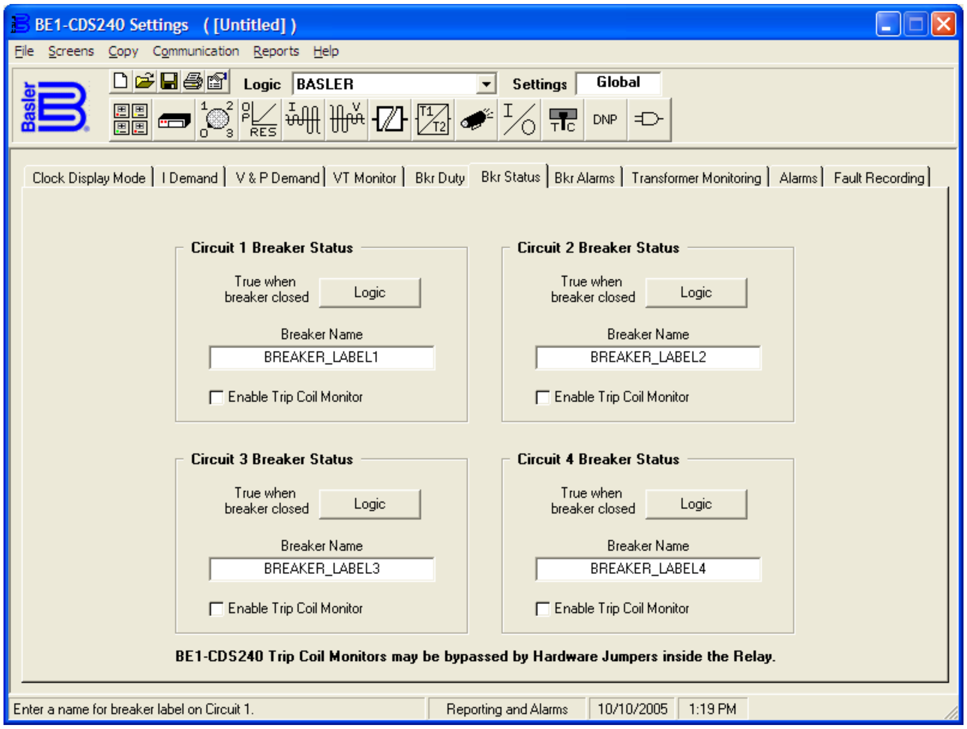

Figure 6-9. Reporting and Alarms Screen, Bkr Status Tab

Table 6-10 lists the settings for the breaker status reporting function.

Table 6-10. Breaker Status Reporting Settings

Setting	Range/Purpose	Default
Breaker Closed Logic	Logic expression that is TRUE when the breaker is closed (e.g., 52a logic)	0
Breaker Label	16 character alpha/numerical label (name)	BREAKER_LABEL

NOTE

The NOT symbol (/) is applied to the variable immediately following the symbol.

Retrieving Breaker Status and Operation Counter Information

The current breaker status can be read from HMI Screen 1.4.5, \STAT\OPER\BKR and from the ASCII command interface using the RG-STAT or RG-BREAKER command. The paragraphs on *General Status Reporting* in this section provide more information on this command.
The current value of the breaker operations counter register can be read from HMI Screen 4.3.1, \REPRT\BRPTS\STATUS. Pressing the *Edit* key allows the user to enter a number into the register to preset it to a value to match an existing mechanical cyclometer on the breaker mechanism. Write access to the reports functional area must be gained to edit this value at the HMI. The current value of the breaker operations counter can also be read or preset from the ASCII command interface using the RB-OPCNTR (report breaker, operations counter) command.

The breaker operations counter can be monitored to give an alarm when the value exceeds a threshold. See *Breaker Alarms* in this section for more information on this feature.

Breaker Duty Monitoring

When the breaker opens, the N^{th} power of the current interrupted in each pole of the circuit breaker is accumulated by the breaker duty monitor. Breaker opening is defined by the breaker status monitoring function (SB-LOGIC). Figure 6-10 illustrates breaker status (SB-LOGIC) during a fault and protective trip. Table 6-11 serves as a legend for the call-outs of Figure 6-10.

The relay sums the N^{th} power of the currents that are interrupted and will set the breaker duty alarm when the sum exceeds the N^{th} power of the maximum breaker duty (D_{max}) setting. The user must enter a value for N and a value for D_{max}.

To determine N and D_{max}, the user needs to find two measurements of allowable breaker wear. These levels would typically be the maximum number of operations at load level currents and the maximum number of operations at maximum fault rating.

Point 1; # Ops @ $I_{max\ load}$

Point 2; # Ops @ $I_{max\ fault}$

To determine the breaker wear exponent N, using the above data points as an example, apply this equation:

$$N = \frac{\log\left(\frac{\#\,Ops@I_{max\ load}}{\#\,Ops@I_{max\ fault}}\right)}{\log\left(\frac{I_{max\ fault}}{I_{max\ load}}\right)}$$

N can be any value from 1 to 3.

Using values for $I_{max\ load}$ and $I_{max\ fault}$ in primary amperes (the relay multiplies by the CTR before doing calculations), the value for maximum breaker duty, D_{max}, is calculated from either of these two equations:

$$D_{max} = \left((I_{max\ load})^{N} \bullet \#\,Ops@I_{max\ load}\right)^{1/N}$$

$$D_{max} = \left((I_{max\ fault})^{N} \bullet \#\,Ops@I_{max\ fault}\right)^{1/N}$$

Both of the last two equations should yield the same value for D_{max}.

When testing the relay by injecting currents into the relay, the values in the duty registers should be read and recorded prior to the start of testing. Once testing is complete and the relay is returned to service, the registers should be reset to the original pre-test values. A block accumulation logic input may be used when testing so that simulated breaker duty is not added to the duty registers. The BLKBKR logic function is an OR logic term (e.g., IN1 or VO7) which blocks the breaker monitoring logic when TRUE (1). BLKBKR is set to zero to disable blocking. When breaker monitoring is blocked (logic expression equals 1), breaker duty is not accumulated.

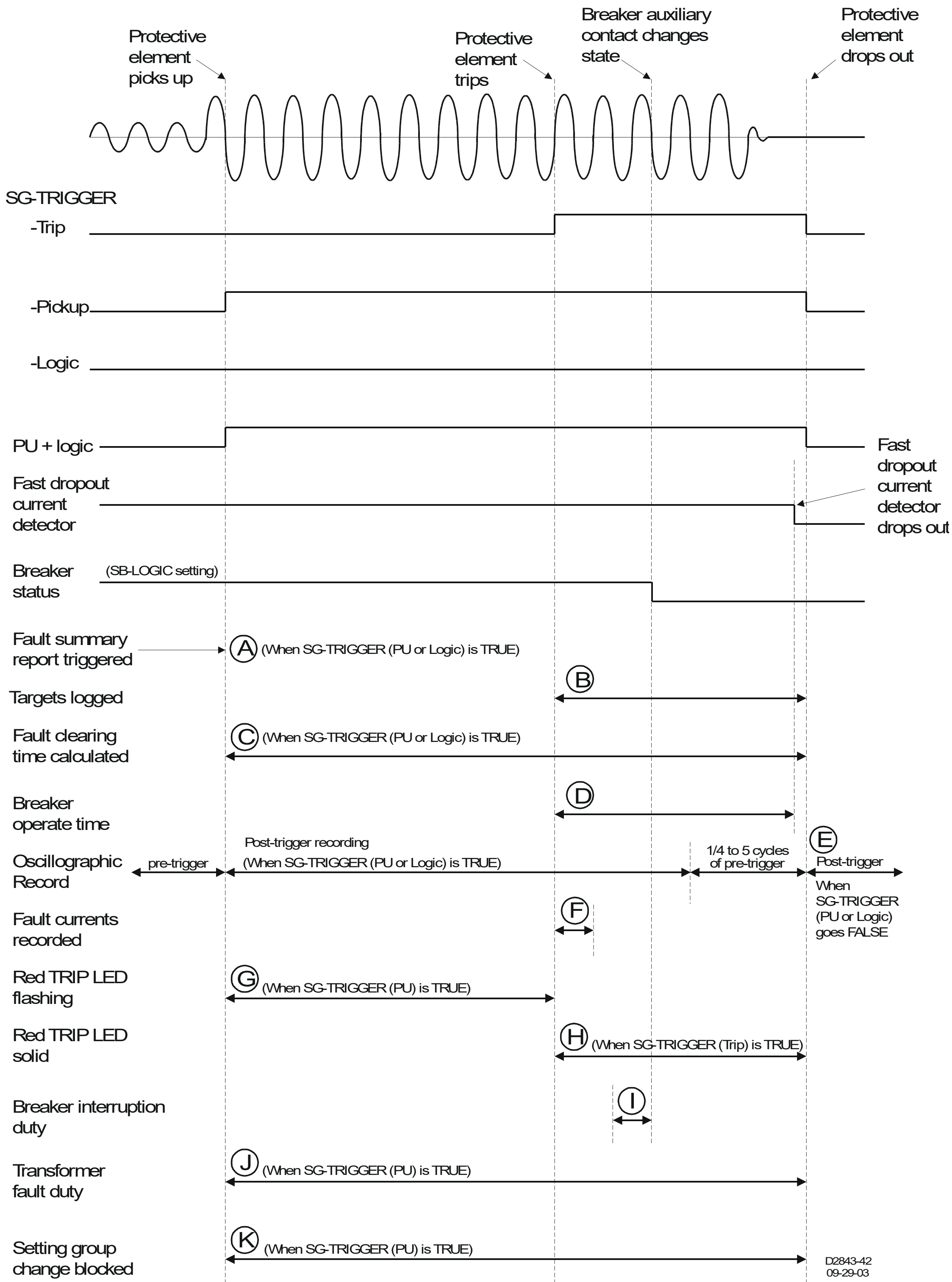

Figure 6-10. Protective Fault Analysis

Table 6-11. Legend for Figure 6-10

Locator	Description
A	A fault summary report and an oscillograph record are triggered when either the SG-TRIGGER pickup or logic expression becomes TRUE. These reports are also triggered through the HMI interface by issuing the ASCII command RF=TRIG.
B	During the time that the SG-TRIGGER trip expression is TRUE, targets are logged from each of the protective functions that reach a trip state. If a protective function is not being used for tripping purposes, the associated target function can be disabled through the SG-TARG setting.
C	Fault clearing time is calculated as the duration of the time that either the SG-TRIGGER pickup or logic expression is TRUE.
D	Breaker operate time is calculated as the time from when the SG-TRIGGER trip expression becomes TRUE until the fast-dropout current detector senses that the breaker has successfully interrupted the current in all poles of the breaker.
E	A second oscillographic record is triggered to record the end of the fault if the SG-TRIGGER pickup or logic trigger expression remains in the TRUE state at the time that the first oscillographic record ends. This second record will have from ¼ to five cycles of pre-trigger data depending upon when both the SG-TRIGGER pickup and logic expressions become FALSE.
F	Recorded fault current and voltage magnitudes are displayed on the *Target* screen of the optional HMI. The same information including phase voltage frequency, auxiliary voltage frequency, and voltage and current angles are recorded in the Fault Summary Report. The magnitude and angle results are based on data captured two cycles after the trip output goes TRUE. If the SG_TRIGGER TRIP expression does not become TRUE, the fault was cleared by a downstream device. For these pickup-only events, fault current, voltage and angle recorded in the fault summary report will be for the power system cycle ending two cycles prior to the end of the fault record. This is also the case if the fault record was triggered through the ASCII command interface by the RF=TRIG command.
G	During the time that the SG-TRIGGER pickup expression is TRUE, the red Trip LED on the front panel flashes indicating that the relay is picked up.
H	During the time the SG-TRIGGER trip expression is TRUE, the red Trip LED on the front panel lights steadily indicating that the relay is in a tripped state. If targets have been logged for the fault, the Trip LED is sealed in until the targets have been reset.
I	Breaker operations and interruption duty functions are driven by the breaker status function. The operations counter is incremented on breaker opening. The magnitudes of the currents that are used for accumulating breaker duty are recorded for the power system cycle ending when the breaker status changes state. Thus, breaker duty is accumulated every time that the breaker opens even if it is not opening under fault.
J	The transformer through fault counter is incremented each time that the SG-TRIGGER pickup expression returns to FALSE. The time used in calculating It or I^2t for transformer through fault duty monitoring is the time that the SG-TRIGGER pickup expression in TRUE.
K	Setting group changes are blocked when the SG-TRIGGER pickup expression is TRUE to prevent protective functions from being reinitialized with new operating parameters while a fault is occurring.

Setting the Breaker Duty Monitoring Function

Breaker Duty Monitoring settings are made using BESTCOMS. Figure 6-11 illustrates the BESTCOMS screen used to select settings for the Breaker Duty Monitoring function for Circuits 1 - 4. To open the screen, select *Reporting and Alarms* from the *Screens* pull-down menu. Then select the *Bkr Duty* tab. Alternately, settings may be made using the SB-DUTY ASCII command.

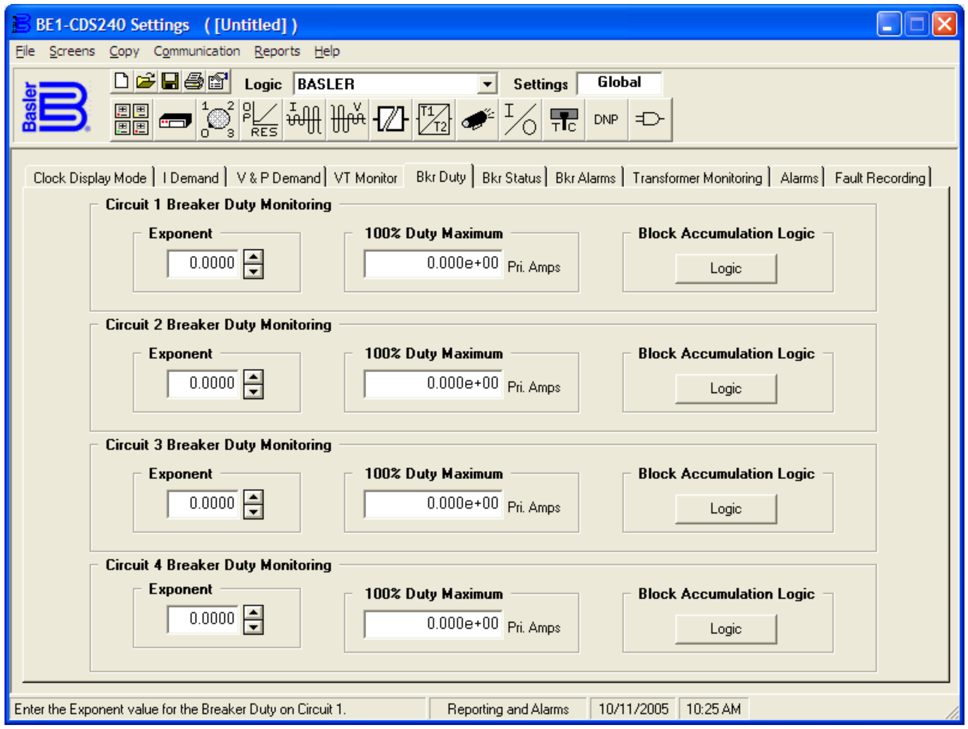

Figure 6-11. Reporting and Alarms Screen, Bkr Duty Tab

To connect the functions *BLOCK* logic input. Select the *Logic* button in the *Block Accumulation Logic* box. The *BESTlogic Function Element* screen for *Breaker Duty Monitoring* will appear. See Figure 6-12. Then select the *BLOCK* input button. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, See Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

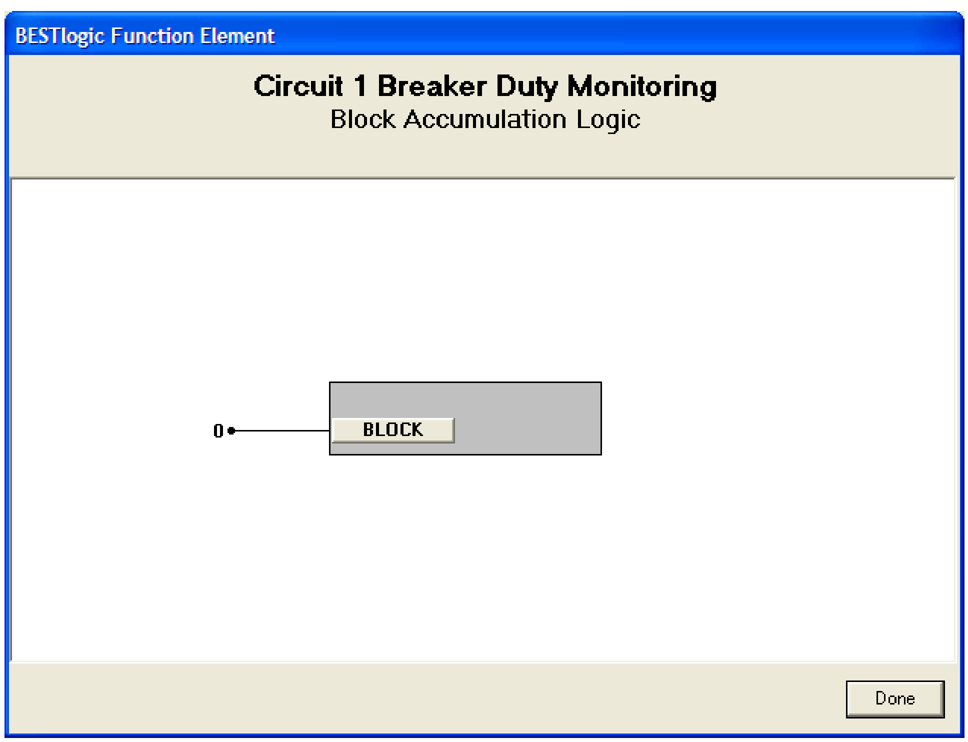

Figure 6-12. BESTlogic Function Element Screen, Circuit 1 Breaker Duty Monitoring, Block

Table 6-12 summarizes the Breaker Duty Monitoring settings.

Table 6-12. Breaker Duty Monitoring Settings

Setting	Range/Purpose	Default
Exponent	1 to 3 in increments of 0.0001 (0 = breaker monitoring disabled)	0.0000
100% Duty Maximum	Maximum duty the breaker contacts can withstand before they need service. DMAX is programmed in primary amperes using exponential floating-point format. The maximum DMAX setting is 4.2e+7.	0.000e+00
Block	Logic expression. Logic OR term which blocks the breaker duty accumulation when TRUE (1).	0

Example 1. Make the following settings to your Breaker Duty Monitoring Settings. Refer to Figures 6-11 and 6-12.

Exponent: 0
100% Duty Maximum: 0.000e+00
Block: 0

Retrieving Breaker Duty Information

The values currently stored in the accumulated interruption duty registers can be read from HMI Screen 4.3.1, \REPRT\BRPTS\STATUS. Pressing the *Edit* key allows the user to enter a number into the register to preset to a previous value. Write access to the reports functional area is required to edit this value. These values can also be read and set through the ASCII command interface using the RB-DUTY (report breaker, duty) command. It should be noted that when reading and writing to these registers, only the set of registers selected to be monitored by the exponent setting and the CT setting (CT 1 - 4) is affected. The other set of registers is ignored.

The breaker duty registers can be monitored to give an alarm when the value exceeds a threshold. See the paragraphs on *Breaker Alarms* in this section for more information on this feature.

Breaker Clearing Time Monitoring

The breaker clearing time monitoring function monitors the time from when a trip output occurs (as defined by the TRIP logic expression) to when the fast dropout current detector detects that current is zero in all three poles of the breaker (see Locator D for Figure 6-10). The monitored breaker is determined by the CT circuit parameters set in the SB-DUTY function. The output of the breaker clearing time function is reported as a line in the fault summary reports. It is important to note that if the TRIP logic expression trips an 86 function and the 86 function trips the breaker, the measured clearing time will not be accurate. To ensure accuracy, the TRIP logic expression must directly trip the monitored breaker. See the paragraphs on *Fault Reporting* in this section for more information on the TRIP logic expression and the Fault Summary reports.

The breaker clearing time can be monitored to give an alarm when the value exceeds a threshold. See the following paragraphs on *Breaker Alarms* for more information on this feature.

Breaker Alarms

Twelve alarm points are included in the programmable alarms for checking breaker monitoring functions. Each alarm point can be programmed to monitor any of the three breaker monitoring functions, operations counter, interruption duty, or clearing time. Circuit 1, 2, 3, or 4 can be chosen for each of the 12 alarms. An alarm threshold can be programmed to monitor each function. Alternately, three different thresholds can be programmed to monitor one of the monitored functions. *Breaker Alarms* settings are made using BESTCOMS. Figure 6-13 illustrates the BESTCOMS screen used to select settings for the Breaker Alarms function. Alternately, settings may be made using the SA-BKR ASCII command or the HMI using Screen 6.5.2, \SETUP\BKR\ALARM.

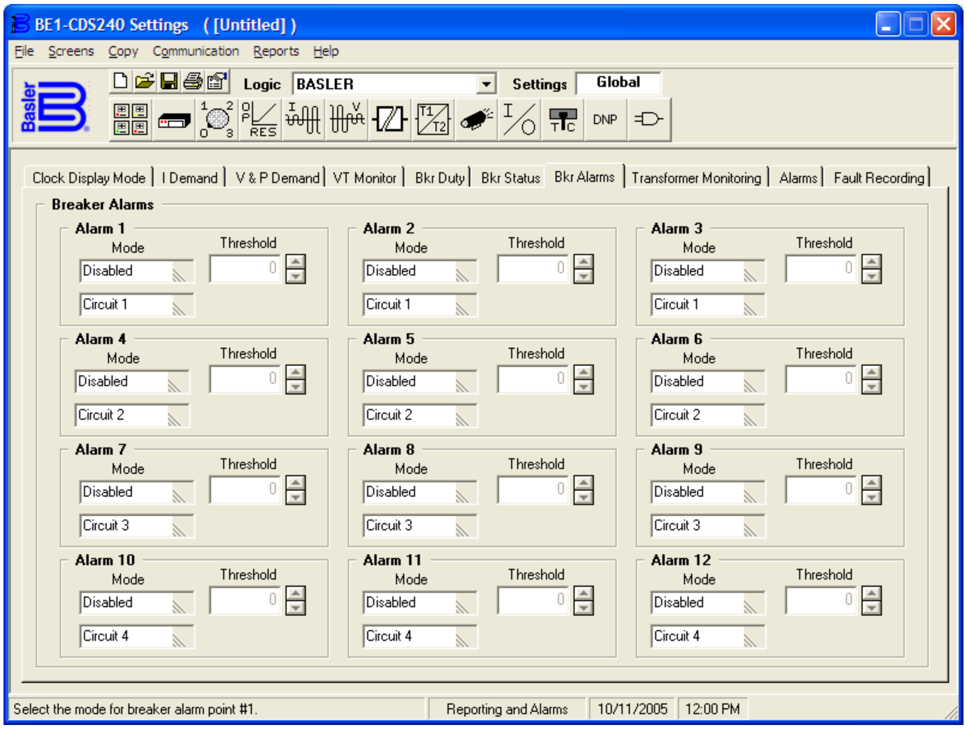

Figure 6-13. Reporting and Alarms Screen, Bkr Alarms Tab

Table 6-13 summarizes the Breaker Alarms settings.

Table 6-13. Breaker Alarms Settings

Setting		Range/Purpose		Default
Mode		0 = Disabled 1 = Percent Duty	2 = Number of Operations 3 = Breaker Clearing Time	0
Threshold	Point 1 Mode	0 to 100 in percent, increment = 0.01		0
	Point 2 Mode	0 to 99,999 in operations, increment = 1		0
	Point 3 Mode	0, 20 to 1,000 in milliseconds (m), seconds (s), or cycles (c). Setting is reported in milliseconds if less than 1 seconds.		0

Trip Circuit Monitor

The trip circuit voltage and continuity monitoring function monitors the trip circuit for voltage and continuity. If a breaker is closed or the 86 Lockout relay is reset and no voltage is detected across the trip contacts, then either the fuse supplying the circuit is blown or there is a loss of continuity in the trip coil circuit.

The trip circuit monitor function obtains the breaker status from a programmable setting, which is set using the <Trip Coil Enable> parameter in the SB-LOGIC command. The detector circuit used by the trip circuit monitoring function is internally connected in parallel with Contact Outputs 7-10. The monitor circuits draw less than two milliamperes of current through the trip coil when the breaker is closed. If this current flow presents a problem for the application, the monitor circuits can be physically disconnected by

Connectors P5, P6, P7, and P8. Figure 6-14 shows the trip circuit monitor logic.

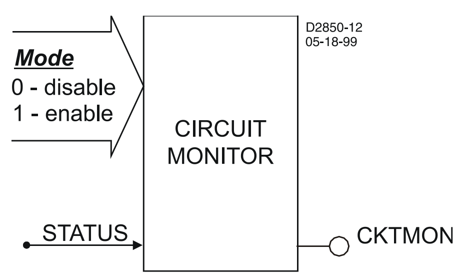

Figure 6-14. Trip Circuit Monitor Logic

If the relay detects that the breaker is closed and no voltage is sensed across the terminals of the open output contact after the appropriate coordination time delay (approximately 500 milliseconds), the relay sets an alarm bit in the programmable alarms function and sets the CKTMON BESTlogic logic variable to TRUE.

Figure 6-15 shows a typical connection diagram for the circuit monitor. Also, see Section 8, *Application, Application Tips,* for instructions on how to program a close-circuit monitoring function in BESTlogic. In this example, OUT7 is tripping the lockout relay (86T) and IN3 is monitoring the lockout relay status.

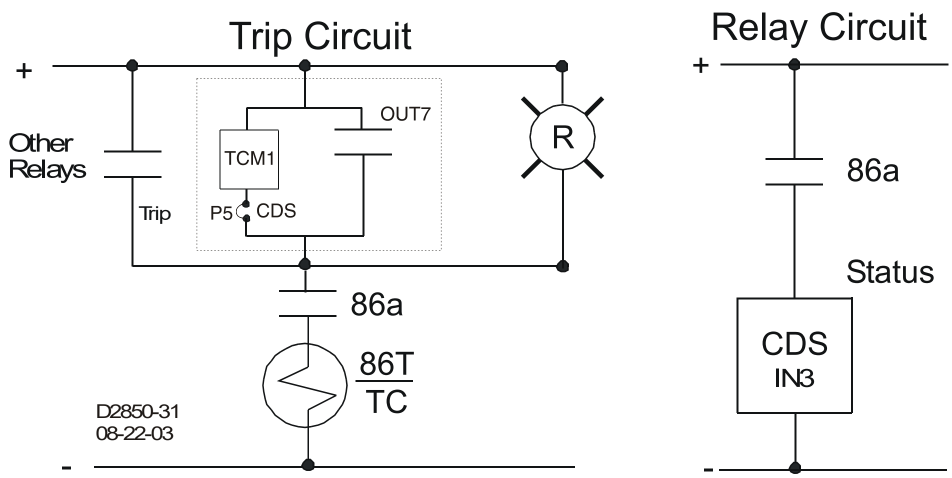

Figure 6-15. Trip Circuit Voltage and Continuity Monitor

CAUTION

Applications that place other device inputs in parallel with the breaker trip coil may not perform as desired when the trip coil monitor is active. The connection of other devices in parallel with the trip coil causes a voltage divider to occur when the breaker or trip circuit is open. (Figure 6-16 shows a schematic representation of the equivalent circuit.) This may cause false tripping of the other devices and prevent the BE1-CDS240 trip circuit monitor from reliably detecting an open circuit. If this situation exists, the trip coil monitor can be removed from the circuit. Refer to Section 12, *Installation, Trip Coil Monitor (TCM) Jumpers,* for complete instructions.

The circuit monitor sensing element has the same rating as the power supply voltage. If the trip circuit voltage is significantly greater than the power supply voltage (for example, when using a capacitor trip device), the trip circuit monitor circuits should be disabled.

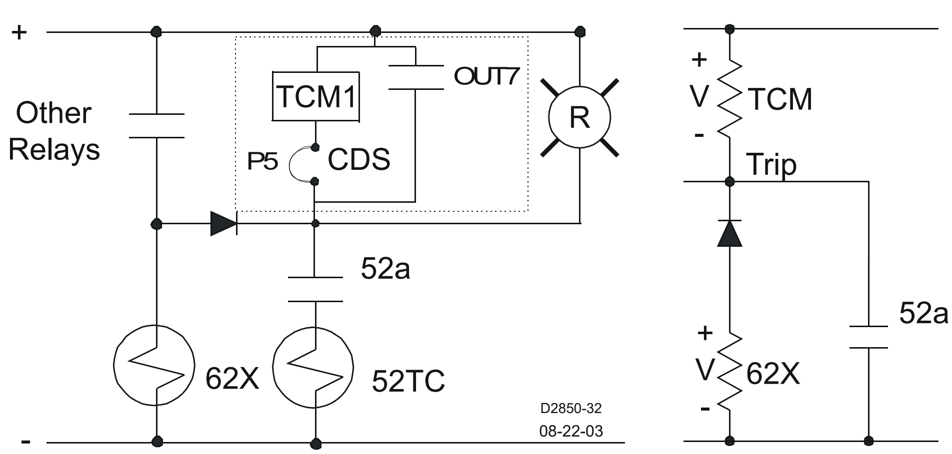

Figure 6-16. TCM with Other Devices

In Figure 6-16, a 62x auxiliary relay is shown. In this case, the impedance of the 62x coil is small compared to the impedance of the TCM circuit so the TCM is always at logic 1. This prevents the TCM logic from working, even if the trip coil is open. Normally, when redundant systems are used, each relay system is on an individual circuit and the sensing input for each relay system is isolated from the tripping circuit.

Setting the Trip Coil Monitor Function

The TCM function can be programmed from the ASCII command interface using the SB-LOGIC (set breaker logic) command. For more information on setting the trip coil monitor, refer to *Setting the Breaker Status Reporting Function* earlier in this section.

Fault Reporting

Fault Reporting Expressions and Settings

The fault reporting function records and reports information about faults that have been detected by the relay. The BE1-CDS240 provides many fault reporting features. These features include Fault Summary Reports, Sequence of Events Recorder Reports, Oscillographic Records, and Targets.

Logic expressions are used to define the three conditions for fault reporting. These conditions are Trip, Pickup, and Logic trigger. Figure 6-10 and Table 6-11 illustrate how each of these logic expressions is used by the various relay functions. Note that even though BESTlogic expressions are used to define these conditions, these expressions are not included here. Section 7, *BESTlogic Programmable Logic*, provides information about using BESTlogic to program the relay.

Trip

Trip expressions are used by the fault reporting function to start logging targets for an event and to record fault current magnitudes at the time of trip. The trip expression is used to illuminate the Trip LED on the HMI. The Trip LED will turn on and remain on as long as the trip expression is true. The Trip LED will remain on (or “sealed-in”) after the trip expression becomes false if targets are associated with the trip. The breaker monitoring function uses the trip expression to start counting the breaker operate time.

Pickup

Pickup expressions are used by the fault reporting function to time-stamp the fault summary record, time the length of the fault from pickup to dropout (fault clearing time), and to control the recording of oscillographic data. The pickup expression is used to flash, on and off, the Trip LED on the HMI. The Trip LED will continue to flash on and off as long as the pickup expression is true and the trip expression is not true. A pickup expression is also used by the setting group selection function to prevent a setting group change during a fault.

Logic

Logic trigger expressions allow the fault reporting function to be triggered even though the relay in not picked up. A logic trigger expression provides an input to the fault reporting function much as the pickup expression does. This logic expression is not used by the setting group selection or the HMI.

Fault Reporting Trigger Settings

Fault reporting trigger settings are made from the *BESTlogic Function Element* screen in BESTCOMS. Figure 6-17 illustrates the BESTCOMS screen used to select BESTlogic settings for the *Fault Recording* function. To open the *BESTlogic Function Element* screen for *Fault Recording*, select *Reporting and Alarms* from the *Screens* pull-down menu. Select the *Fault Recording* tab. Then select the *Logic* button in the *Fault Recording* box in the upper left hand corner of the screen. Alternately, settings may be made using SG-TRIGGER ASCII command.

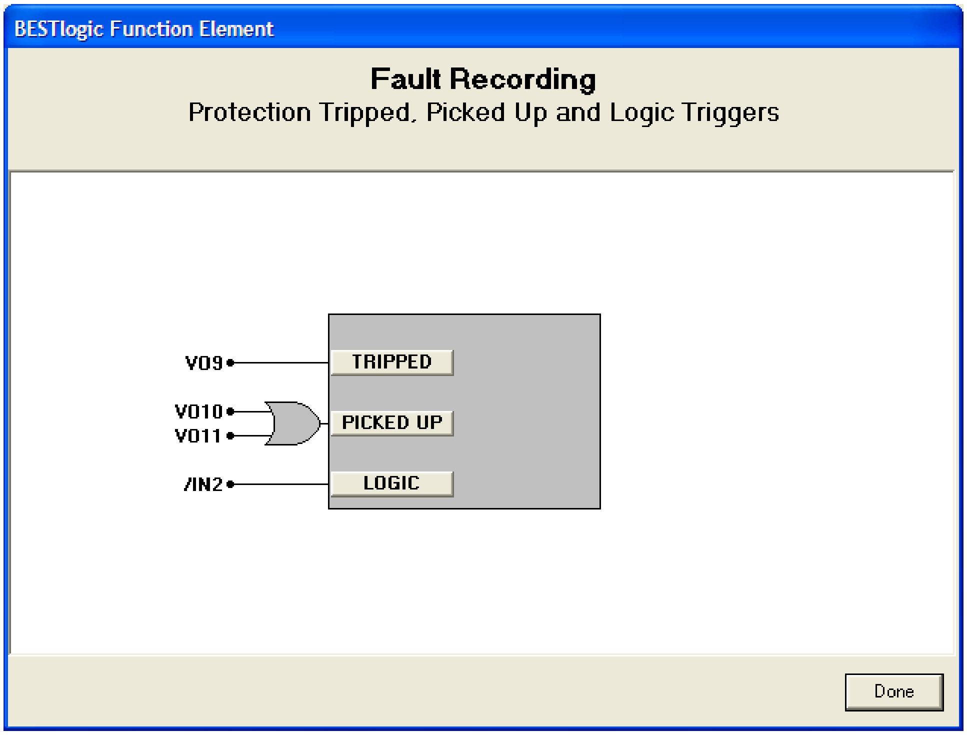

Figure 6-17. BESTlogic Function Element Screen, Fault Recording

To connect the function's inputs, select the button for the corresponding input in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited. Trigger settings for fault reports are made using the SG-TRIGGER (settings-general, trigger) command.

Table 6-14 lists the function's trigger settings.

Table 6-14. Fault Reporting Trigger Settings

Function	Purpose	Default
TRIPPED	Logic expression used to define Trip fault reporting condition. When this expression becomes TRUE (1), it triggers data recording and illuminates the Trip LED.	BFT1+BFT2+BFT3+ BFT4+VO11
PICKED UP	Logic expression used to define Pickup fault reporting condition. When this expression becomes TRUE (1), it initiates the pickup timing sequence and the Trip LED will flash on and off.	BFRT1+BFRT2+BFRT3+ BFRT4+VO12
LOGIC	Logic expression used to define the trigger for fault reporting when relay is not picked up. When this expression is TRUE (1), fault reporting is triggered.	0

Targets

Each protective function (see Table 6-15) logs target information to the fault reporting function when a trip condition occurs and the trip output of the function block becomes TRUE (refer to Figure 6-11 and Table 6-10, call-out B). Target information can be viewed and reset at the HMI and through the communication ports.

Table 6-15. Protective Functions with Targets

Name	Protective Function	Target Default
87R	Phase Differential Restrained Pickup	Enabled
87U	Phase Differential Unrestrained Pickup	Enabled
87ND, 187ND	Neutral Differential Restrained Pickup	Enabled
51P, 151P, 251P, 351P	Phase Inverse Time Overcurrent	Enabled
51N, 151N, 251N, 351N, 451N	Neutral Inverse Time Overcurrent	Enabled
51Q, 151Q, 251Q, 351Q	Negative-Sequence Inverse Time Overcurrent	Enabled
50TP, 150TP, 250TP, 350TP, 450TP, 550TP, 650TP, 750TP	Phase Instantaneous Overcurrent	Enabled
50TN, 150TN, 250TN, 350TN, 450TN	Neutral Instantaneous Overcurrent	Enabled
50TQ, 150TQ, 250TQ, 350TQ	Negative-Sequence Instantaneous Overcurrent	Enabled
50BF, 150BF, 250BF, 350BF	Breaker Failure	Enabled
24	Volts per Hertz	Enabled
27P, 127P	Phase Undervoltage	Enabled
47	Negative-Sequence Overvoltage	Enabled
59P, 159P	Phase Overvoltage	Enabled
59X	Auxiliary Overvoltage	Enabled
81, 181, 281, 381, 481, 581	Under/Over Frequency	Enabled
62, 162, 262, 362	General Purpose Logic Timer	Enabled
60FL	Fuse Loss Detection	Enabled

Target logging for a protective function can be disabled if the function is used in a supervisory or monitoring capacity. The following paragraphs describe how the relay is programmed to define which protective functions log targets.

Setting the Targets Function

Targets are enabled using the BESTCOMS screen shown in Figure 6-18. You can select which protective elements trigger a target and what type of logic condition will reset the targets. To open the screen, select *Reporting and Alarms* from the *Screens* pull-down menu. Then select the *Fault Recording* tab. Enable the targets by checking the appropriate boxes.

Alternately, targets can be enabled using the SG-TARG ASCII command. Using the SG-TARG command, you can select which protective elements trigger a target and what type of logic condition will reset the targets.

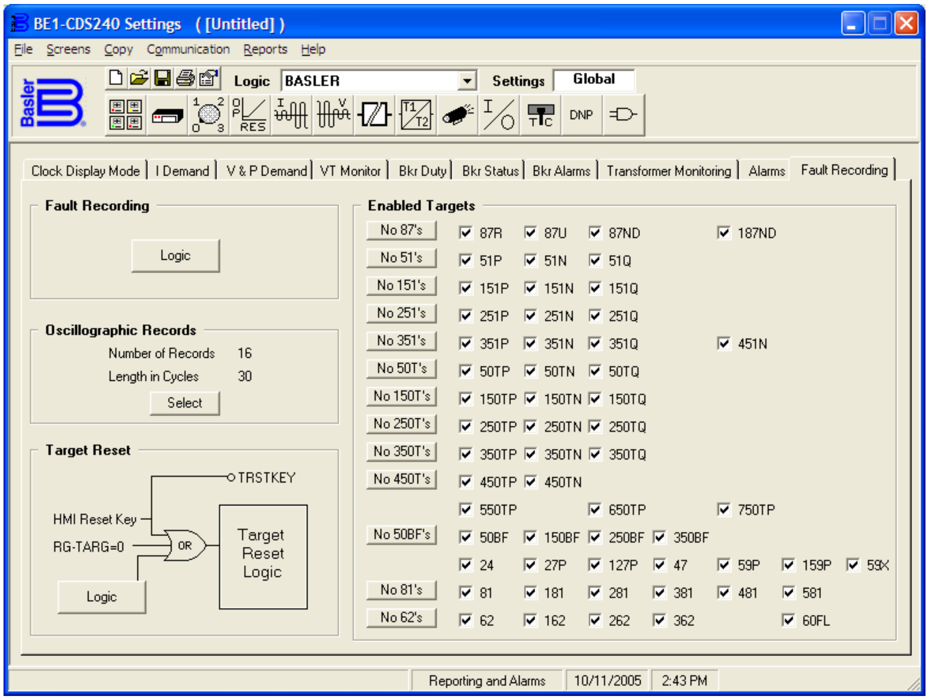

Figure 6-18. Reporting and Alarms Screen, Fault Recording Tab

Target settings are summarized in Table 6-16.

Table 6-16. Target Settings

Function	Purpose
Enabled Targets	Specifies which protective elements will trigger a target. When the programmed protective element's BESTlogic expression is TRUE (1) and the trip output is TRUE (1), a trip event is recorded in the target log.
Target Reset Logic	Logic expression that will reset the targets when TRUE.

Retrieving and Resetting Target Information

Target information can be obtained from the front panel HMI Screen 1.1.1, \STAT\TARGETS or through the ASCII command interface using the RG-TARG (report general, targets) command. The target information provided by the relay is from the most recent trip event. It is specific to an event and not cumulative. The two most recent target reports are stored in nonvolatile memory. These two reports are available from the front panel HMI Screen 4.1.1, \REPRT\FAULT\M_REC and 4.1.2, \REPRT\FAULT\PREV. Targets for previous events are recorded in the fault summary reports, which are described in detail later in this section.

When the relay trips and targets are logged for the event, the Trip LED is sealed-in on the front of the relay and menu tree branch Screen 1.1.1, \STAT\TARGETS is automatically displayed on the LCD. See Section 4, *Human Machine Interface,* for more information about the automatic display priority logic. The display scrolls between the targets and the fault current magnitudes that were recorded during the fault. See the paragraphs on *Fault Summary Reports* in this section for more information on how these fault current magnitudes are recorded. Figure 6-19 illustrates the target reset logic.

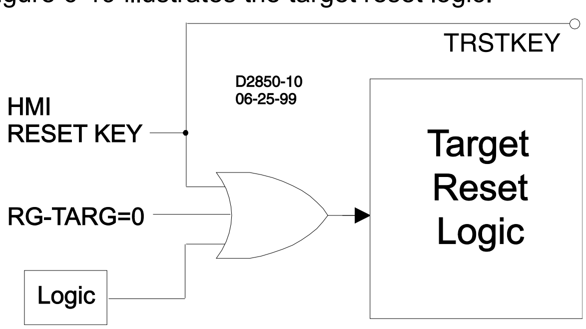

Figure 6-19. Target Reset Logic

Pressing the *Reset* key on the HMI while the *Target Screen* is displayed will clear these targets and the trip LED. No password access is required to reset targets from the front panel. After reset, the two most recent target reports are still available from the HMI menu branch 4, *Reports.* Password access is not required to reset targets at the HMI.

A logic input can be used to reset the target. Using BESTCOMS, select *Reporting and Alarms* from the *Screens* pull-down menu. Then select *Fault Recording* tab. The logic input can be connected by selecting the *Logic* button in the *Target Reset* pane. When the logic input becomes TRUE, the target is reset.

BESTCOMS can also be used to review targets and alarms after an operation by selecting *Metering* from the *Reports* pull-down menu. Using the *View* pull-down menu, select *Alarms Status* and *Targets Status.* These panes (Figure 6-20) will contain target and alarm information.

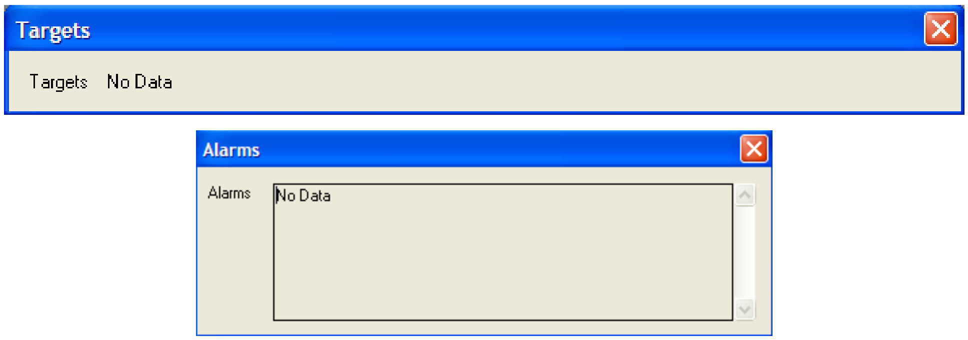

Figure 6-20. Targets and Alarms Status, BESTCOMS™ Metering Screen

Table 6-17 provides the possible targets that may be displayed on the *Metering* screen.

Table 6-17. Targets as Displayed

IEEE Device Number	Definition
24	Overexcitation
27/127 ABC	Phase Undervoltage
47	Negative Sequence Overvoltage
50/150/250/350 ABC, N, Q; 450 ABC, N; 550/650/750 ABC	Instantaneous Overcurrents
51/151/251/351 ABC, N, Q; 451 N	Time Overcurrents
50BF/150BF/250BF/350BF	Breaker Failure
59/159 ABC	Phase Overvoltage
59BUS, 59N, 59-3BUS (59X fundamental, 3V0, 3rd harmonic)	Auxiliary Overvoltage
60FL	Fuse Loss
62/162/262/362	Logic Timers
81/181/281/381/481/581	Frequency
87R ABC	Phase Differential Restrained
87U	Phase Differential Unrestrained
87ND/187ND	Neutral Differential Restrained

The RG-TARG (report general, targets) command can be used to read and reset the targets. Write access to Reports must be gained to reset the targets using the ASCII command interface.

Fault Summary Reports

The BE1-CDS240 records information about faults and creates fault summary reports. A maximum of 16 fault summary reports are stored in the relay. The two most recent reports are stored in nonvolatile memory. When a new fault summary report is generated, the relay discards the oldest of the 16 events and replaces it with a new one. Each fault summary report is assigned a sequential number (from 1 to 255) by the relay. After event number 255 has been assigned, the numbering starts over at 1.

BE1-CDS240 relays generate five different event types. They are BKR FAIL, PICKUP, TRIP, LOGIC, and RF-TRIG.

BESTCOMS™ Fault Summary Report

To view fault reports using BESTCOMS, select *Oscillography Download* from the *Reports* pull-down menu. A screen such as the one shown in Figure 6-21 will appear.

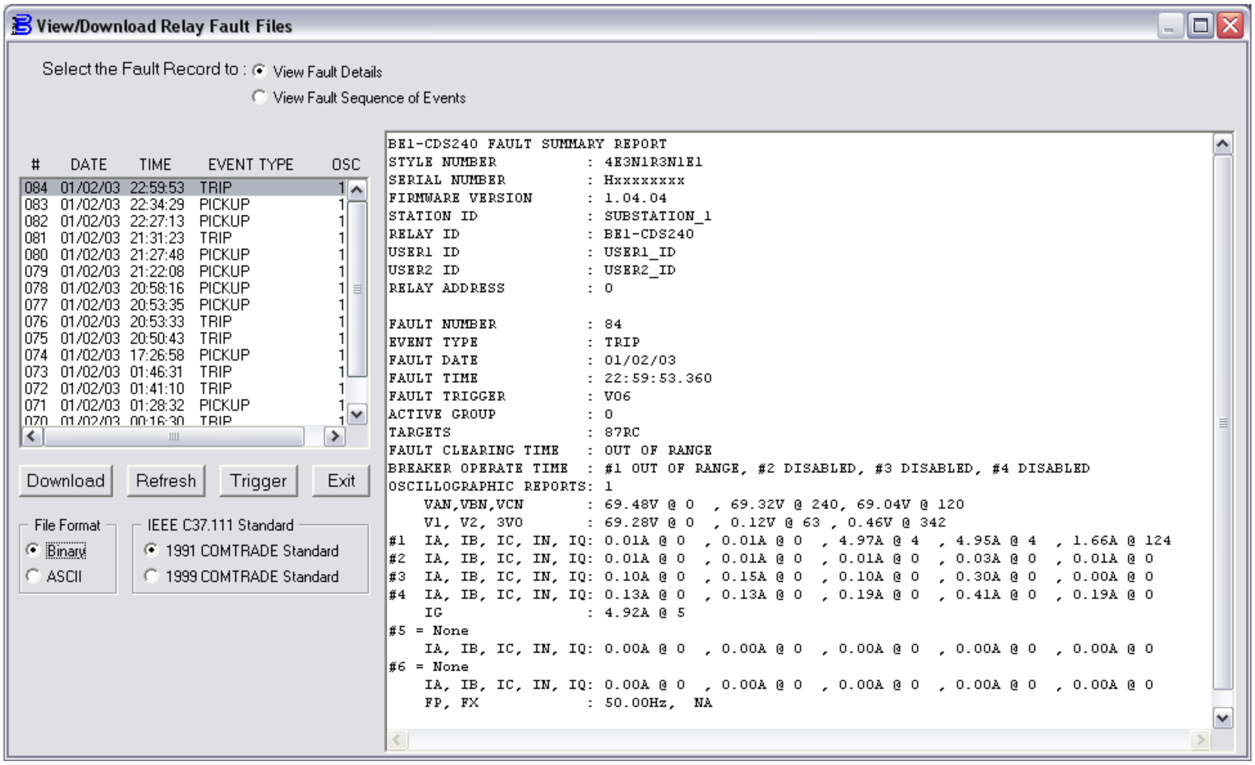

Figure 6-21. View/Download Relay Fault Files Screen

From this screen, you can *View Fault Details* or *View Fault Sequence of Events* by selecting your choice at the top of the screen and then highlighting the fault to be displayed. In Figure 6-21, fault 084 is highlighted.

The *Trigger* button allows a fault to be manually triggered. This can also be done using the SG-TRIGGER ASCII command.

The *Refresh* button is used to refresh the list of faults. The *Download* button will download the selected fault, storing it on the selected drive as either a binary or ASCII file, selected beneath the button.

Fault Summary Report Example

A fault summary report collects several items of information about a fault that can aid in determining why a fault occurred without having to sort through all of the detailed information available. The following example illustrates a typical fault summary report. Call-outs shown in the report are references to the legend of Table 6-11.

Fault Summary Report Example:

>RF-1

```
BE1-CDS240 FAULT SUMMARY REPORT
STYLE NUMBER          : 4E3N1H3N3E1
SERIAL NUMBER         : H00556743
FIRMWARE VERSION      : 1.03.00
STATION ID            : SUBSTATION_1
RELAY ID              : BE1-CDS240
USER1 ID              : USER1_ID
USER2 ID              : USER2_ID
RELAY ADDRESS         : 0

FAULT NUMBER          : 1
EVENT TYPE            : TRIP
FAULT DATE            : 09/21/06
FAULT TIME            : 14:55:12.640
FAULT TRIGGER         : VO11,VO12
ACTIVE GROUP          : 0
TARGETS               : 60FL,51A
FAULT CLEARING TIME   : 0.266 SEC
BREAKER OPERATE TIME  : #1 0.241 SEC, #2 0.241 SEC, #3 0.241 SEC, #4 0.241 SEC,
OSCILLOGRAPHIC REPORTS: 1
    VAN,VBN,VCN       : 119.1V @ 0  , 119.4V @ 120, 119.4V @ 240
    V1, V2, 3V0       : 0.26V @ 175, 119.3V @ 0  , 0.34V @ 309
#1  IA, IB, IC, IN, IQ: 1.97A @ 34 , 0.48A @ 158, 0.48A @ 277, 1.47A @ 34 , 0.97A @ 35
#2  IA, IB, IC, IN, IQ: 1.99A @ 35 , 0.49A @ 157, 0.47A @ 277, 1.51A @ 35 , 0.99A @ 35
#3  IA, IB, IC, IN, IQ: 1.98A @ 36 , 0.49A @ 156, 0.48A @ 278, 1.51A @ 36 , 0.98A @ 36
#4  IA, IB, IC, IN, IQ: 1.97A @ 34 , 0.49A @ 156, 0.47A @ 276, 1.49A @ 34 , 0.98A @ 35
    IG                : 1.50A @ 217
#5 = Ckt1 + Ckt4
    IA, IB, IC, IN, IQ: 3.94A @ 34 , 0.98A @ 157, 0.95A @ 276, 2.96A @ 34 , 1.96A @ 35
#6 = Ckt2 + Ckt3
    IA, IB, IC, IN, IQ: 3.97A @ 35 , 0.97A @ 156, 0.95A @ 277, 3.01A @ 35 , 1.97A @ 36
    FP, FX            : 60.00Hz, 61.11Hz
```

Callouts: A (report title), B (targets), C (fault clearing time), D (breaker operate time), E (oscillographic reports), F (#1–#6 current lines)

P0038-27

Style Number. This line reports the style number of the relay.

Serial Number. This line reports the serial number of the relay.

Firmware Version. This line reports the version of firmware that the relay holds.

Fault Date and Time. These lines report the date and time of the initial trigger of the event. This is based on either the pickup logic expression or the logic trigger expression becoming TRUE as defined by the SG-TRIGGER command. Refer to Figure 6-10 and Table 6-11, call-out A.

Station ID, Relay ID, User1 ID, and *User2 ID*. These lines report station and device identifier information as defined by the SG-ID command.

Relay Address. This line reports the communications port address that the report was requested from. The relay address number is assigned using the SG-COM command, described in Section 11, *ASCII Command Interface.*

Fault Number. This line reports the sequential number (from 1 to 255) assigned to the report by the BE1-CDS240.

Event Type. This line reports the type of event that occurred. There are five fault event categories:

- Trip: A fault was detected as defined by the pickup expression and the relay tripped to clear the fault.
- Pickup: A fault was detected as defined by the pickup expression but the relay never tripped indicating that the fault was cleared by another device.
- Logic: A fault report was recorded by the logic trigger expression but no fault was detected as defined by the pickup expression.
- Breaker Failure: A fault was detected as defined by the pickup expression and the breaker failure trip became TRUE before the fault was cleared.

- RF=TRIG: A fault report was recorded by the ASCII command interface.

Fault Date and Time. These lines report the date and time of the initial trigger of the fault. This is based on either the pickup logic expression or the logic trigger expression becoming TRUE as defined by the SG-TRIGGER command.

Fault Trigger. This line reports the logic variables in the pickup or logic trigger expressions that became TRUE to trigger the recording of the event.

Active Group. This line reports what setting group was active at the time that the fault occurred.

Targets. This line reports the targets that were logged to the fault report between the time that the trip expression became TRUE until the end of the fault. Refer to Figure 6-10 and Table 6-11, call-out B.

Fault Clearing Time. This line reports the time from when the relay detected the fault until the relay detected that the fault had cleared. Refer to Figure 6-10 and Table 6-11, call-out C.

If the fault report was triggered by the RF-TRIG command, the recording of the report was terminated after 60 seconds and this line is reported as N/A.

If the pickup or logic expressions stay TRUE for more than 60 seconds, an alarm bit in the programmable alarm function is set and this line is reported as N/A. In this situation, the fault reporting functions (including targets) won't operate again until the pickup and logic trigger expressions return to a FALSE state to enable another trigger.

Breaker Operate Time. This line reports the breaker trip time from the breaker monitoring and alarm function. This is the time measured from when the breaker is tripped until the fast-dropout current detector function detects that the arc has been extinguished. Refer to Figure 6-10 and Table 6-11, call-out D.

Oscillographic Reports. This line reports the number of oscillographic records that are stored in memory for this fault report. Refer to Figure 6-10 and Table 6-11, call-out E. Recording of oscillographic records is described in the *Oscillographic Records* subsection.

IA1...IA6, IB1...IB6, IC1...IC6, IN1...IN6, IQ1...IQ6, IG1, IG2. These lines report the current magnitudes and angles measured two power system cycles immediately following the trip trigger. If the fault is cleared prior to the relay tripping, the recorded fault currents are for the power system cycle two cycles prior to the end of the fault. Refer to Figure 6-10 and Table 6-11, call-out F.

VAN, VBN, VCN, V1, V2, 3V0. These lines report the voltage magnitudes and angles measured two power system cycles immediately following the trip trigger. If the fault is cleared prior to the relay tripping, the recorded fault voltages are for the power system cycle two cycles prior to the end of the fault. Refer to Figure 6-10 and Table 6-11, call-out F.

FP and FX. This line reports the frequency for the phase voltage input and auxiliary voltage input measured immediately following the trip trigger. Refer to Figure 6-10 and Table 6-11, call-out F.

Retrieving Fault Report Information from the Relay

Fault Summary Directory Report. The fault reporting function provides a directory of fault summary reports that lists the number assigned to the fault summary report along with the date and time of the fault, the event type, and the total number of oscillography records stored in memory for that event. The event number is important because it is required to retrieve information about that event from the relay. This directory report can be accessed by using the RF command.

New Faults Counter. One line of the fault summary directory report contains the new faults counter. The new faults counter tracks how many new fault reports have been recorded since the new faults counter was reset to 0. This counter provides a way to check the fault information and then reset the new faults counter. Then, the next time that the relay is checked, it's easy to determine if any fault reports have been entered. Resetting the new faults counter is achieved using the RF-NEW=0 command. Write access to Reports must be gained to reset the new faults counter through the communication ports. The new faults counter can also be viewed at HMI Screen 4.1, \REPRT\FAULT. The new faults counter cannot be reset at the HMI.

Fault Summary Reports. Individual fault summary reports can be retrieved using the RF-n command, where n represents the number assigned to the fault summary report. To obtain the most recent report, use RF-NEW. If additional detail is desired, Sequence of Events Recorder data and Oscillographic data can be obtained for the faults also. This is discussed in greater detail later in this section.

Oscillographic Records

Recording Oscillographic Records

The fault reporting function can record 480 cycles of sample data at 24 samples per cycle for current inputs $I_{A<n>}$, $I_{B<n>}$, $I_{C<n>}$ and I_G (independent ground input). Each oscillographic record length is determined by the number of partitions programmed. Table 6-18 lists the possible numbers of oscillographic records for each partition. For more information on programming partitions (record lengths), see *Oscillographic Records Settings,* later in this section. The records are formatted to IEEE Standard C37.111, *Common Format for Transient Data Exchange (COMTRADE).*

Table 6-18. Possible Oscillographic Records

Number of Records	Length in Cycles
6	80
8	60
10	48
15	32
20	24
24	20
32	15

Each time the fault reporting function starts recording a fault summary report, it freezes a three cycle pre-fault buffer and records for the length of the record. If the pickup and logic trigger expressions have not returned to false within that time, the oscillographic recording function records a second record to capture the end of the fault. The second record records one-forth cycle to five cycles of pre-trigger depending on when the second record begins. If the second record begins within five cycles of the end of the first record, then there is no gap in data between the two records. If the second record begins after five cycles, there will be a gap (some data not recorded) between the records. Refer to Figure 6-10, Legend E. In that illustration, the number of records was set to 32, which equates to 15 cycles recorded. The first record is triggered and has 3 cycles of pre-trigger data and 12 cycles of post-trigger data. The fault takes longer than 12 cycles to clear so a second record is necessary. The pickup condition drops out approximately 3.5 cycles into the second record, which is the trigger point for the second record. In this case, the second record will consist of 3.5 cycles of pre-trigger and 11.5 cycles of post-trigger data.

The oscillographic records are stored in nonvolatile memory. As additional faults are recorded, the oldest oscillographic records are overwritten.

Oscillographic Records Settings

The oscillographic records settings can be programmed through BESTCOMS. To select the number of records, select *Reporting and Alarms* from the *Screens* pull-down menu. Select the *Fault Recording* tab and click the *Select* box in the *Oscillographic Records* pane. Make your selection as shown in Figure 6-22, *Oscillographic Records Selector*. Select *Done* once the setting has been made.

The oscillographic records settings can also be made using the SG-OSC (settings general, oscillography) ASCII command. See Table 6-19 for possible settings.

Table 6-19. Oscillographic Records Settings

Range	6, 8, 10, 12, 15, 16, 20, 24, 32
Default	16

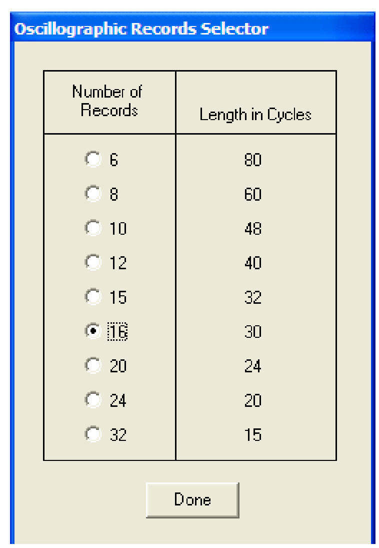

Figure 6-22. Oscillographic Records Selector

Retrieving Oscillographic Records

The fault summary directory and the fault summary reports list the numbers assigned to each fault record and the number of oscillographic records associated with each fault. Oscillographic records can be retrieved using BESTCOMS. Alternately, oscillographic records can be retrieved using the RO ASCII command.

To download oscillographic records, select *Oscillography Download* from the *Reports* pull-down menu. Highlight the record to be downloaded and select either *ASCII* or *Binary* as the file type for download. Select the *Download* button.

Assume record 003 is selected for a binary download. When the *Download* button is selected, the *Browse for Folder* screen (Figure 6-23) appears. Select a location for the file to be stored or create a *New Folder* and press *OK*. The *Fault Record Filenames* screen (Figure 6-24) will appear. Type the base filename in the first row. The rest of the filenames will respond by changing to match the base filename. Select *OK* to save the file.

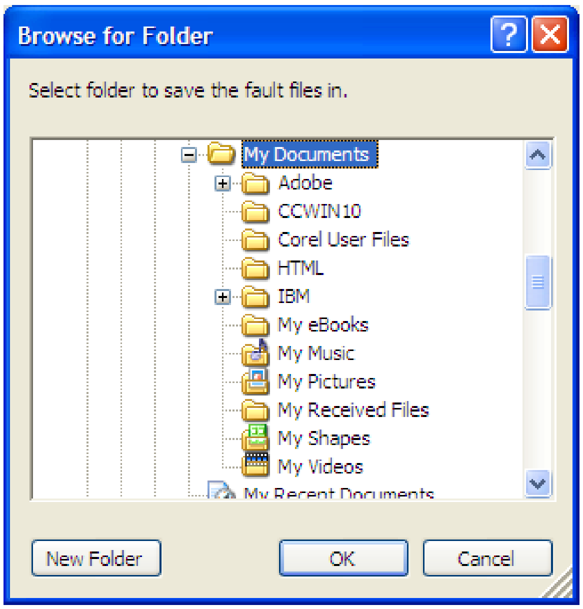

Figure 6-23. Browse for Folder Screen

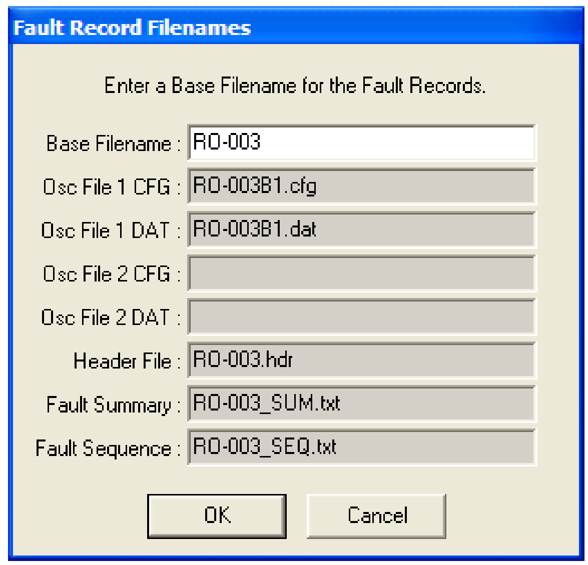

Figure 6-24. Fault Record Filenames

Only one oscillographic report file can be requested at a time. Reports are transmitted in COMTRADE format. A configuration file (CFG), a data file (DAT), or a header report (HDR) can be requested. Header files contain the fault summary report followed by all the pertinent settings that are associated with the requested fault record. These settings include the following:

- BESTlogic settings for User Programmable Logic Scheme.
- User Programmable Label settings, Global I/O settings.
- The protection setting group active during the fault.
- General protection settings.
- Fault reporting settings.
- Breaker monitoring settings.
- Alarm settings.

Files can be requested in ASCII or binary format but both file transfers use the same format. Binary file transfer is much faster and consumes less disk space. ASCII format data is human readable and can be analyzed by standard text editing software. Software for IBM compatible computers is available from Basler Electric to convert binary files to ASCII format. The download protocol may be either XMODEM or XMODEM CRC format. For ease of reference the name of the downloaded file should be the same as the command.

Sequence of Events Recorder

A sequence of events recorder (SER) report is very useful in reconstructing the exact sequence and timing of events during a power disturbance or even normal system operations. The SER tracks over 100 data points by monitoring the internal and external status of the relay. Data points are scanned every quarter-cycle. All changes of state that occur during each scan are time tagged to 1 millisecond resolution. A total of 511 records are stored in volatile memory; when the SER memory becomes full, the oldest record is replaced by the latest one acquired.

The SER monitors the following points and conditions:

- Single-state events such as resetting demands or targets, changing settings, etc.
- Programmable logic variables
- Targets
- Relay trouble alarm variables
- Programmable alarm variables
- Output contact status
- Fault reporting trigger expressions

When a monitored event occurs or a monitored variable changes state, the SER logs the time and date of the event, the event or variable name, and the state that the variable changed to. For user-programmable logic variables (contact sensing inputs, virtual switches, and virtual outputs), the user-programmed variable name and state names are logged in the SER report instead of the generic variable name and state names. For more information, refer to Section 7, *BESTlogic Programmable Logic, User Input and Output Logic Variable Names.*

Retrieving SER Information Using BESTCOMS™

To view SER information using BESTCOMS, select *Oscillography Download* from the *Reports* pull-down menu. A screen such as the one shown in Figure 6-25 will appear. Select *View Fault Sequence of Events* and highlight a fault record to view.

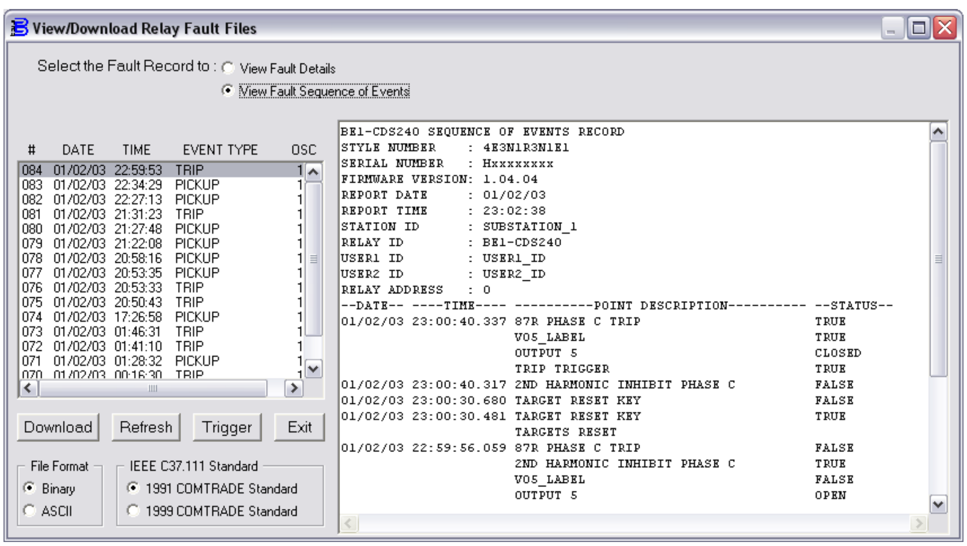

Figure 6-25. View/Download Relay Fault Files Screen

Retrieving SER Information Using ASCII Commands

SER information is retrieved through SER Directory Reports, the New Events Counter, and by obtaining specific SER Reports.

SER Directory Report

A directory report lists the number of events currently in memory and the time span that the events cover. Directory reports are accessed using the RS (report SER) command.

New Events Counter

The new events counter tracks how many new entries have been logged to the SER since the new events counter was reset to zero. After SER information is checked, the new events counter can be reset. Then, the next time that the relay is checked, it is easy to determine if there are new events that haven't been evaluated. One line of an SER directory report contains the new events counter information. The new events counter is reset by obtaining write access to *Reports* and using the RS=0 command. The new events counter can be viewed but not reset at HMI Screen 4.2.

SER Report

A directory of SER reports can be obtained using the RS (report SER) command. Six sub-reports are available through the RS command: RS-n, RS-Fn, RS-ALM, RS-I/O, RS-LGC, and RS-NEW. These sub-reports give specific types of data without confusing the user with every internal state change and event occurrence. Each sub-report is defined in the following paragraphs:

1. RS-n (report SER, number of most recent events)

   Events are retrieved for the most recent entries. Entering RS-4 would view an SER report for the last four events.

2. RS-<n> (report SER, for Fault <event number>)

   Events are retrieved for the period of time specific to a fault event. The report includes all events within the time span of the fault plus one event before and after the fault. Entering RS-F9 views a SER report associated with fault record 9.

3. RS-ALM (report SER, alarm)

   This command retrieves all alarm events that exist since the last RS=0 command was issued. (RS=0 resets the new records counter to zero.) This information can also be obtained using the RA-SER command.

4. RS-IO (report SER, input/output)

   This command reports all input and output events since the last RS=0 command was issued. (RS=0 resets the new records counter to zero.)

5. RS-LGC (report SER, logic)

   A report is retrieved for all logic events since the last RS=0 command was issued. (RS=0 resets the new records counter to zero.)

6. RS-NEW (report SER, new events since RS=0 reset)

   Events are retrieved for the period of time covered by the New Events Counter register.

The time tag associated with each event represents the time that the change was recognized. The SER update rate time is every one-forth cycle (4.167 milliseconds at 60 hertz).

Alarms Function

The alarms function monitors internal relay systems, external relay interfaces, and power system equipment. Alarm points are segregated into Relay Trouble Alarms and Programmable Alarms. Alarm point status is stored in nonvolatile memory and is retained when relay operating power is lost.

The ability to program the reporting and display of alarms along with the automatic display priority feature of the HMI gives the relay the functionality of a local and remote alarm annunciator. See Section 10, *Human-Machine Interface*, for more information on the automatic display priority logic.

Relay Trouble Alarms

All internal circuitry and software that affects how the relay functions is monitored by the continuous self-test diagnostics function of the relay trouble alarms. A detailed list of relay trouble alarms is provided in Table 6-20. If any one of these points asserts, the failsafe alarm output relay de-energizes and closes the OUTA contact, the HMI Relay Trouble LED lights, all output relays are disabled, logic variable ALMREL is set and the relay is taken offline. The relay trouble alarms function is not programmable.

If your application requires a normally closed contact that opens to indicate a relay trouble condition, use BESTlogic to program the output logic. One of the output relays with normally open contacts (OUT1 through OUT6) can be programmed to be held closed. For example, to open OUT5 for indication of relay trouble, set the VO5 logic expression at /0 (SL-VO5=/0). A not zero setting is equal to logic 1. When the relay is fully functional, the OUT5 output contact is closed. Since all output relays are disabled when a relay trouble alarm exists, OUT5 opens when relay trouble occurs.

Table 6-20. Relay Trouble Alarms

I.D. #	Name	Description
1	RAM FAILURE	Static RAM read/write error.
2	ROM FAILURE	EPROM program memory checksum error.
3	UP FAILURE	Microprocessor exception or self-test error.
4	EEPROM FATAL ERROR	EEPROM read/write error.
5	ANALOG FAILURE	Analog to digital converter error.
6	CALIBRATION ERR	Relay not calibrated or calibration checksum error.
7	PWR SUPPLY ERR	Power supply out of tolerance.
8	WATCHDOG FAILURE	Microprocessor watchdog circuit timed out.
9	SET DEFLTS LOADED	Relay using setting defaults.
10	CAL DFLTS LOADED	Relay using calibration defaults.

Relay trouble alarms, except for CALIBRATION ERR, EEPROM FATAL ERR, SET DFLTS LOADED, and CALDFLTS LOADED indicate that the relay is not functional and causes the self-test diagnostics to force a microprocessor reset to try to correct the problem.

CALIBRATION ERR, EEPROM FATAL ERROR, or DFLTS LOADED errors indicate that the relay is functional but needs re-calibration or the settings reprogrammed.

Any relay trouble alarm will disable the protection functions, light the Relay Trouble LED, and place the output contacts in their normal, de-energized state. If a relay trouble (RA-REL) alarm is cleared by pressing the HMI *Reset* key while viewing Screen 1.3 or using the RA=0 or RA-REL=0 commands, then the relay will attempt to return back online by issuing a software reset. The relay resets by going through a full startup and initialization cycle. If no problems are detected, the relay returns online and enables protection.

Major, Minor, and Logic Programmable Alarms

The programmable alarms function covers all circuits monitored by the continuous self-test diagnostics function that do not affect the relay core functions. Alarm functions used to monitor the power system and equipment are also part of the programmable alarms. Table 6-21 provides a detailed list of all programmable alarms. The programmable alarm points can be prioritized into Major and Minor alarms using BESTCOMS. Major alarm points, when triggered, causes the HMI Major Alarm LED to light and the BESTlogic variable ALMMAJ to assert. Minor alarm points, when triggered, causes the HMI Minor Alarm LED to light and the BESTlogic variable ALMMIN to assert.

Any programmable alarm can also be used in programmable logic expressions without programming it to be reported by the programmable alarm reporting function. The ALMLGC variable is provided for this purpose. Programmable alarm variables can be masked to drive BESTlogic variable ALMLGC by using the SA-LGC command.

Table 6-21. Programmable Alarms

I.D. #	Name	Description
1	CKT MON 1 OPEN ALARM ∗	Trip circuit continuity and voltage monitor 1 (OUT7).
2	CKT MON 2 OPEN ALARM ∗	Trip circuit continuity and voltage monitor 2 (OUT8).
3	CKT MON 3 OPEN ALARM ∗	Trip circuit continuity and voltage monitor 3 (OUT9).
4	CKT MON 4 OPEN ALARM ∗	Trip circuit continuity and voltage monitor 4 (OUT10).

I.D. #	Name	Description
5	BKR 1 FAIL ALARM	Breaker Failure Initiate > Control Time (50BF).
6	BKR 2 FAIL ALARM	Breaker Failure Initiate > Control Time (150BF).
7	BKR 3 FAIL ALARM	Breaker Failure Initiate > Control Time (250BF).
8	BKR 4 FAIL ALARM	Breaker Failure Initiate > Control Time (350BF).
9	DIFFERENTIAL ALARM ∗	Differential threshold exceeded.
10	CHANGES LOST ALARM ∗	Password access lost. No changes saved.
11	BREAKER ALARM 1	Breaker Alarm 1 threshold (SA-BKR1 setting) exceeded.
12	BREAKER ALARM 2	Breaker Alarm 2 threshold (SA-BKR2 setting) exceeded.
13	BREAKER ALARM 3	Breaker Alarm 3 threshold (SA-BKR3 setting) exceeded.
14	BREAKER ALARM 4	Breaker Alarm 4 threshold (SA-BKR4 setting) exceeded.
15	BREAKER ALARM 5	Breaker Alarm 5 threshold (SA-BKR5 setting) exceeded.
16	BREAKER ALARM 6	Breaker Alarm 6 threshold (SA-BKR6 setting) exceeded.
17	BREAKER ALARM 7	Breaker Alarm 7 threshold (SA-BKR7 setting) exceeded.
18	BREAKER ALARM 8	Breaker Alarm 8 threshold (SA-BKR8 setting) exceeded.
19	BREAKER ALARM 9	Breaker Alarm 9 threshold (SA-BKR9 setting) exceeded.
20	BREAKER ALARM 10	Breaker Alarm 10 threshold (SA-BKR10 setting) exceeded.
21	BREAKER ALARM 11	Breaker Alarm 11 threshold (SA-BKR11 setting) exceeded.
22	BREAKER ALARM 12	Breaker Alarm 12 threshold (SA-BKR12 setting) exceeded.
23	GROUP OVERRIDE ALARM ∗	Setting Group override in effect.
24	SYS I/O DELAY ALARM	Excessive delay in HMI or serial communication operation.
25	COMM ERROR ALARM ∗	Communication failure.
26	CLOCK ERROR ALARM ∗	Real-time clock not set.
27	uP RESET ALARM	Microprocessor has been reset.
28	SETTING CHANGE ALARM	Setting change made by user.
29	EE NON-FATAL ERR ALARM	EEPROM nonfatal recoverable error.
30	OUTPUT OVERRIDE ALARM ∗	One or more output contacts have logic override condition.
31	IRIG SYNC LOST ALARM ∗	Loss of IRIG synchronization.
32	SGC ACTIVE ALARM ∗	Active setting group changed.
33	VO13_LABEL ∗	VO13 logic is TRUE (user programmable logic alarm).
34	VO14_LABEL ∗	VO14 logic is TRUE (user programmable logic alarm).
35	VO15_LABEL ∗	VO15 logic is TRUE (user programmable logic alarm).
36	FLT RPT TIMEOUT ALARM	TRUE if fault event trigger lasts longer than 60 seconds.
37	TRANSFORMER ALARM 1	Transformer Alarm 1 threshold (SA-TX1 setting) exceeded.
38	TRANSFORMER ALARM 2	Transformer Alarm 2 threshold (SA-TX2 setting) exceeded.
39	TRANSFORMER ALARM 3	Transformer Alarm 3 threshold (SA-TX3 setting) exceeded.
40	TRANSFORMER ALARM 4	Transformer Alarm 4 threshold (SA-TX4 setting) exceeded.
41	TRANSFORMER ALARM 5	Transformer Alarm 5 threshold (SA-TX5 setting) exceeded.
42	TRANSFORMER ALARM 6	Transformer Alarm 6 threshold (SA-TX6 setting) exceeded.
43	TRANSFORMER ALARM 7	Transformer Alarm 7 threshold (SA-TX7 setting) exceeded.
44	TRANSFORMER ALARM 8	Transformer Alarm 8 threshold (SA-TX8 setting) exceeded.
45	LOGIC = NONE ALARM ∗	Active Logic=NONE. No logic selected.
46	PHASE DEMAND 1 ALARM ∗	Circuit 1 Phase Current Demand threshold exceeded.

I.D. #	Name	Description
47	PHASE DEMAND 2 ALARM ∗	Circuit 2 Phase Current Demand threshold exceeded.
48	PHASE DEMAND 3 ALARM ∗	Circuit 3 Phase Current Demand threshold exceeded.
49	PHASE DEMAND 4 ALARM ∗	Circuit 4 Phase Current Demand threshold exceeded.
50	NEUTRAL DEMAND 1 ALARM ∗	Circuit 1 Neutral Current Demand threshold exceeded.
51	NEUTRAL DEMAND 2 ALARM ∗	Circuit 2 Neutral Current Demand threshold exceeded.
52	NEUTRAL DEMAND 3 ALARM ∗	Circuit 3 Neutral Current Demand threshold exceeded.
53	NEUTRAL DEMAND 4 ALARM ∗	Circuit 4 Neutral Current Demand threshold exceeded.
54	NEG SEQ DEMAND 1 ALARM ∗	Circuit 1 Neg. Sequence I Demand threshold exceeded.
55	NEG SEQ DEMAND 2 ALARM ∗	Circuit 2 Neg. Sequence I Demand threshold exceeded.
56	NEG SEQ DEMAND 3 ALARM ∗	Circuit 3 Neg. Sequence I Demand threshold exceeded.
57	NEG SEQ DEMAND 4 ALARM ∗	Circuit 4 Neg. Sequence I Demand threshold exceeded.
58	IG DEMAND ALARM ∗	Ground Current Demand threshold exceeded.
59	VAR POS DEMAND ALARM ∗	Positive Var Demand threshold exceeded.
60	VAR NEG DEMAND ALARM ∗	Negative Var Demand threshold exceeded.
61	WATT POS DEMAND ALARM ∗	Positive Watt Demand threshold exceeded.
62	WATT NEG DEMAND ALARM ∗	Negative Watt Demand threshold exceeded.
63	VP MAX DEMAND ALARM ∗	Max Phase Voltage Demand threshold exceeded.
64	VP MIN DEMAND ALARM ∗	Min Phase Voltage Demand threshold exceeded.
65	VN MAX DEMAND ALARM ∗	Max Neutral Voltage Demand threshold exceeded.
66	VN MIN DEMAND ALARM ∗	Min Neutral Voltage Demand threshold exceeded.
67	VOLTS PER HERTZ ALARM ∗	Volts per Hertz Alarm threshold exceeded.
68	27 UNDER VOLTAGE ALARM ∗	Phase Undervoltage Alarm threshold exceeded.
69	59 OVER VOLTAGE ALARM ∗	Phase Overvoltage Alarm threshold exceeded.
70	60 FUSE LOSS ALARM ∗	One or more phases of voltage lost.
71	FREQ RANGE ALARM ∗†	Frequency out of range.

∗ Alarms with an asterisk are non-latching. A non-latching alarm clears itself automatically when the alarm condition goes away. All other alarms are latching and must be manually reset by using the HMI *Reset* button or the RA=0 command.

† The frequency range alarm is set and cleared based on two possible inputs:

1. Voltage sensing present on phase A-N terminals if 4W sensing is selected or phase A-B if 3W sensing is selected. A minimum of 10 V secondary is required at the terminals of the BE1-CDS240 to detect frequency.
2. Current sensing present on CKT1 phase A terminals. A minimum current of approximately 2.5 A (5 A CT) or 0.5 A (1 A CT) is required on this circuit to detect frequency.

If either the current or voltage input is present and the frequency is between 10 and 75 Hz, the frequency range alarm is cleared. If the frequency is outside the 10 to 75 Hz range or both current and voltage are below the minimum detectable levels, the frequency range alarm is set.

Programming Alarm Priorities

Alarm settings include Major, Minor, and Logic alarm priorities, Demand alarm points, and the Breaker alarm points. Programming details for Demand alarm points is available in the *Demand Functions* subsection. Refer to the *Breaker Monitoring* subsection for details about programming Breaker alarm points. Major, Minor, and Logic programmable alarm settings are made using BESTCOMS. To select alarm priority, select *Reporting and Alarms* from the *Screens* pull-down menu. Select the *Alarms* tab. See Figure 6-26. Set the alarm point priority by checking the box or boxes to its right.

Alternately, settings for Major, Minor, and Logic alarms can be made using the SA-MAJ, SA-MIN, or SA-LGC ASCII commands. Refer to Section 11, *ASCII Command Interface, Command Summary, Alarm Setting Commands,* for complete command descriptions.

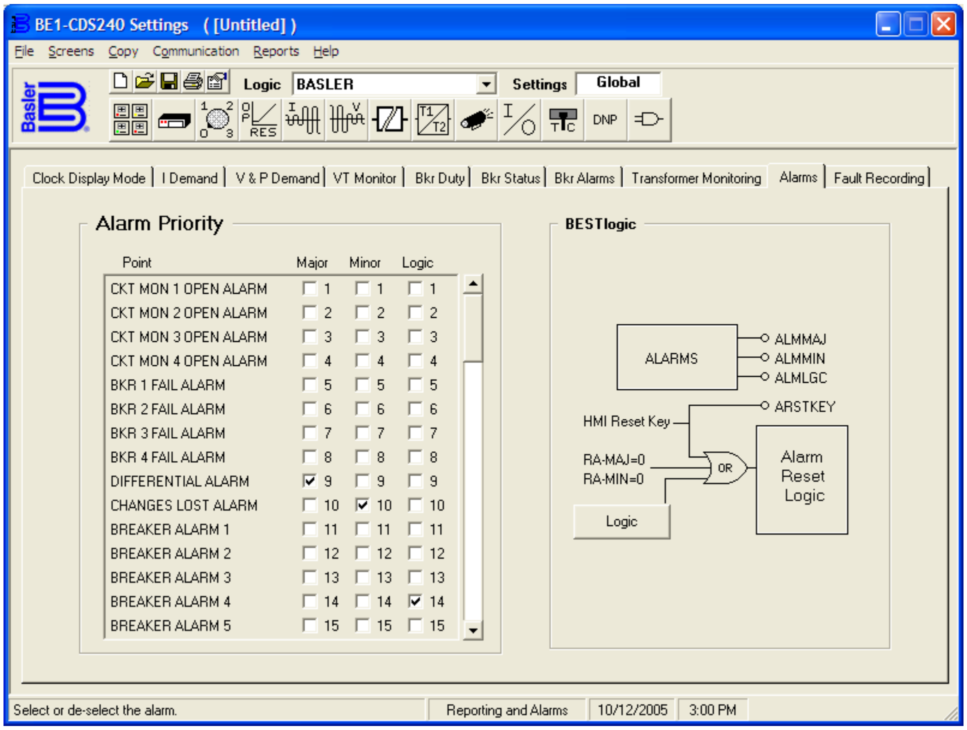

Figure 6-26. Reporting and Alarms Screen, Alarms Tab

Table 6-22 summarizes major, minor, and logic programmable alarm settings.

Table 6-22. Programmable Alarm Settings

Setting	Range/Purpose	Default
Major alarm points (drives Major Alarm LED and ALMMAJ logic variable).	List of alarm functions per Table 6-21.	9, 45
Minor alarm points (drives Minor Alarm LED and ALMMAJ logic variable).	List of alarm functions per Table 6-21.	10
Logic alarm points (drives ALMLGC logic variable).	List of alarm functions per Table 6-21.	0

Retrieving and Resetting Alarm Reports

When an alarm condition occurs, the appropriate front panel LED lights and HMI Screen 1.2.1, \STAT\ALARMS\DETAILS, is displayed. (See Section 10, *Human-Machine Interface*, for more information about automatic display priority logic.) The HMI display scrolls between displaying all active alarm points. This includes alarms that are not programmable (relay trouble alarms). Any latched alarms that are not currently active can be reset by pressing the HMI *Reset* key. See Figure 6-27 for logic.

Logic variables for ALMMAJ, ALMMIN, and ALMLGC can also be set to operate any of the output contacts to give an indication that an alarm condition exists. Section 7, *BESTlogic Programmable Logic*, provides more details about this feature.

The status of the three front-panel LEDs (Relay Trouble, Minor Alarm, and Major Alarm) can be read through the communication ports by using the RG-STAT command. Alarm status is given in the DIAG/ALARM line of the General Status Report. Refer to the *General Status Reporting* subsection for more information about obtaining relay status with the RG-STAT command. Figure 6-27 shows the alarm reset logic.

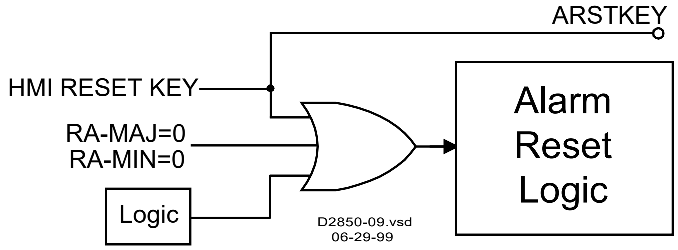

Figure 6-27. Alarm Reset Logic

The *Reset* key of the HMI is context sensitive. That is, the functionality depends upon what screen is currently being displayed. BESTlogic variable ARSTKEY takes advantage of this to allow the front panel *Reset* key to be used in the programmable logic scheme when Alarm Screen 1.2, \STAT\ALARMS, is active. An example of the use of this logic variable is to break the seal-in for a logic expression. The logic expression can be programmed so that the seal-in function uses VO13, VO14, or VO15. If the virtual output expression is included in one of the programmable alarm masks, the automatic display priority logic will cause the display to go to Alarm Screen 1.2, \STAT\ALARMS. When the HMI *Reset* key is pressed, the ARSTKEY logic variable is asserted and the logic expression seal-in is broken. See Section 8, *Application, Application Tips*, for more information. Pressing the HMI *Reset* key while the *Alarm* screen is displayed, will clear any latched alarms that are not currently active. Refer to Table 6-21 for a list of latching alarm points and self-clearing alarm points. Figure 6-27 shows the alarm reset logic.

After an operation, alarms information can be viewed using BESTCOMS. Select *Metering* from the *Reports* pull-down menu. From the *View* pull-down menu, select *Alarms Status* (Figure 6-28).

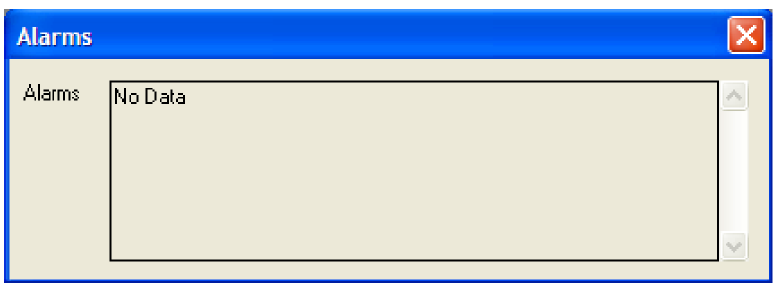

Figure 6-28. Alarms Status, Metering Screen

The RA (report alarms) command can be used to read detailed alarm reports and reset latched alarms.

Links between Programmable Alarms and BESTlogic

Several links between the programmable alarms and BESTlogic allow alarm functions to be used in the logic scheme and programmable logic functions to be used in the alarm reporting function.

Programmable Alarms Controlled by BESTlogic Elements

Virtual Outputs VO13, VO14, and VO15 are driven by BESTlogic expressions and are available in the programmable alarms function. These three virtual outputs have labels that can be assigned meaningful names. Then, when a logic condition that is used for an alarm exists, the label will be reported in the alarm reporting function.

Programmable Alarms Reset

Programmable alarms can be reset by any one of three methods:

- The programmable alarms reset logic expression becomes TRUE.
- Pressing the front panel *Reset* key when HMI Screen 1.2, \STAT\ALARMS is active.
- By connecting the alarms reset logic in BESTCOMS. Alternately, this can be done using the SA-RESET ASCII command.

To reset the alarms using BESTCOMS select *Reporting and Alarms* from the *Screens* pull-down menu. Then select the *Alarms* tab. Select the *Logic* button in the *BESTlogic* box on the right side of the screen. Refer to Figure 6-26. The *BESTlogic Function Element* screen for *Alarm Reset Logic* will appear. See Figure 6-29.

To connect the function's input, select the *Reset* button in the *BESTlogic Function Element* screen. The *BESTlogic Expression Builder* screen will open. Select the expression type to be used. Then, select the BESTlogic variable, or series of variables to be connected to the input. Select *Save* when finished to return to the *BESTlogic Function Element* screen. For more details on the *BESTlogic Expression Builder*, see Section 7, *BESTlogic Programmable Logic*. Select *Done* when the settings have been completely edited.

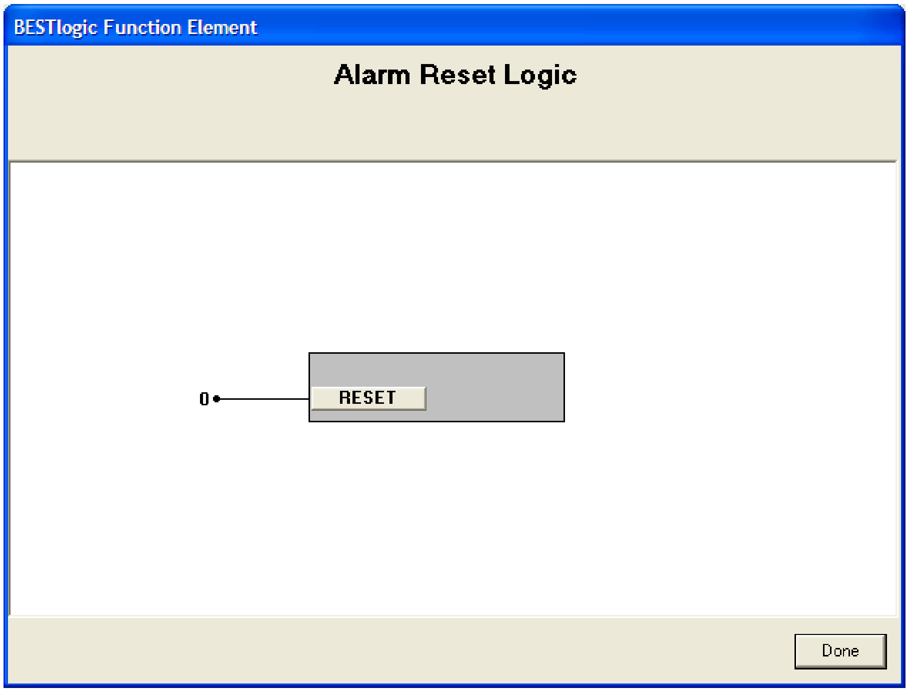

Figure 6-29. BESTlogic Function Element Screen, Alarm Reset Logic

BESTlogic Elements Controlled by Programmable Alarms

Major, Minor, and Logic programmable alarm settings drive BESTlogic variables ALMMAJ, ALMMIN, and ALMLGC. These variables can be used in logic expressions to control logic when the alarm is active. For example, these variables could be used to actuate an output relay to signal a SCADA RTU that an alarm condition exists.

Hardware and Software Version Reporting

Hardware and software version reporting is used to determine what style chart selections are included in the relay, the relay serial number and the version of the embedded software (firmware).

Model (style) number serial number information is contained on the label on the front panel. Embedded software information can be obtained at HMI Screen 4.6, \REPRT\VERSION. The information of Screen 4.6 is also displayed briefly when operating power is applied to the relay.

A software and hardware version report can be obtained through BESTCOMS. Alternately, it can be obtained using the RG-VER ASCII command.

To obtain the relay's version report through BESTCOMS, select *Download Settings from Device* from the *Communication* pull-down menu. Downloaded settings from the relay will overwrite any settings you have made in BESTCOMS; the relay will ask you to save your current file before continuing the download.

To view the version of the relay once the download is complete, select *General Operation* from the *Screens* pull-down menu. Then select the *Identification* tab (Figure 6-30). The *General Info* tab (Figure 6-31) displays all of the style information about the relay.

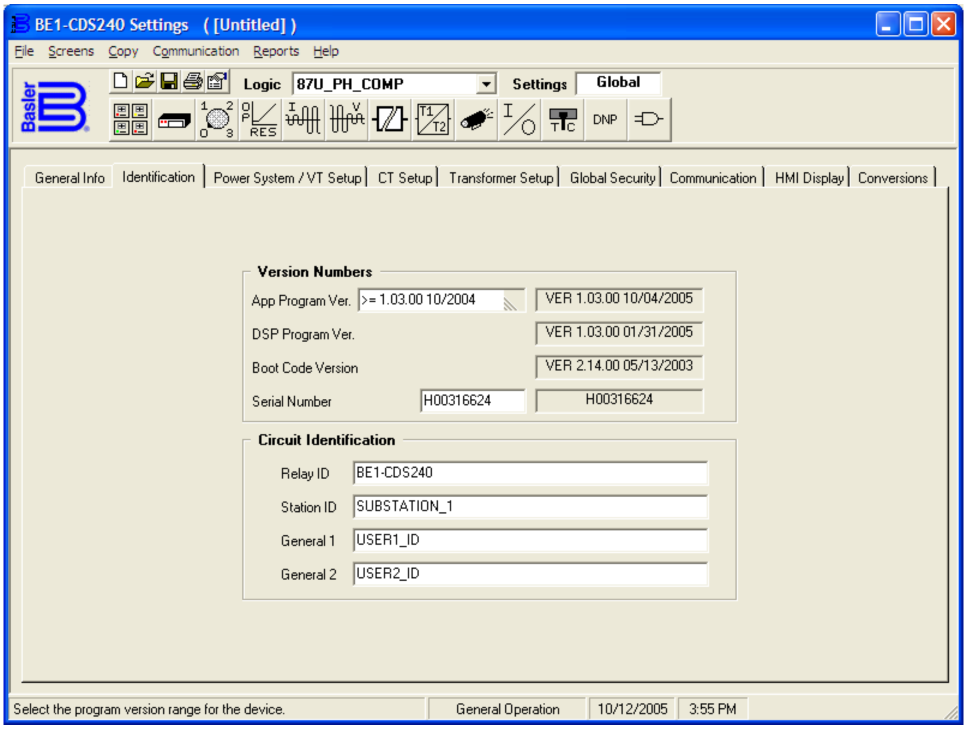

Figure 6-30. General Operation Screen, Identification Tab

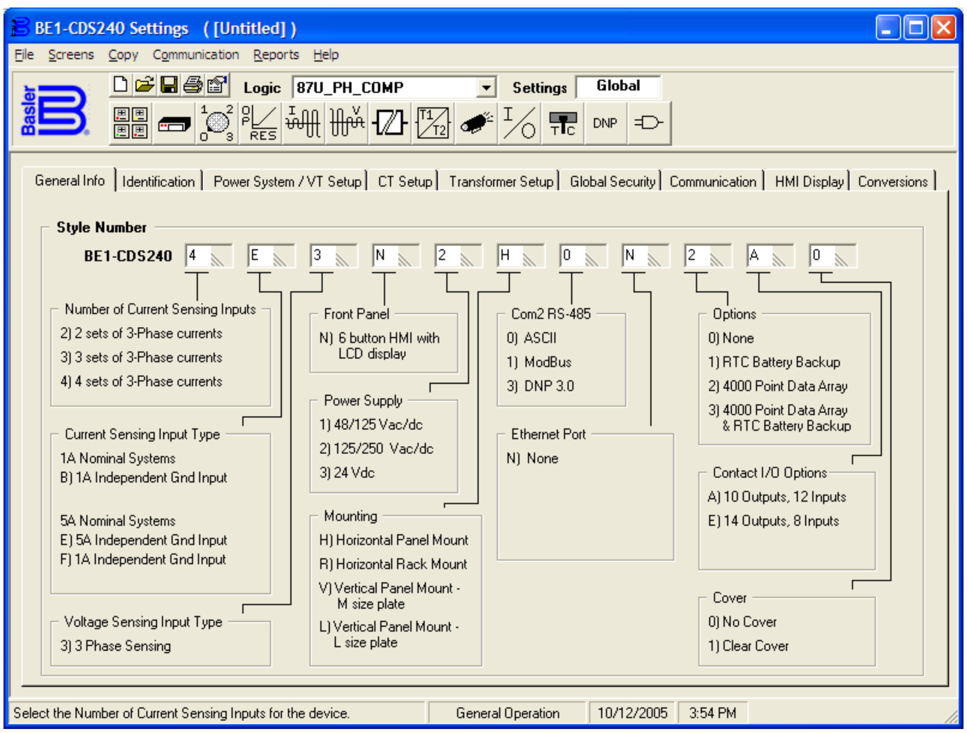

Figure 6-31. General Operation Screen, General Info Tab

Settings Compare

BESTCOMS has the ability to compare two different settings files. To use this feature, pull down the *Reports* menu and select *Settings Compare*. The *BESTCOMS Settings Compare Setup* dialog box appears. See Figure 6-32. Select the location of the first file to compare under *Left Settings Source* and select the location of the second file to compare under *Right Settings Source*. If you are comparing a *Settings file on disk*, click on the folder button and browse for the file. If you wish to *Download settings from unit* to compare, click on the RS-232 button to setup the *Com Port* and *Baud Rate*. Click on the *Compare* button to compare the settings files that you have selected.

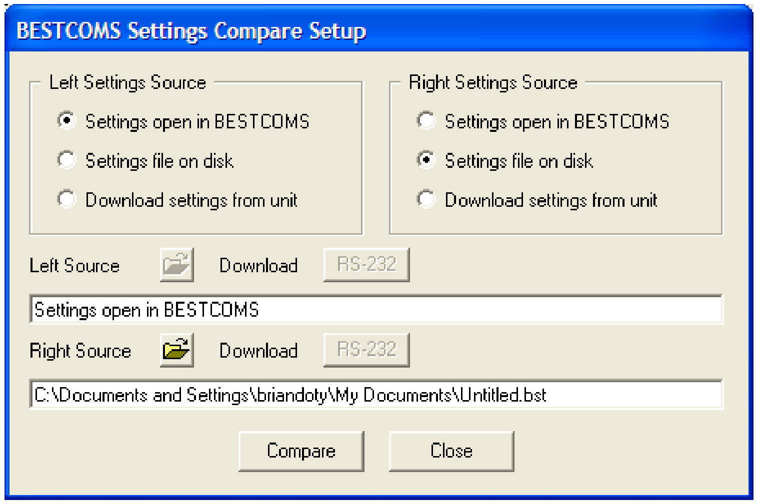

Figure 6-32. BESTCOMS™ Settings Compare Setup Dialog Box

If there are any differences in the two files, a dialog box will pop up notifying you that *Differences Are Found*. The *BESTCOMS Settings Compare* dialog box pops up (Figure 6-33) where you can select to *Show All* or *Show Diffs*.

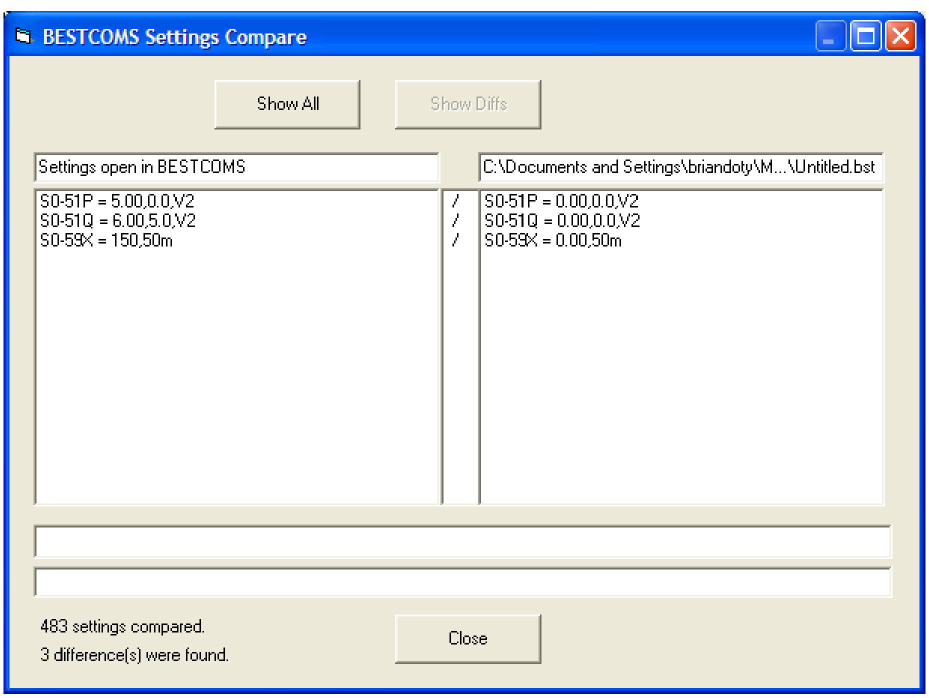

Figure 6-33. BESTCOMS™ Settings Compare Dialog Box

SECTION 7 • BESTlogic PROGRAMMABLE LOGIC

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SECTION 7 • BESTlogic PROGRAMMABLE LOGIC

Introduction

Multifunction relays such as the BE1-CDS240 Current Differential System are similar in nature to a panel of single-function protective relays. Both must be wired together with ancillary devices to operate as a complete protection and control system. In the single-function static and electromechanical environment, elementary diagrams and wiring diagrams provide direction for wiring protective elements, switches, meters, and indicator lights into a unique protection and control system. In the digital, multifunction environment, the process of wiring individual protection or control elements is replaced with the entry of logic settings. The process of creating a logic scheme is the digital equivalent of wiring a panel. It integrates the multifunction protection, control, and input/output elements into a unique protection and control system.

BESTlogic is a programming method used for managing the input, output, protection, control, monitoring, and reporting capabilities of Basler Electric's digital, multifunction, protective relay systems. Each relay system has multiple, self-contained function blocks that have all of the inputs and outputs of its discrete component counterpart. Each independent function block interacts with control inputs, virtual outputs, and hardware outputs based on logic variables defined in equation form with BESTlogic. BESTlogic equations entered and saved in the relay system's nonvolatile memory integrate (electronically wire) the selected or enabled protection and control blocks with control inputs, virtual outputs, and hardware outputs. A group of logic equations defining the function of the multifunction relay is called a logic scheme.

One preprogrammed relay logic scheme is stored (embedded) in the relays memory and several others are available in the logic library of BESTCOMS™, Basler Electric's Windows® based graphical user interface program. Each scheme is configured for a typical protection application and virtually eliminates the need for “start-from-scratch” programming. Any of the preprogrammed schemes can be copied and saved as the active logic. Preprogrammed logic schemes can also be copied and then customized to suit your application. Detailed information about preprogrammed logic schemes is provided later in this section.

BESTlogic is not used to define the operating settings (pickup thresholds and time delays) of the individual protection and control functions. Operating settings and logic settings are interdependent but separately programmed functions. Changing logic settings is similar to rewiring a panel and is separate and distinct from making the operating settings that control the pickup thresholds and time delays of a relay. Detailed information about operating settings is provided in Section 4, *Protection and Control*.

CAUTION
This product contains one or more *nonvolatile memory* devices. Nonvolatile memory is used to store information (such as settings) that needs to be preserved when the product is power-cycled or otherwise restarted. Established nonvolatile memory technologies have a physical limit on the number of times they can be erased and written. In this product, the limit is 100,000 erase/write cycles. During product application, consideration should be given to communications, logic, and other factors that may cause frequent/repeated writes of settings or other information that is retained by the product. Applications that result in such frequent/repeated writes may reduce the useable product life and result in loss of information and/or product inoperability.

Working with Programmable Logic

BESTlogic uses two types of logic settings: output logic settings and function logic block settings. These two types of settings are discussed in the following paragraphs. Output logic settings are entered in equation form and control the hardware outputs of the relay. BESTlogic function blocks are illustrated in Figures 7-1 through 7-5 and are discussed in the following paragraphs.

Names assigned to inputs, outputs, timers, and protection and control elements represent the logic variables in the equations. Table 7-1 lists the logic variable names and descriptions.

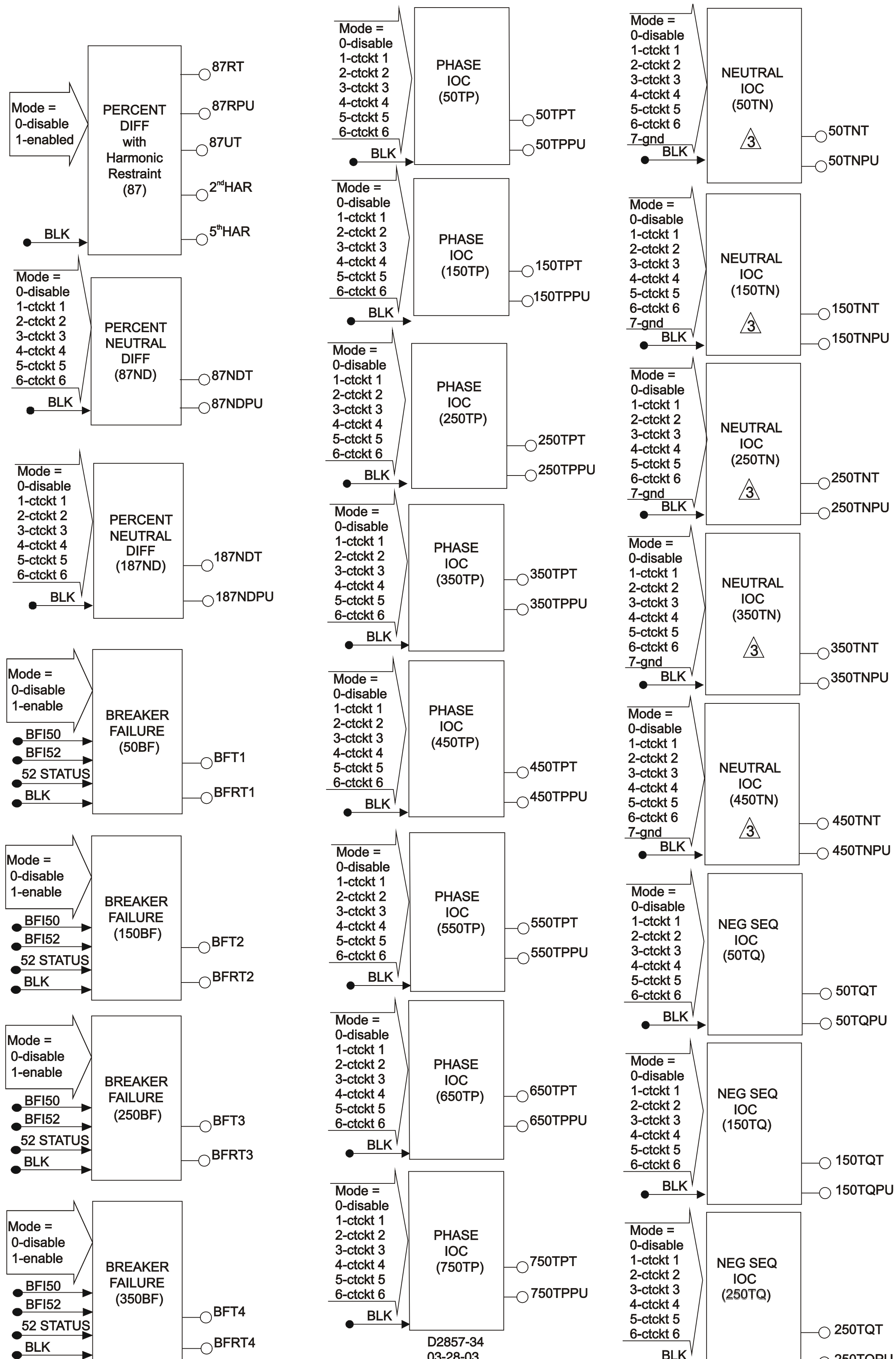

Figure 7-1. BESTlogic Function Blocks - page 1 of 5

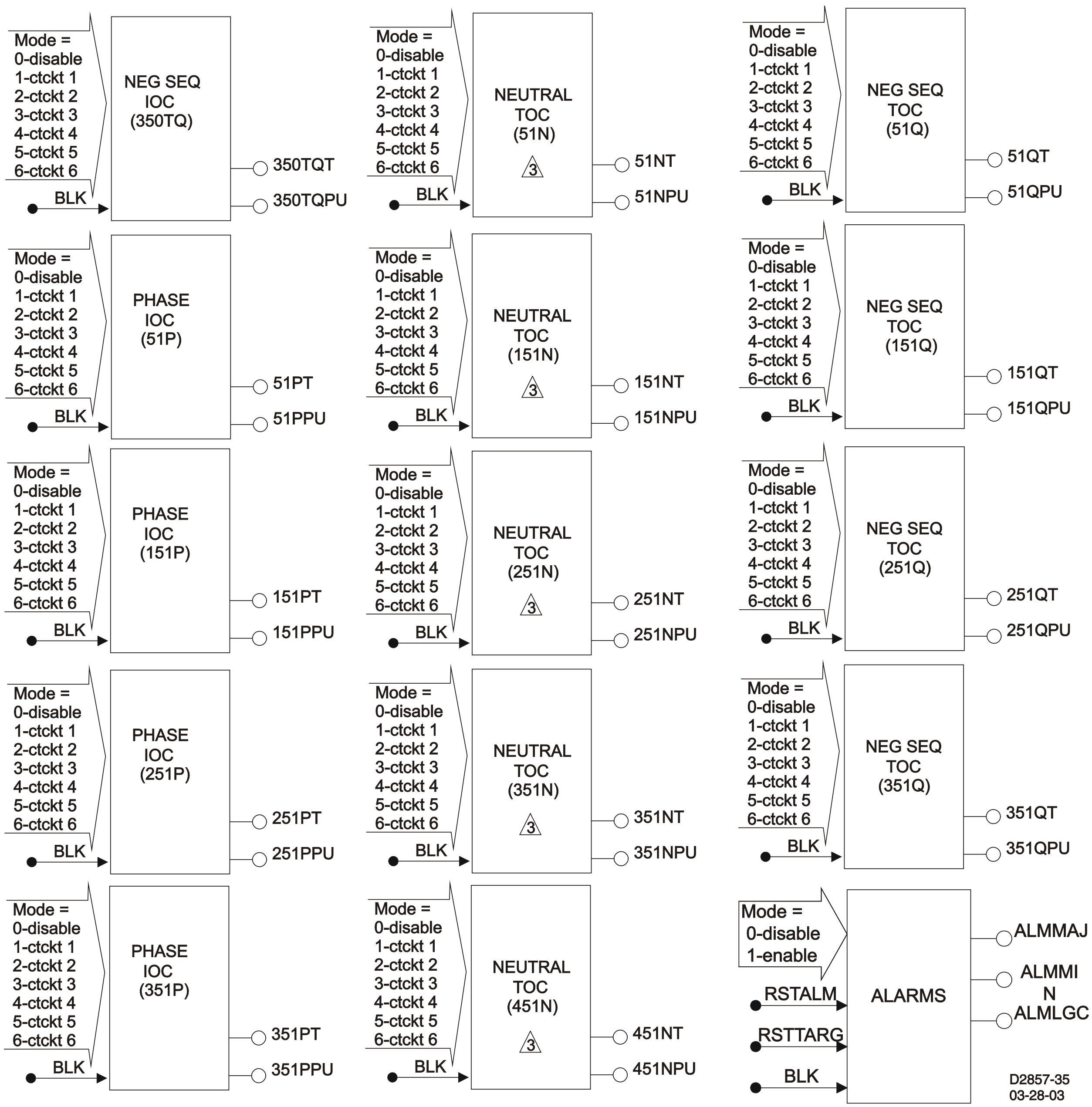

Figure 7-2. BESTlogic Function Blocks - page 2 of 5

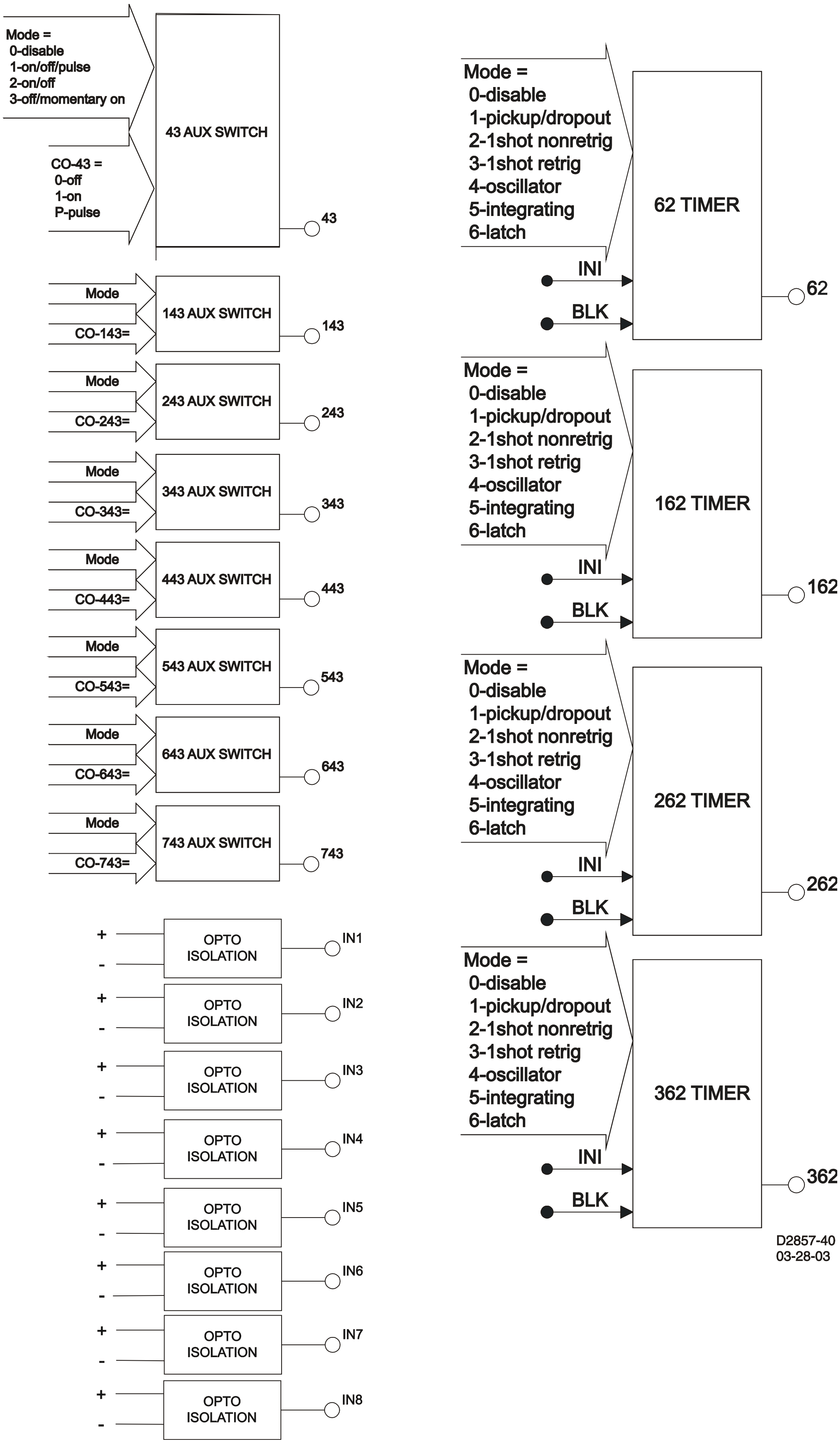

Figure 7-3. BESTlogic Function Blocks - page 3 of 5

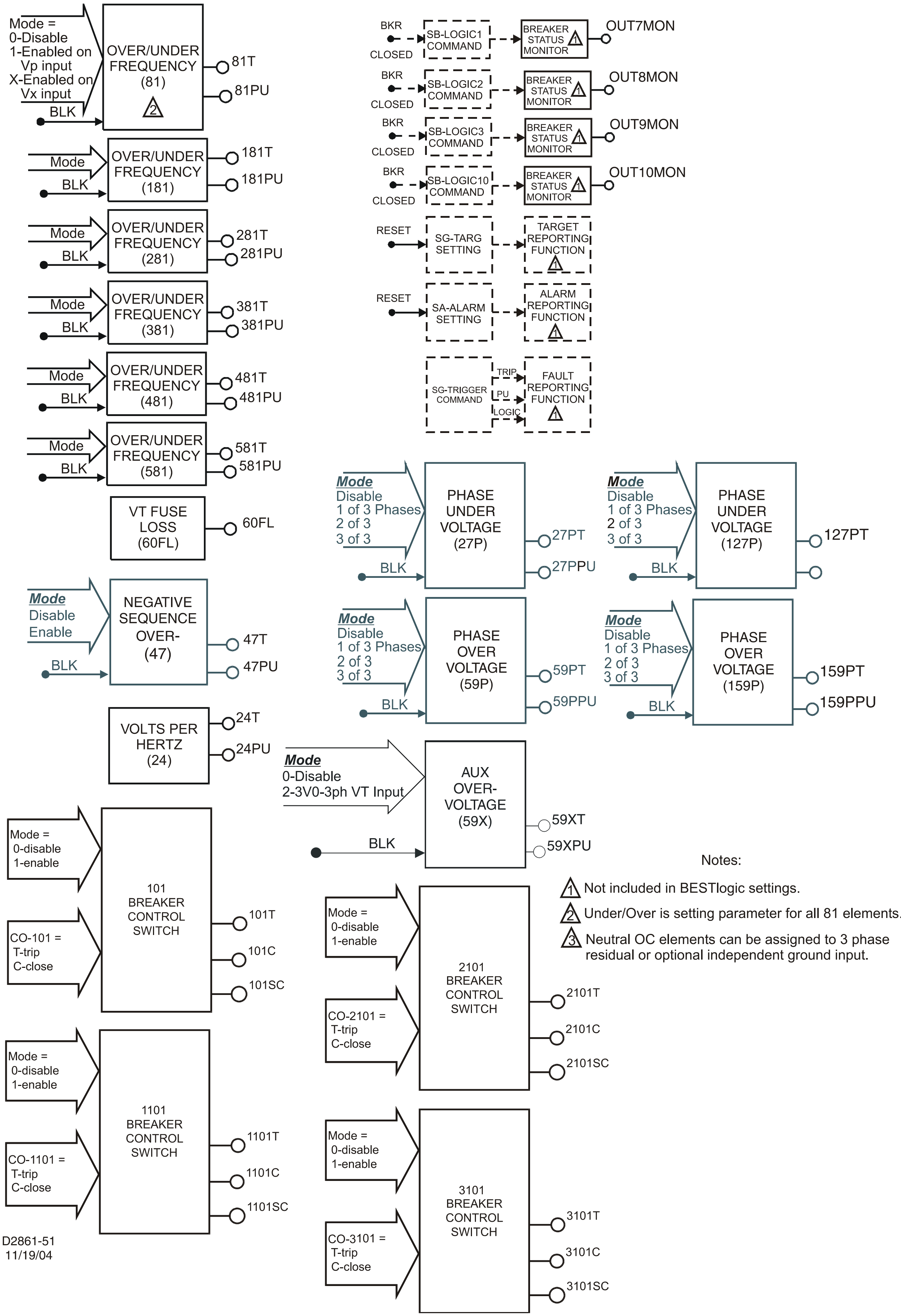

Figure 7-4. BESTlogic Function Blocks - page 4 of 5

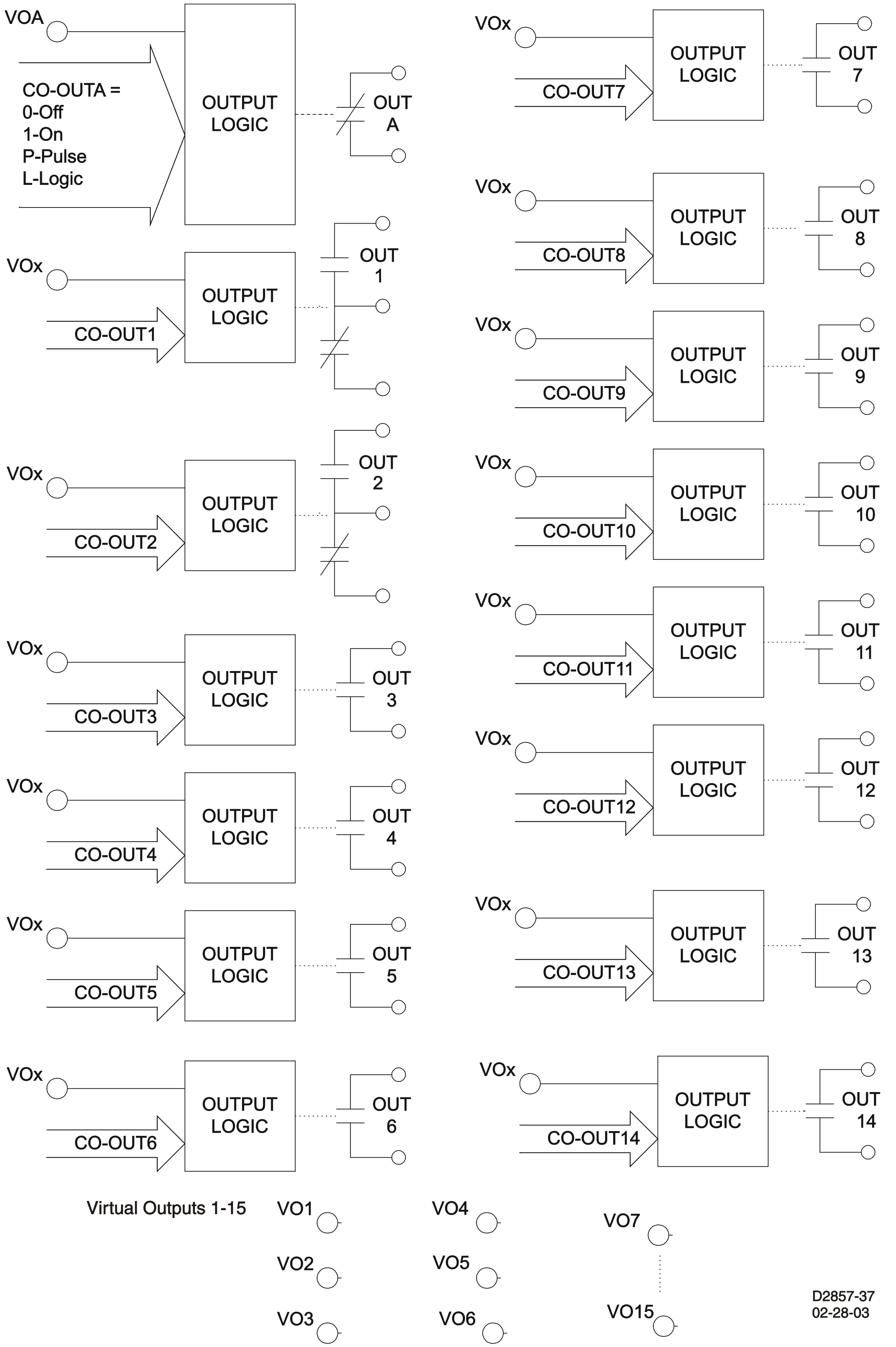

Figure 7-5. BESTlogic Function Blocks - page 5 of 5

Table 7-1. Logic Variable Names and Descriptions

Variable Name	Description	Variable Name	Description
Inputs and Outputs		**Alarms and Monitors**	
IN1-IN12	Inputs 1 through 12 Status	ALMLGC	Logic Alarm
VOA	Relay Trouble Alarm Output Status	ALMMAJ	Major Alarm
VO1-VO6	Virtual Outputs 1 through 6 (hardware outputs)	ALMMIN	Minor Alarm
VO7-VO15	Virtual Outputs 7 through 15	CKTMON1	Output 7 Monitor (circuit continuity)
HMI Reset Keys		CKTMON2	Output 8 Monitor (circuit continuity)
TRSTKEY	Target Reset Key	CKTMON3	Output 9 Monitor (circuit continuity)
ARSTKEY	Alarm Reset Key	CKTMON4	Output 10 Monitor (circuit continuity)
Virtual Breaker Control Switches		**Setting Groups**	
101T	101 Tripped	SG0	Setting Group 0 Active (default)
101C	101 Closed	SG1	Setting Group 1 Active
101SC	101 Slip Contact	SG2	Setting Group 2 Active
1101T	1101 Tripped	SG3	Setting Group 3 Active
1101C	1101 Closed	**Time Overcurrent**	
1101SC	1101 Slip Contact	51PT	51 Phase Tripped
2101T	2101 Tripped	51PPU	51 Phase Picked Up
2101C	2101 Closed	51NT	51Neutral Tripped
2101SC	2101 Slip Contact	51NPU	51 Neutral Picked Up
3101T	3101 Tripped	51QT	51 Negative-Sequence Tripped
3101C	3101 Closed	51QPU	51 Negative-Sequence Picked Up
3101SC	3101 Slip Contact	151PT	151 Phase Tripped
Timers		151PPU	151 Phase Picked Up
62	62 Output	151NT	151 Neutral Tripped
162	162 Output	151NPU	151 Neutral Picked Up
262	262 Output	151QT	151 Negative-Sequence Tripped
362	362 Output	151QPU	151 Negative-Sequence Picked Up
Virtual Switches		251PT	251 Phase Tripped
43	43 Output	251PPU	251 Phase Picked Up
143	143 Output	251NT	251 Neutral Tripped
243	243 Output	251NPU	251 Neutral Picked Up
343	343 Output	251QT	251 Negative-Sequence Tripped
443	443 Output	251QPU	251 Negative-Sequence Picked Up
543	543 Output	351PT	351 Phase Tripped
643	643 Output	351PPU	351 Phase Picked Up
743	743 Output	351NT	351 Neutral Tripped
Breaker Failure		351NPU	351 Neutral Picked Up
BFT1	50BF Tripped	351QT	351 Negative-Sequence Tripped
BFRT1	50BF Retrip	351QPU	351 Negative-Sequence Picked Up
BFT2	150BF Tripped	451NT	451 Neutral Tripped
BFRT2	150BF Retrip	451NPU	451 Neutral Picked Up
BFT3	250BF Tripped		
BFRT3	250BF Retrip		
BFT4	350BF Tripped		
BFRT4	350BF Retrip		
Fuse Loss			
60FL	60 Loss of Potential Alarm		

Variable Name	Description	Variable Name	Description
Instantaneous Overcurrent		**Voltage**	
50TPT	50T Phase Tripped	24T	24 Overexcitation Tripped
50TPPU	50T Phase Picked Up	24PU	24 Overexcitation Picked Up
50TNT	50T Neutral Tripped	47T	47 Negative-Sequence Tripped
50TNPU	50T Neutral Picked Up	47PU	47 Negative-Sequence Picked Up
50TQT	50T Negative-Sequence Tripped	27PT	27 Phase Undervoltage Tripped
50TQPU	50T Negative-Sequence Picked Up	27PPU	27 Phase Undervoltage Picked Up
150TPT	150T Phase Tripped	127PT	127 Phase Undervoltage Tripped
150TPPU	150T Phase Picked Up	127PPU	127 Phase Undervoltage Picked Up
150TNT	150T Neutral Tripped	59PT	59 Phase Overvoltage Tripped
150TNPU	150T Neutral Picked Up	59PPU	59 Phase Overvoltage Picked Up
150TQT	150T Negative-Sequence Tripped	159PT	159 Phase Overvoltage Tripped
150TQPU	150T Negative-Sequence Picked Up	159PPU	159 Phase Overvoltage Picked Up
250TPT	250T Phase Tripped	59XT	59 Auxiliary Overvoltage Tripped
250TPPU	250T Phase Picked Up	59XPU	59 Auxiliary Overvoltage Picked Up
250TNT	250T Neutral Tripped	**Percentage Differential**	
250TNPU	250T Neutral Picked Up	87RT	87 Phase Restraint Tripped
250TQT	250T Negative-Sequence Tripped	87RPU	87 Phase Restraint Picked Up
250TQPU	250T Negative-Sequence Picked Up	87UT	87 Phase Unrestraint Tripped
350TPT	350T Phase Tripped	87NDT	87 Neutral Tripped
350TPPU	350T Phase Picked Up	87NDPU	87 Neutral Picked Up
350TNT	350T Neutral Tripped	187NDT	187 Neutral Tripped
350TNPU	350T Neutral Picked Up	187NDPU	187 Neutral Picked Up
350TQT	350T Negative-Sequence Tripped	2NDHARA	2^{ND} Harmonic Restraint, A-phase
350TQPU	350T Negative-Sequence Picked Up	2NDHARB	2^{ND} Harmonic Restraint, B-phase
450TPT	450T Phase Tripped	2NDHARC	2^{ND} Harmonic Restraint, C-phase
450TPPU	450T Phase Picked Up	5THHARA	5^{th} Harmonic Restraint, A-phase
450TNT	450T Neutral Tripped	5THHARB	5^{th} Harmonic Restraint, B-phase
450TNPU	450T Neutral Picked Up	5THHARC	5^{th} Harmonic Restraint, C-phase
550TPT	550T Phase Tripped		
550TPPU	550T Phase Picked Up		
650TPT	650T Phase Tripped		
650TPPU	650T Phase Picked Up		
750TPT	750T Phase Tripped		
750TPPU	750T Phase Picked Up		
Over/Under Frequency			
81T	81 Tripped		
81PU	81 Picked Up		
181T	181 Tripped		
181PU	181 Picked Up		
281T	281 Tripped		
281PU	281 Picked Up		
381T	381 Tripped		
381PU	381 Picked Up		
481T	481 Tripped		
481PU	481 Picked Up		
581T	581 Tripped		
581PU	581 Picked Up		

Function Block Logic Settings

Each function block is equivalent to its discrete device counterpart. For example, the phase percentage differential function block in the BE1-CDS240 relay shown in Figure 7-1 has many of the characteristics of a BE1-87T transformer differential relay.

Before using a protection or control function block, two items must be set: the *Mode* and the *Input Logic*. Setting the *Mode* is equivalent to deciding which protection or control functions will be used in a logic scheme. The *Input Logic* establishes control of a function block.

Mode and input logic information is contained in logic setting command strings. Depending on the command, the mode setting can either enable or disable a logic input or determine how a function block operates. Input logic defines which logic variables control or disable a logic function. An example of an input logic equation is SL-87=1,IN2. In this differential logic command string, the 1 parameter indicates that the 87 function is enabled. The IN2 expression indicates that the 87 function will be blocked when input two goes TRUE.

The AND operator may not be applied to the terms of an input logic equation. Any number of variables or their inverse can be combined in a function element input logic expression. Section 4, *Protection and Control,* provides detailed information about setting the logic for each function element.

Output Logic Settings

Defining Output Operation

Output operation is defined by Boolean logic equations. Each variable in an equation corresponds to the current state (evaluated every quarter cycle) of an input, output, or timer. Figure 7-6 illustrates this relationship. Every quarter cycle, output expressions are evaluated as TRUE or FALSE. If a logic output that corresponds to a hardware output changes state, then the corresponding output relay contact also changes state.

Figure 7-6. Virtual Output Logic

When the relay is powered up, all logic outputs are disabled and most variables (including virtual outputs) initialize as FALSE. Some variable states are stored in EEPROM and are restored to the last state prior to loss of power. These variables include 43/143/243/343/443/543/643/743,101SC, 1101SC, 2101SC, 3101SC, and SG0 through SG3. All control commands, including logic override control, are also stored in EEPROM. If you override output logic and force an output to open, that condition will be maintained even if operating power is cycled.

When the logic is running and logic expression SL-VO[n] is FALSE, then output VO[n] = 0. When the logic is running and logic expression SL-VO[n] is TRUE, then VO[n] = 1. Hardware Output OUTA follows the corresponding Logic Output VOA. Hardware outputs 1 through 14 can be operated by any virtual output (SL-VO(n)) or combination.

Logic equations are defined by logic variables, logic operators, and their position in an equation. The available logic operators include AND (∗), OR (+) and NOT (/). The NOT operator is applied to the variable immediately following the symbol (/). For virtual output equations, OR logic can be applied to any number of variables if no AND logic is used in the expression. Similarly, AND logic can be applied to any number of variables if no OR logic is used. Any number of NOT operators may be used. For complex expressions that use both AND and OR operators, OR logic is limited to four terms. Up to four AND terms with any number of variables can be ORed together. When the relay is processing a complex expression, it performs AND operations before performing OR operations.

Virtual and Hardware Outputs

A virtual output exists only as a logical state inside the relay (VO1 through VO15). A hardware output is a physical relay contact that can be used for protection or control. The BE1-CDS240 relay has up to 14 isolated output contacts (I/O Option E) (OUT1 - OUT14) consisting of two Form C output contacts (OUT1,2) and 12 Form A output contacts (OUT 3-14). I/O Option A consists of 10 outputs. Alarm contact output, OUTA, is a Form B contact so that upon loss of power, it will "fail safe" close. Output contacts OUT1 through OUT14 are controlled by the status of the internal virtual logic signals VO1 through VO15. If VO[n] becomes TRUE, it can be mapped to any of the 14 output relays, operating the associated contact. For the alarm output, if VOA becomes TRUE, the ALM output de-energizes and closes. For more information about input and output functions, see Section 3, *Input and Output Functions.*

BESTlogic Expression Builder

The *BESTlogic Expression Builder* is used to connect the inputs of the relay's function blocks, physical inputs and outputs, and virtual outputs. Using the *BESTlogic Expression Builder* is analogous to physically attaching wire between discrete relay terminals. The *BESTlogic Expression Builder* is opened each time the input of a BESTlogic function block is selected. Figure 7-7 illustrates the *BESTlogic Expression Builder* screen.

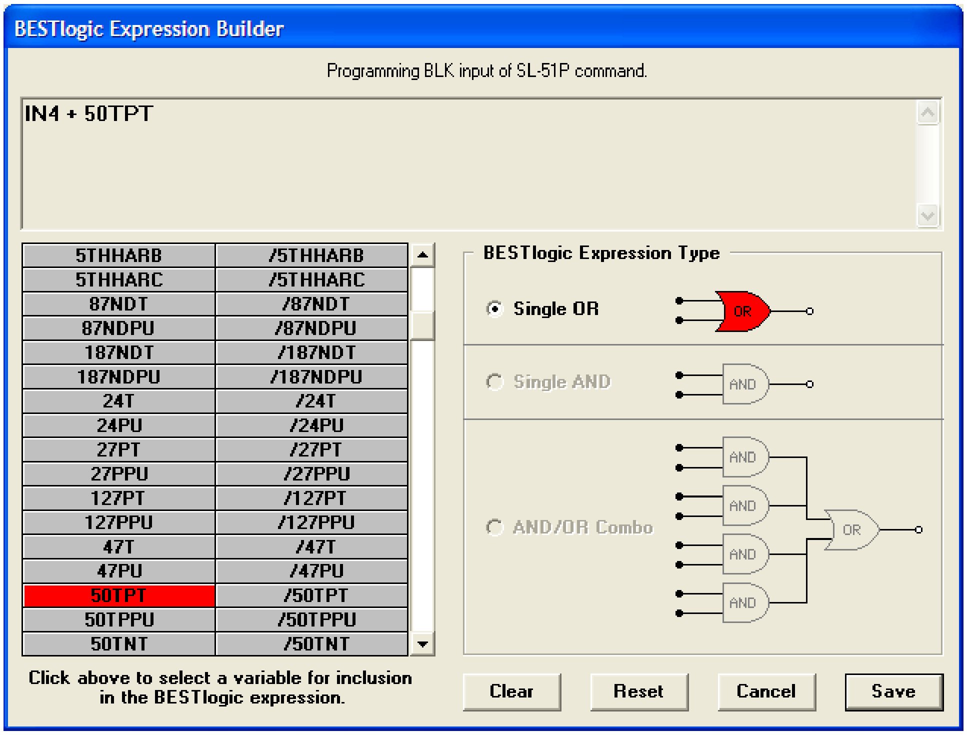

Figure 7-7. BESTlogic Expression Builder Screen

The *BESTlogic Expression Builder* provides a point and click interface that allows the selected input to be easily connected using a single OR gate, single AND gate, or an AND/OR combination. The usable list of inputs and outputs in the bottom left of the screen corresponds with the variable lists of Table 7-1. Currently, the virtual outputs are the only functions that can use the single AND or AND/OR combination *BESTlogic Expression Type*.

The top of the screen displays the BESTlogic expression in a text window. Above the text window, the selected input and the associated ASCII command are displayed.

The *Clear* button will clear the expression to 0. The *Reset* button will reset the expression to its original state when the *BESTlogic Expression Builder* was first opened. The *Cancel* button resets the expression to its original state when the *BESTlogic Expression Builder* was first opened and returns the user to the previous screen. The *Save* button saves the expression shown in the text window and returns the user to the previous window.

Logic Schemes

A logic scheme is a group of logic variables written in equation form that defines the operation of a multifunction relay. Each logic scheme is given a unique name up to 16 characters in length (i.e., CDS240-BATX-A-BE). This allows the user to select a specific scheme and be confident that the selected scheme is in operation. Several preprogrammed logic schemes are available, one embedded in the relay firmware and several schemes that can be copied from the BESTCOMS logic library. Only one of these logic schemes can be active at a given time. In most applications, preprogrammed logic schemes eliminate the need for custom programming. Preprogrammed logic schemes may provide more inputs, outputs, or features than are needed for a particular application. This is because the preprogrammed schemes are designed for a large number of applications with no special programming required. Unneeded inputs or outputs may be left open to disable a function. Or a function element can be disabled through operating settings. Unused current sensing inputs should be shorted to minimize noise pickup.

When a custom logic scheme is required, programming time can be reduced by copying a preprogrammed scheme into the active logic. The logic scheme can then be modified to meet the specific application.

The Active Logic Scheme

Digital, multifunction relays must have an active logic scheme in order to function. All Basler Electric multifunction relays are delivered with a default, active logic loaded into memory. The default, active logic scheme for the BE1-CDS240 is named CDS240-BATX-A-BE. If the function element configuration and output logic of Basic Transformer Logic Scheme meets the requirements of your application, then only the operating settings (power system parameters and threshold settings) need to be adjusted before placing the relay in service.

If you wish to modify the scheme, it must be saved under a different name than that found in the logic library (read only files). Any of the preprogrammed logic schemes discussed in Section 8, *Application,* can be copied to the active logic and customized, or used as is. To copy a logic scheme into active logic, select the scheme from the BESTCOMS logic library and upload it to the relay. To modify the preprogrammed scheme, it is necessary to enter a unique name for the new logic before modifying the settings. Naming the new logic distinguishes it from the preprogrammed logic scheme. In the 16 character preprogrammed logic name, the last 4 characters refer to revision A, dash (-), and BE (Basler Electric). When customizing a programmed logic scheme, it is recommended that the user include the revision level of their scheme and change the BE to a 2-digit code representative of the user's company name. For example, if VA Power were modifying the CDS240-BATX-A-BE logic scheme, the preprogrammed logic scheme might be CDS240-BATX-B-VP. The B stands for revision level B and VP stands for VA Power. After a preprogrammed logic scheme is uploaded to the relay from BESTCOMS, it can also be renamed with the SL-N<name> and customized using ASCII commands.

Logic schemes can be selected from the logic select tab on the *BESTlogic* screen. To access this screen, select *BESTlogic* from the *Screens* pull-down menu. Then select the *Logic Select* tab. Select the desired logic scheme to *Copy to Active Logic* (Internal Logic). The active logic scheme is shown in the *Logic Name* box. In Figure 7-8, CDS240-BATX-A-BE has been selected as the user logic.

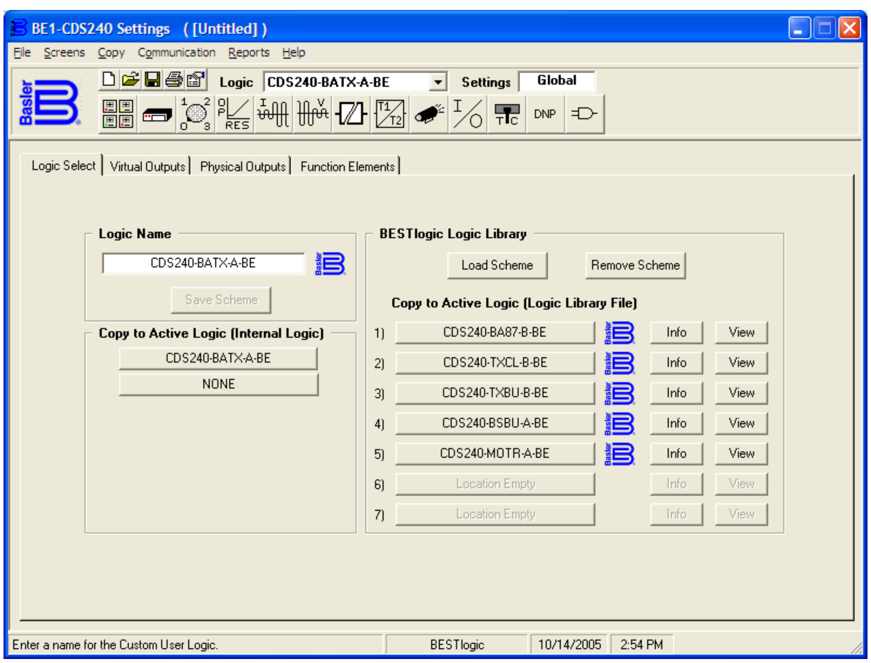

Figure 7-8. BESTlogic Screen, Logic Select Tab

CAUTION
Selecting a logic scheme to be active in BESTCOMS does not automatically make that scheme active in the relay. See the paragraphs later in this section titled, *Sending and Retrieving Relay Settings.*

Custom Logic Schemes

CAUTION
If "NONE" logic is selected, the protection elements are not connected to the virtual outputs or output relays and fault recording features including targets are not enabled.

A custom logic scheme can be created from scratch by copying NONE to *Logic Name* and then renaming the logic. A custom logic scheme can also be created by modifying a preprogrammed logic scheme after copying it to *Logic Name* and then renaming it. A preprogrammed logic scheme copied to *Logic Name* with no name change is treated as a read-only scheme and cannot have its logic expressions altered. Before modifying a logic scheme copied to *Logic Name*, the scheme must be assigned a unique name of one to eight alphanumeric characters. This scheme is then referred to as a custom or user programmable logic scheme because the variable expressions of the logic can be customized or created from scratch to suit the needs of an application. A custom logic scheme may be revised many times but only the most recent changes are saved to as the active (*Logic Name*) logic.

CAUTION
Always remove the relay from service prior to changing or modifying the active logic scheme. Attempting to modify a logic scheme while the relay is in service could generate unexpected or unwanted outputs.

Copying and Renaming Preprogrammed Logic Schemes

Copying a preprogrammed logic scheme to the active logic (*Logic Name*) and assigning a unique name is accomplished by selecting the desired logic scheme in BESTCOMS and then typing over the logic scheme's name. Changes are not activated until the new settings have been uploaded to the device.

Creating or Customizing a Logic Scheme

Before customizing a preprogrammed logic scheme, the scheme must be renamed. The following procedure outlines the process of customizing or creating a logic scheme:

Step 1. Copy the preprogrammed scheme.

Step 2. Rename the scheme with a unique, non-preprogrammed name.

Step 3. Using BESTCOMS, enable or disable the desired relay functions.

Step 4. Edit the logic expressions, as required.

Step 5. Save the changes. Refer to Section 14, *BESTCOMS Software*, for more information on how to save and export settings files.

Sending and Retrieving Relay Settings

Retrieving Relay Settings

To retrieve settings from the relay, the relay must be connected to a computer through a serial port. Once the necessary connections are made, settings can be downloaded from the relay by selecting *Download Settings from Device* on the *Communication* pull-down menu.

Sending Relay Settings

To send settings to the relay, the relay must be connected to a computer through a serial port. Once the necessary connections are made, settings can be uploaded to the relay by selecting *Upload Settings to Device* on the *Communication* pull-down menu.

Debugging the Logic Scheme

If there are problems with a customized logic scheme, the RG-STAT command can be used to check the status of all logic variables. More information about the RG-STAT command can be found in Section 6, *Reporting and Alarms.*

User Input and Output Logic Variable Names

Assigning meaningful names to the inputs and outputs makes sequential events reports easier to analyze. Input and output logic variable names are assigned by typing them into the appropriate text box on the related *BESTCOMS* screen. All of the BE1-CDS240's inputs, outputs, and 43 switches have labels that can be edited. Table 7-2 shows the range and purpose of each label. Alternately, labels may be edited using the SN-ASCII command.

Table 7-2. Programmable Variable Name Setting

Settings	Range/Purpose	Default
Name/Label	1 to 10 characters. User name to replace <var> in the RS report.	INPUT_x SWITCH_x43 VOx_LABEL
True/Energized State	1 to 7 characters. Used to replace default labels.	TRUE
False/De-Energized State	1 to 7 characters. Used to replace default labels.	FALSE

BESTlogic Application Tips

When designing a completely new logic scheme, logic evaluation order should be considered. Contact sensing inputs are evaluated first, then the function elements, and then the virtual outputs. VO15 is evaluated first and VOA is evaluated last. If a virtual output is used in a logic expression to control another virtual output, the virtual output used in the expression should be numerically higher. Otherwise, a logic expression for a numerically smaller virtual output won't be available to a numerically higher virtual output until the next processing interval. Logic is evaluated every quarter-cycle.

When designing custom protection schemes, avoid confusion by maintaining consistency between input and output functions in the custom scheme and the preprogrammed schemes.

OUT3 through OUT14 have normally open contacts (coil is de-energized). OUT1 and 2 are form C and have one normally open and one normally closed contact. Normally open contacts can be used as normally closed outputs by inverting the logic expressions that drive them. Inverting an output logic expression causes the coil to be energized with the contacts closed in the normal state. Caution should be taken with normally closed contact logic because there are no shorting bars to maintain the closed condition if the draw-out assembly is removed from the chassis. In applications where a normally closed output is needed even when the electronics are removed, a normally open contact from the relay can be used to drive a low-cost auxiliary relay. The normally closed output of the auxiliary relay will maintain the closed output when the draw-out assembly is removed from the case. Alternately, an external switch can be used to short across a normally closed relay output when the draw-out assembly is removed. Extra care is required to ensure that the switch is closed prior to removing the draw-out assembly and that the switch is open after the relay is placed back in service.

Several links between the programmable alarms function and BESTlogic programmable logic allow alarm functions to be used in a logic scheme and programmable logic functions to be used in the alarm reporting function.

Programmable alarm settings for Major, Minor, and Logic alarms drive BESTlogic variables ALMMAJ, ALMMIN, and ALMLGC. These variables can be used in logic expressions to control logic when an alarm is active.

Virtual outputs VO13, VO14, and VO15 are driven by BESTlogic expressions. These three logic variables are also available in the programmable alarm function. Virtual outputs can also be assigned user programmable labels (described previously). With this feature, a logic condition can be designed and used for an alarm. The virtual output label would then be reported in the alarm reporting function.

SECTION 8 • APPLICATION

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SECTION 8 • APPLICATION

Introduction

This section discusses the application of the BE1-CDS240 Current Differential System using a preprogrammed logic scheme. The CDS240 has one embedded, default logic scheme (CDS240-BATX-A-BE) as delivered from the factory. This scheme was developed based on customer requirements, input from Basler Electric Application Engineers, and on IEEE C37.91 Guide for Protective Relay Applications to Power Transformers. Other preprogrammed logic schemes such as Basic Differential, Basic Transformer with Control Logic, Basic Transformer with Backup Logic, Bus Protection with Backup Logic, and Motor Protection are available on the Basler Web site and included in the logic library of BESTCOMS™, Basler Electric's Windows® based graphical user interface program. A description of each of those schemes follows the Basic Transformer discussion. The paragraphs on *Details of Preprogrammed Logic* describe the characteristics of the logic scheme and how they combine to create a Transformer Differential Scheme for application on network and radial transformers at any voltage level. A detailed description of the preprogrammed scheme is also provided. This section concludes with tips on programming custom logic schemes to meet specific user applications.

This preprogrammed logic scheme is designed to take advantage of all the CDS240 protection capabilities. However, not all elements have to be set. The protection engineer can choose which elements receive operational settings or adapt the scheme to user specific needs by changing the protection and control elements and settings. In many cases, this eliminates the need to create a custom logic scheme from scratch.

Please note that this preprogrammed logic scheme also illustrates typical ways of using or controlling various functions. The user may choose to create a custom logic scheme by mixing preprogrammed logic with user defined logic. The logic also can be modified to incorporate some of the features described in the *Application Tips* provided at the end of this section. The flexibility of BESTlogic in combination with easy to use BESTCOMS allows the engineer to quickly create a protection and control scheme that meets the exact requirements of the application.

CAUTION
If "NONE" logic is selected, the protection elements are not connected to the virtual outputs or output relays, and fault recording features including targets are not enabled. The user will have to program and enable these features and functions as part of building a custom logic scheme.

Explanation Terms

Understanding the following terms and definitions will help to clarify the application discussions that follow:

Function Element

Stand-alone protection or control function that is equivalent to the discrete component counterpart.

Virtual Switches

Virtual switches are logic switches that emulate traditional protection and control panel switches such as the breaker control switch (101) and on/off, selector switches (43). Virtual switches may be operated via the ASCII command interface or the front panel human-machine interface (HMI). Operation of these switches can be password protected or disabled if the user chooses not to use them. You might do this when using a preprogrammed logic scheme without changing the preprogrammed logic.

Overview of Preprogrammed Basic Transformer Protection Logic

This logic scheme, CDS240-BATX-A-BE provides three-phase, percent-restrained differential protection with high-speed unrestrained instantaneous differential protection. The differential protection also includes 2nd and 5th harmonic restraint to improve security for transformer inrush. Time overcurrent phase, neutral, and negative sequence protection are included on the high side (151P, N, and Q) and low side (251P, N, and Q) of the transformer to provide time delay backup protection for the transformer and low-side zones. A separate 51N fed from an optional ground CT (IG) input is also included in this scheme and provides sensitive, time overcurrent ground fault backup protection for the transformer low-side winding, the bus, and the feeders.

Details of Preprogrammed Basic Transformer Protection Logic

The following paragraphs expand on the Basic Transformer Protection (CDS240-BATX-A-BE) preprogrammed logic scheme. The application features of the logic scheme are broken down into their separate protection elements and described in detail. The integration of protection and control elements, and alarm elements are also described in detail.

CAUTION
Never use a protection element from a multifunction relay to backup another protection element in the same relay!

Multifunction protection products are the best things to happen to the protection industry in the last 30 years. The operating information they provide, along with their flexibility, versatility, and economics, provide the protection engineer with options that were never available with previous technologies. There is, however, one cardinal rule that must be followed to ensure continuous, reliable, and secure protection of the user's facilities.

Regardless of the product manufacturer, common mode failure is a possibility that the protection engineer must consider in his design. For example, if a BE1-CDS240 is used to protect a two-winding transformer, the protection engineer cannot depend on the internal 51 time overcurrent element to backup the primary differential 87 protection element of the same relay. A common mode failure such as the power supply could disable the entire relay and leave the transformer with no protection. In addition, the self-testing feature of the product is designed to disable the relay outputs when a problem is detected.

Basler Electric products are among the most reliable in the industry, but we believe that it does not make good engineering sense to place all your eggs in one basket. That is why Basler strongly recommends that a second multifunction device be installed to provide independent backup and zone overlapping for each protected zone. In the transformer example given in the previous paragraph, the 87 protection element of the BE1-CDS240 would require 51 backup protection from a separate BE1-851 or BE1-951 device. Conversely, a BE1-CDS240 50 or 51 overcurrent element would backup a separate BE1-851 or BE1-951 zone used for low-side bus protection.

The following paragraphs discuss the protection and control capabilities of this logic scheme. Although it is not discussed in each paragraph, the reader should be aware that the application of an independent, overlapping, backup zone of protection is recommended for a complete protection design.

This preprogrammed protection logic scheme begins with the application intent of the design. Next, the protection elements are discussed in detail, including CT connections and typical zone and reach information, followed by protection and control integration, and alarm information specific to the preprogrammed design. Unique references, including one-line and logic diagrams, and program codes are included.

Preprogrammed logic can be a starting point or an ending point for the protection engineer depending on how closely the logic meets engineering requirements. This logic schemes was created by applications personnel from the utility industry and is easily modified to meet specific user needs. For applications assistance, contact your local Basler Electric representative.

CDS240-BATX-A-BE Logic Scheme (Basic Transformer Protection)

The basic transformer logic scheme (CDS240-BATX-A-BE) was designed to provide a primary zone of differential protection and three backup zones of time overcurrent protection for detecting phase and ground faults in two-winding transformer applications.

Figure 8-1 is a one-line drawing and Figure 8-2 is a logic drawing. Both represent the logic settings and equations shown in Table 8-1. In Table 8-1, the user can see the protection and control elements that are enabled for the CDS240-BATX-A-BE application and how the elements are logically wired together (equations). If the user should decide to build on this scheme, all elements required for a more detailed application are available through programming. For programming details, refer to Section 7, *BESTlogic Programmable Logic.*

Table 8-1. CDS240-BATX-A-BE (Basic Transformer) Logic Settings and Equations

SL-N=CDS240-BATX-A-BE,BASLER	SL-62=0,0,0
SL-87=1,0	SL-162=0,0,0
SL-87ND=0,0	SL-262=0,0,0
SL-187ND=0,0	SL-362=0,0,0
SL-50BF=0,0,0,0,0	SL-GROUP=1,0,0,0,0,/0
SL-150BF=0,0,0,0,0	SL-43=0
SL-250BF=0,0,0,0,0	SL-143=0
SL-350BF=0,0,0,0,0	SL-243=0
SL-50TP=0,0	SL-343=0
SL-50TN=0,0	SL-443=0
SL-50TQ=0,0	SL-543=0
SL-150TP=0,0	SL-643=0
SL-150TN=0,0	SL-743=0
SL-150TQ=0,0	SL-101=0
SL-250TP=0,0	SL-1101=0
SL-250TN=0,0	SL-2101=0
SL-250TQ=0,0	SL-3101=0
SL-350TP=0,0	SL-VOA=0
SL-350TN=0,0	SL-VO1=87RT+87UT
SL-350TQ=0,0	SL-VO2=0
SL-450TP=0,0	SL-VO3=0
SL-450TN=0,0	SL-VO4=151PT+51NT+151NT+151QT
SL-550TP=0,0	SL-VO5=251PT+251NT+251QT
SL-650TP=0,0	SL-VO6=ALMMAJ
SL-750TP=0,0	SL-VO7=0
SL-51P=0,0	SL-VO8=0
SL-51N=G,0	SL-VO9=0
SL-51Q=0,0	SL-VO10=0
SL-151P=1,0	SL-VO11=87RT+87UT+151PT+251PT+51NT+ 151NT+251NT+151QT+251QT
SL-151N=1,0	
SL-151Q=1,0	SL-VO12=87RPU+87UT+151PPU+251PPU+ 51NPU+151NPU+251NPU+151QPU+251QPU
SL-251P=2,0	
SL-251N=2,0	SL-VO13=IN6
SL-251Q=2,0	SL-VO14=IN7
SL-351P=0,0	SL-VO15=IN8
SL-351N=0,0	SL-OUTA=VOA
SL-351Q=0,0	SL-OUT1=VO1
SL-451N=0,0	SL-OUT2=VO1
SL-24=0,0	SL-OUT3=VO1
SL-27P=0,0	SL-OUT4=VO4
SL-127P=0,0	SL-OUT5=VO5
SL-47=0,0	SL-OUT6=VO6
SL-59P=0,0	SL-OUT7=0
SL-59X=0,0	SL-OUT8=0
SL-159P=0,0	SL-OUT9=0
SL-81=0,0	SL-OUT10=0
SL-181=0,0	SL-OUT11=0
SL-281=0,0	SL-OUT12=0
SL-381=0,0	SL-OUT13=0
SL-481=0,0	SL-OUT14=0
SL-581=0,0	

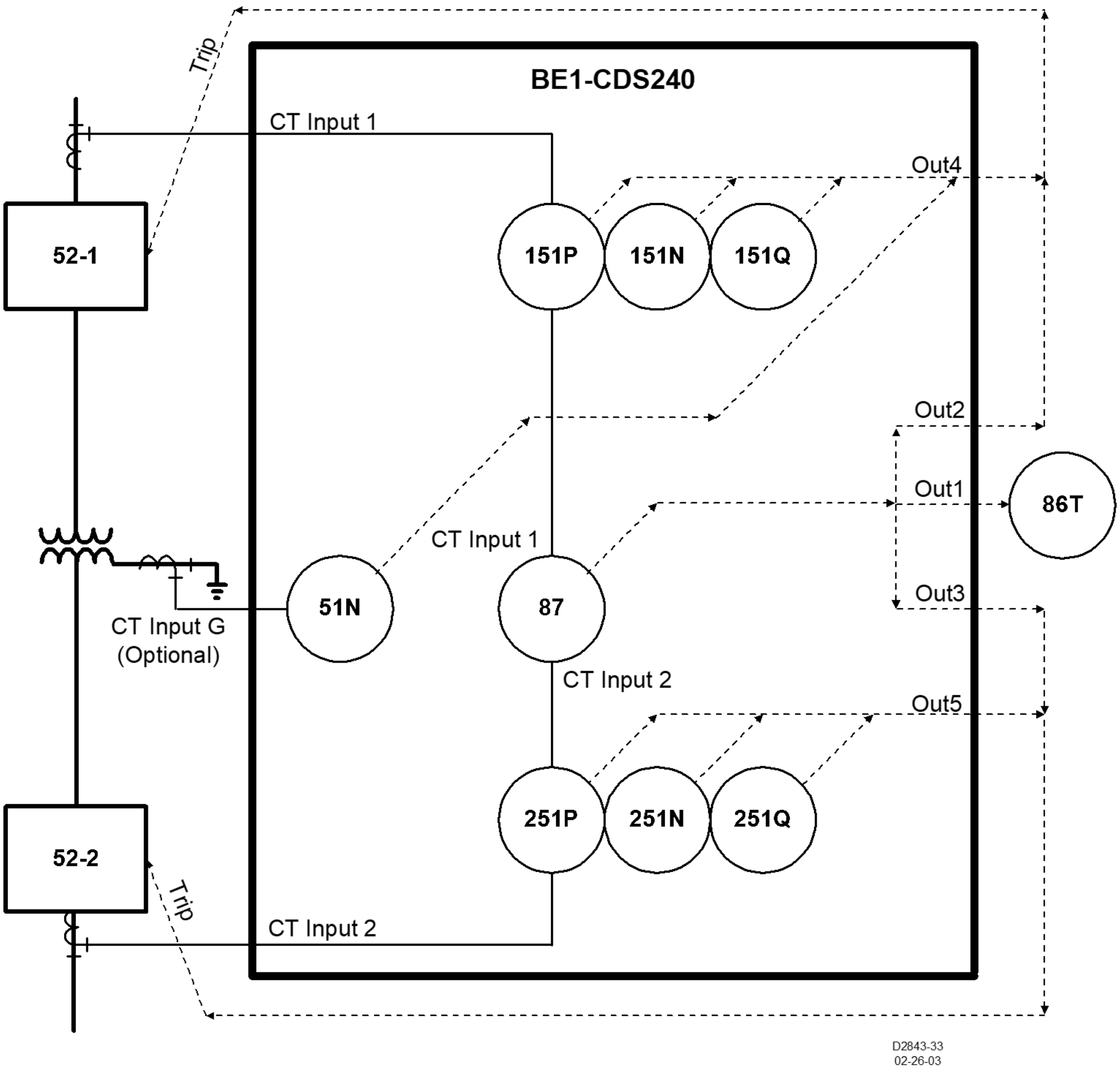

Figure 8-1. Typical One-line Diagram for CDS240-BATX-A-BE

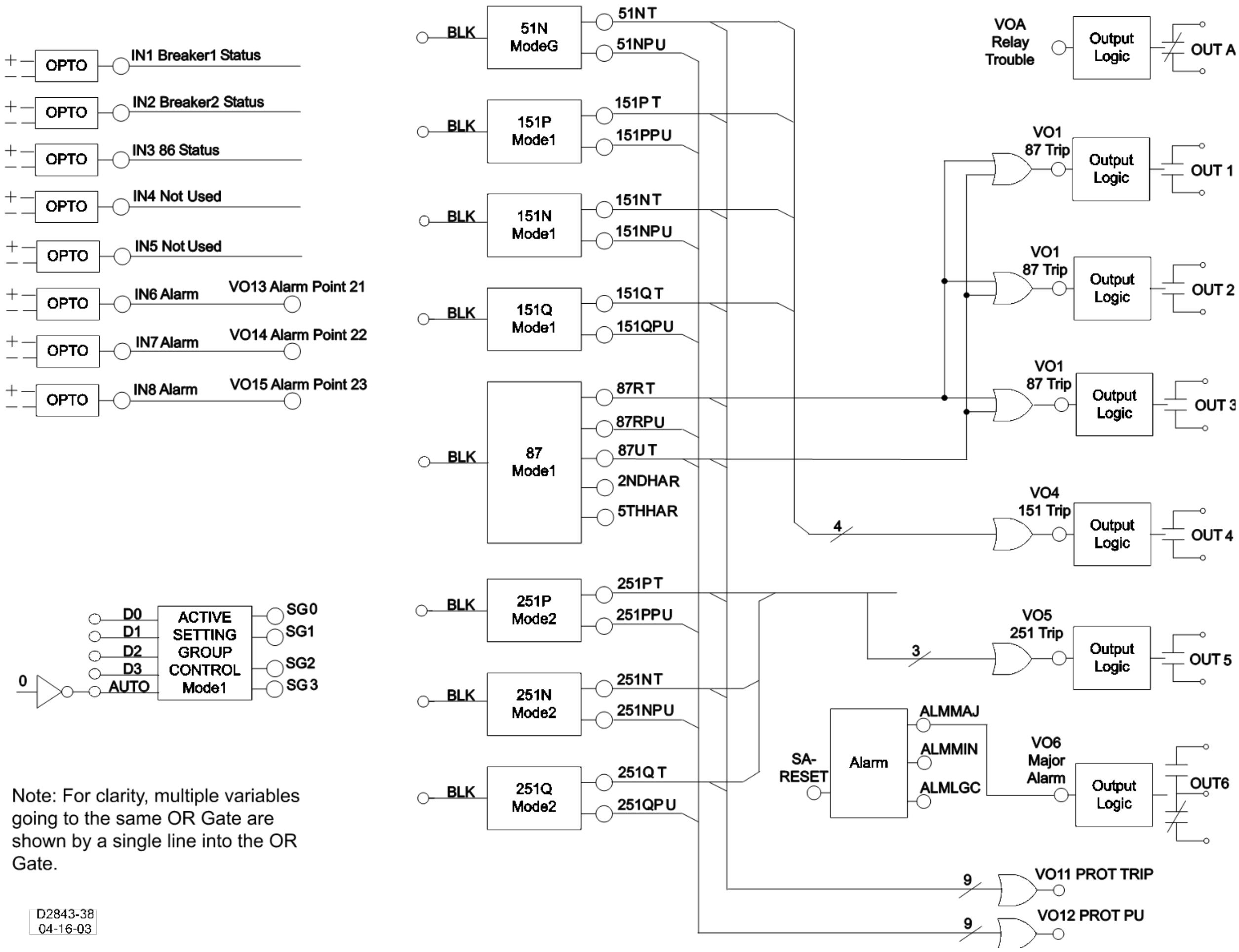

Figure 8-2. Typical Logic Diagram for CDS240-BATX-A-BE Protection Elements

Referring to Figure 8-1, the 87 and 151 protection elements are connected to the high-side CT, input 1. The 87 and 251 protection elements are connected to the low-side CT, input 2. The 51 protection element (N only) is connected to a ground CT at the grounded side of a delta-wye transformer. The ground-input (G) is an option on the BE1-CDS240 and must be ordered. Paralleled CTs inside a delta tertiary (3Io) can also feed the 51N. The 87, 51, 151, and 251 protection elements are logic enabled by the settings shown in Table 8-1 to provide a trip through the BE1-CDS240 output contacts. Protection elements set to 0 are setting disabled and will not provide a trip output even if logic enabled.

Typically, the BE1-CDS240 would be applied with a BE1-851 or BE1-951 multifunction overcurrent relay to provide independent, overlapping, backup protection in the event of a common mode failure. Typically, the 87 protection element provides high-speed restrained differential and unrestrained differential phase and ground protection for faults inside the differential zone. At the same time, it provides security against mis-operations resulting from transformer inrush by restraining and preventing a trip in the presence of 2nd and 5th harmonics.

Typically, the 151 protection element is coordinated with the low-side bus protection to provide Phase, Neutral, and Negative-Sequence timed backup protection for the low-side bus if the bus protection is out of service.

Typically, the 251 protection element is coordinated with the low-side feeder protection to provide Phase, Neutral, and Negative Sequence timed backup protection for feeder faults if the feeder protection is out of service.

Typically, the 51N protection element is coordinated with the low-side bus and feeder protection to provide Neutral (ground) timed backup protection for transformer low-side, bus and feeder ground faults if any primary zone of protection is of service.

Integration of Protection, Control, and I/O Elements

The logic equations of Table 8-1 establish the control connections between CDS240-BATX-A-BE scheme elements. For example, the three underlined logic settings in the equations of Table 8-1 provide the electrical connection between the 87 element (trip enabled by the settings) and trip outputs 1, 2, and 3. Referring to Figures 8-1 and 8-2, the 87 protection element trips through outputs 1, 2, and 3. The user can apply any or all of the outputs. The 151 and 51N protection elements (also trip enabled by the settings) trip through output 4, while the 251 protective element (also trip enabled by the settings) trips through output 5. Protection elements set at 0 are setting disabled and will not provide a trip output even if logic enabled.

Control of the active setting group can be manual or automatic. For the CDS240 application, setting group control is programmed for continuous automatic operation because the /0 (not 0), logic 1 is applied to the AUTO input of the Active Setting Group Control Logic as shown in Figure 8-2. Tables 8-2 through 8-6 provide detailed logic definitions for the inputs, outputs, protection, and control elements.

Alarms

Three logic variables drive the front panel LEDs: Relay Trouble (ALMREL), Major Alarm (ALMMAJ), and Minor Alarm (ALMMIN). A fourth logic variable, Logic Alarm (ALMLGC), has no associated front panel LED. When the relay self-test detects a problem in the relay (ALMREL) as programmed for the CDS240-BATX-A-BE scheme, the Relay Trouble LED lights, output A operates and all outputs are disabled. When a Major Alarm is detected (ALMMAJ), the associated LED lights and output 6 operates. When a Minor Alarm (ALMMIN) is detected, the associated LED lights, but in this scheme, no output relay is programmed to operate.

NOTE

Tables 8-2 through 8-6 provide detailed logic definitions for the inputs, outputs, protection, and control elements. Only those inputs, logic blocks, virtual switches, and outputs in use for the CDS240-BATX-A-BE preprogrammed logic are described in the following tables.

Table 8-2. CDS240-BATX-A-BE Contact Input Logic

Input	Purpose	Name Label	State Labels	
			Energized	De-Energized
IN1	Optional input. Used for CT input circuit 1 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-1	CLOSED	OPEN
IN2	Optional input. Used for CT input circuit 2 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-2	CLOSED	OPEN
IN3	Optional input. Used for 86 status indication in SER reports. TRUE when 86 is tripped.	86-TRIPPED	TRIPPED	NORMAL
IN6 - IN8	Optional inputs. Used for programmable alarms and SER reporting. For example, sudden pressure trip or transformer hot spot alarm, etc. Drives VO13 - VO15 that are programmable alarm points 21 - 23. Label inputs as appropriate.	INPUT_6, INPUT_7, INPUT_8	CLOSED	OPEN

Table 8-3. CDS240-BATX-A-BE Function Block Logic

Function	Purpose	BESTlogic Expression	Mode Setting
87	Used for percent-restrained differential protection with high-speed unrestrained instantaneous differential protection.	0	1 (Enabled)
51N	Used for timed ground overcurrent protection for independent ground input circuit.	0	G (Ground Input)
151P	Used for timed phase overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
151N	Used for timed neutral overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
151Q	Used for timed negative-sequence overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
251P	Used for timed phase overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
251N	Used for timed neutral overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
251Q	Used for timed negative-sequence overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
GROUP	*Input 0 Logic:* No manual selection logic is used.	0	1 (Discrete Inputs)
	Input 1 Logic: No manual selection logic is used.	0	
	Input 2 Logic: No manual selection logic is used.	0	
	Input 3 Logic: No manual selection logic is used.	0	
	Auto/Manual Logic: Set to 1 (/0) to enable automatic selection. No manual selection is used.	/0	

Table 8-4. CDS240-BATX-A-BE Virtual Switch Logic

Switch	Purpose	Mode	Label	State Labels	
				True	False
N/A	No virtual switches used.	N/A	N/A	N/A	N/A

Table 8-5. CDS240-BATX-A-BE Virtual Output Logic

Output	Purpose	Description	Label	State Labels	
				True	False
VOA	Relay Trouble Alarm.	VOA TRUE if relay trouble alarm occurs.	RELAY-TROUBLE	ACTIVE	NORMAL
BESTlogic Expression: VOA=0					
VO1	Phase differential trip. OUT1 is a high-speed trip contact.	VO1 TRUE if restrained or unrestrained trip occurs.	87TRIP-VO1	TRIP	NORMAL
BESTlogic Expression: VO1=87RT+87UT					
VO4	Time overcurrent trip. May be used to direct trip main breaker or lockout.	VO4 TRUE if any time overcurrent (51N, 151P, N, or Q) trip occurs.	151TRIP-VO4	TRIP	NORMAL
BESTlogic Expression: VO4=51NT+151NT+151PT+151QT					

Output	Purpose	Description	Label	State Labels	
				True	False
VO5	Time overcurrent trip. May be used to direct trip main breaker or lockout.	VO5 TRUE if any time overcurrent (251P, N, or Q) trip occurs.	251TRIP-VO5	TRIP	NORMAL
BESTlogic Expression: VO5=251PT+251NT+251QT					
VO6	Used to annunciate an alarm.	VO6 TRUE when any programmed major alarm condition is TRUE.	MAJOR-ALARM	ALARM	NORMAL
BESTlogic Expression: VO6=ALMMAJ					
VO11	Protective Trip expression.	TRUE when any 87, 51N, 151, or 251 element trips.	PROTECT-TRIP	TRIP	NORMAL
BESTlogic Expression: VO11=87RT+87UT+151PT+251PT+51NT+151NT+251NT+151QT+251QT					
VO12	Protection Picked Up expression.	TRUE when any 87, 51N, 151, or 251 element picks up.	PROT-PICKED-UP	PU	NORMAL
BESTlogic Expression: VO12=87RPU+87UT+151PPU+251PPU+51NPU+151NPU+251NPU+151QPU+251QPU (Note: 87UT is included to trigger the fault recorder because there is no unrestrained pickup output.)					
VO13	Optional. Use to annunciate an alarm when alarm point 21 is enabled.	VO13 is TRUE when IN6 is TRUE.	IN6-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO13=IN6					
VO14	Optional. Use to annunciate an alarm when alarm point 22 is enabled.	VO14 is TRUE when IN7 is TRUE.	IN7-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO14=IN7					
VO15	Optional. Use to annunciate an alarm when alarm point 23 is enabled.	VO15 is TRUE when IN8 is TRUE.	IN8-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO15=IN8					

Table 8-6 . CDS240-BATX-A-BE Hardware Output Logic

Output	Purpose	Description
OUTA	Relay Trouble Alarm.	OUTA contact closes when relay trouble alarm occurs.
BESTlogic Expression: OUTA=VOA		
OUT1	Phase differential trip. OUT1 is a high-speed trip contact.	OUT1 contact closes if restrained or unrestrained trip occurs.
BESTlogic Expression: OUT1=VO1		
OUT2	Phase differential trip.	OUT2 contact closes if restrained or unrestrained trip occurs.
BESTlogic Expression: OUT2=VO1		
OUT3	Phase differential trip.	OUT3 contact closes if restrained or unrestrained trip occurs.
BESTlogic Expression: OUT3=VO1		

Output	Purpose	Description
OUT4	Time overcurrent trip. May be used to direct trip main breaker or lockout.	OUT4 contact closes if any time overcurrent (51N, 151P, N, or Q) trip occurs.
BESTlogic Expression: OUT4=VO4		
OUT5	Time overcurrent trip. May be used to direct trip main breaker or lockout.	OUT5 contact closes if any time overcurrent (251P, N, or Q) trip occurs.
BESTlogic Expression: OUT5=VO5		
OUT6	Used to annunciate an alarm.	OUT6 contact closes when any programmed major alarm condition is TRUE.
BESTlogic Expression: OUT6=VO6		
OUT7 - 14	Spare output contacts.	N/A
BESTlogic Expression: OUT7-14 =0		

Overview of Additional Preprogrammed Logic Schemes

The following preprogrammed logic schemes can be found in logic library of BESTCOMS for the CDS240 or at the Basler Electric Web site. Two of the logic schemes are intended for use on transformers. One of the schemes is for motor protection with a speed sensing input, one is for bus protection with backup, and one is a basic 87 function designed for multiple applications including transformer, motor, bus, or generator protection.

The 87 function as applied to transformer protection is fundamentally different from the application of the 87 function to motors, generators, and buses. That is, the 2^{nd} and 5^{th} harmonic restraint elements are required on transformer applications to prevent false tripping resulting from magnetizing inrush currents. However, waveform distortion resulting from heavy current transformer (CT) saturation can cause the harmonic restraint units to block restrained differential tripping (87RT) for internal faults. Therefore, a high-speed, unrestrained instantaneous differential element (87UT) is also required for transformer applications.

When the 87 protection element is applied to other than transformer protection, set the pickup thresholds for the 2^{nd}, 5^{th}, and 87UT units to 0 (setting disabled).

CDS240-BA87-B-BE (Basic Differential) Logic Scheme

This logic scheme (CDS240-BA87-B-BE) provides three-phase, percent-restrained differential protection, with high-speed unrestrained instantaneous differential protection for motor, generator, bus, and transformer applications. A single zone of time overcurrent phase, neutral and negative sequence protection (51P, N, and Q) is also included for backup protection.

CDS240-TXCL-B-BE (Basic Transformer with Control) Logic Scheme

This logic scheme (CDS240-TXCL-B-BE) provides the same differential and overcurrent protection elements as the basic transformer logic scheme but with different outputs and the addition of virtual control switch logic that can be operated locally or remotely (SCADA). The Virtual 101 Control Switch is applied for tripping and closing the low-side breaker, while 43 and 143 Control Switch elements are applied for tripping and closing the high-side breaker. Virtual Control Switch 243 is used to turn off the differential protection element and Virtual Control Switch 343 allows for automatic or manual selection of the active setting group.

CDS240-TXBU-B-BE (Transformer Differential with Backup) Logic Scheme

This logic (CDS240-TXBU-B-BE) incorporates nearly all the protection elements available in the BE1-CDS240. These include the differential functions with harmonic restraint as well as 51 phase, neutral, and negative-sequence backup protection as seen from the transformer high side. Also included is a separate 51N fed from an optional ground CT (IG), 50P N, and Q definite time bus protection as seen from the transformer low-side breaker, and low-side breaker BF (breaker failure) protection with fast current reset. A current supervised, external breaker failure initiate (BFI), 50/62, and a contact supervised BFI, 62 are also included. The 101 Virtual Control Switch is used to trip and close the low-side breaker while the Virtual

43 Switch is used to turn off the 87 function. Both virtual functions can be operated locally or remotely (SCADA).

CDS240-BSBU-A-BE (Bus Protection with Backup) Logic Scheme

This logic scheme (CDS240-BSBU-A-BE) provides a primary zone of high-speed, low impedance, bus differential protection and a backup zone of high-speed instantaneous overcurrent (bus interlocking) protection. Feeder circuit backup protection and overall backup protection from the bus main to the first down-line interrupting device for each feeder circuit are also provided.

The percent-restrained differential protection function is the only function of the 87 protection element required for this application. Set the pickup of the 2^{nd}, 5^{th}, and 87 unrestrained functions to 0 (setting disabled). The 87 unrestrained function has a setting only when the 2^{nd} and 5^{th} harmonic restraint functions are set for transformer applications (refer to the discussion in *Overview of Preprogrammed Logic Schemes*).

The 87 restrained element provides conventional high speed, low impedance, and bus differential protection. On feeder circuits using the 851 or 951 distribution feeder protection relays, the 50T, P, and Q elements from the BE1-CDS240 are hard wired to the feeder protection package, providing a high-speed backup, bus interlocked, zone of bus protection. When the BE1-CDS240 detects a feeder relay out of service, the BE1-CDS240 50/51P, N, and Q protection elements and outputs are automatically reconfigured to provide feeder protection. The 150/151P, N, and Q protection elements of the BE1-CDS240 are time coordinated with the bus and feeder circuit protection, providing overall backup protection from the transformer side of the bus main breaker through the first down-line interrupting device on the distribution circuit.

CDS240-MOTR-A-BE (Motor Protection) Logic Scheme

This logic scheme (CDS240-MOTR-A-BE) incorporates the essential differential and overcurrent protection elements that are ideally suited for large motor protection. The 87 restrained element provides high-speed differential fault protection. Sensitive instantaneous and time overcurrent, negative-sequence elements, 50TQ and 51Q are incorporated for open phase and phase imbalance protection. High-speed ground fault protection is accomplished with an instantaneous overcurrent element 50TN and the 51P and 251P elements provide motor overload and stall (jam) protection. Further protection, locked rotor protection and start/run detection for low and high inertia motors, is accomplished using a combination of instantaneous and time overcurrent phase elements, virtual logic switches, and a speed sensing input from the motor.

The percent-restrained differential protection function is the only function of the 87 protection element required for this application. Set the pickup of the 2^{nd}, 5^{th}, and 87 unrestrained functions to 0 (setting disabled). The 87 unrestrained function has a setting only when the 2^{nd} and 5^{th} harmonic restraint functions are set for transformer applications (refer to the discussion in *Overview of Preprogrammed Logic Schemes*).

Details of Additional Preprogrammed Logic Schemes

The following subsections describe each of the five additional logic library preprogrammed logic schemes in detail. For each scheme, operation of the protection, and control logic under normal conditions is described. The features of each logic scheme are broken down into functional groups and described in detail.

CDS240-BA87-B-BE (Basic Differential) Logic Scheme

The basic differential logic scheme (CDS240-BA87-B-BE) provides a primary zone of low-impedance, differential protection, and one backup zone of time overcurrent protection for transformer, generator, motor, and radial bus applications.

Figure 8-3 is a one-line drawing and Figure 8-4 is a logic drawing representing the logic settings and equations shown in Table 8-7. In Table 8-1, the user can see the protection and control elements that are enabled (set to logic 1) for the CDS240-BA87-B-BE application. They can also see how the elements are logically wired together (equations). If the user should decide to build on this scheme, all elements required for a more detailed application are available through programming. For programming details, refer to Section 7, *BESTlogic Programmable Logic.*

Table 8-7. CDS240-BA87-B-BE Logic Settings and Equations

SL-N=CDS240-BA87-B-BE,BASLER	SL-62=0,0,0
SL-87=1,0	SL-162=0,0,0
SL-87ND=0,0	SL-262=0,0,0
SL-187ND=0,0	SL-362=0,0,0
SL-50BF=0,0,0,0,0	SL-GROUP=1,0,0,0,0,/0
SL-150BF=0,0,0,0,0	SL-43=0
SL-250BF=0,0,0,0,0	SL-143=0
SL-350BF=0,0,0,0,0	SL-243=0
SL-50TP=0,0	SL-343=0
SL-50TN=0,0	SL-443=0
SL-50TQ=0,0	SL-543=0
SL-150TP=0,0	SL-643=0
SL-150TN=0,0	SL-743=0
SL-150TQ=0,0	SL-101=0
SL-250TP=0,0	SL-1101=0
SL-250TN=0,0	SL-2101=0
SL-250TQ=0,0	SL-3101=0
SL-350TP=0,0	SL-VOA=0
SL-350TN=0,0	SL-VO1=87RT+87UT
SL-350TQ=0,0	SL-VO2=0
SL-450TP=0,0	SL-VO3=0
SL-450TN=0,0	SL-VO4=51PT+51NT+51QT
SL-550TP=0,0	SL-VO5=0
SL-650TP=0,0	SL-VO6=ALMMAJ
SL-750TP=0,0	SL-VO7=0
SL-51P=1,0	SL-VO8=0
SL-51N=1,0	SL-VO9=0
SL-51Q=1,0	SL-VO10=0
SL-151P=0,0	SL-VO11=87RT+87UT+51PT+51NT+51QT
SL-151N=0,0	SL-VO12=87RPU+87UT+51PPU+51NPU+51QPU
SL-151Q=0,0	SL-VO13=IN6
SL-251P=0,0	SL-VO14=IN7
SL-251N=0,0	SL-VO15=IN8
SL-251Q=0,0	SL-OUTA=VOA
SL-351P=0,0	SL-OUT1=VO1
SL-351N=0,0	SL-OUT2=VO1
SL-351Q=0,0	SL-OUT3=VO1
SL-451N=0,0	SL-OUT4=VO4
SL-24=0,0	SL-OUT5=0
SL-27P=0,0	SL-OUT6=VO6
SL-127P=0,0	SL-OUT7=0
SL-47=0,0	SL-OUT8=0
SL-59P=0,0	SL-OUT9=0
SL-59X=0,0	SL-OUT10=0
SL-159P=0,0	SL-OUT11=0
SL-81=0,0	SL-OUT12=0
SL-181=0,0	SL-OUT13=0
SL-281=0,0	SL-OUT14=0
SL-381=0,0	
SL-481=0,0	
SL-581=0,0	

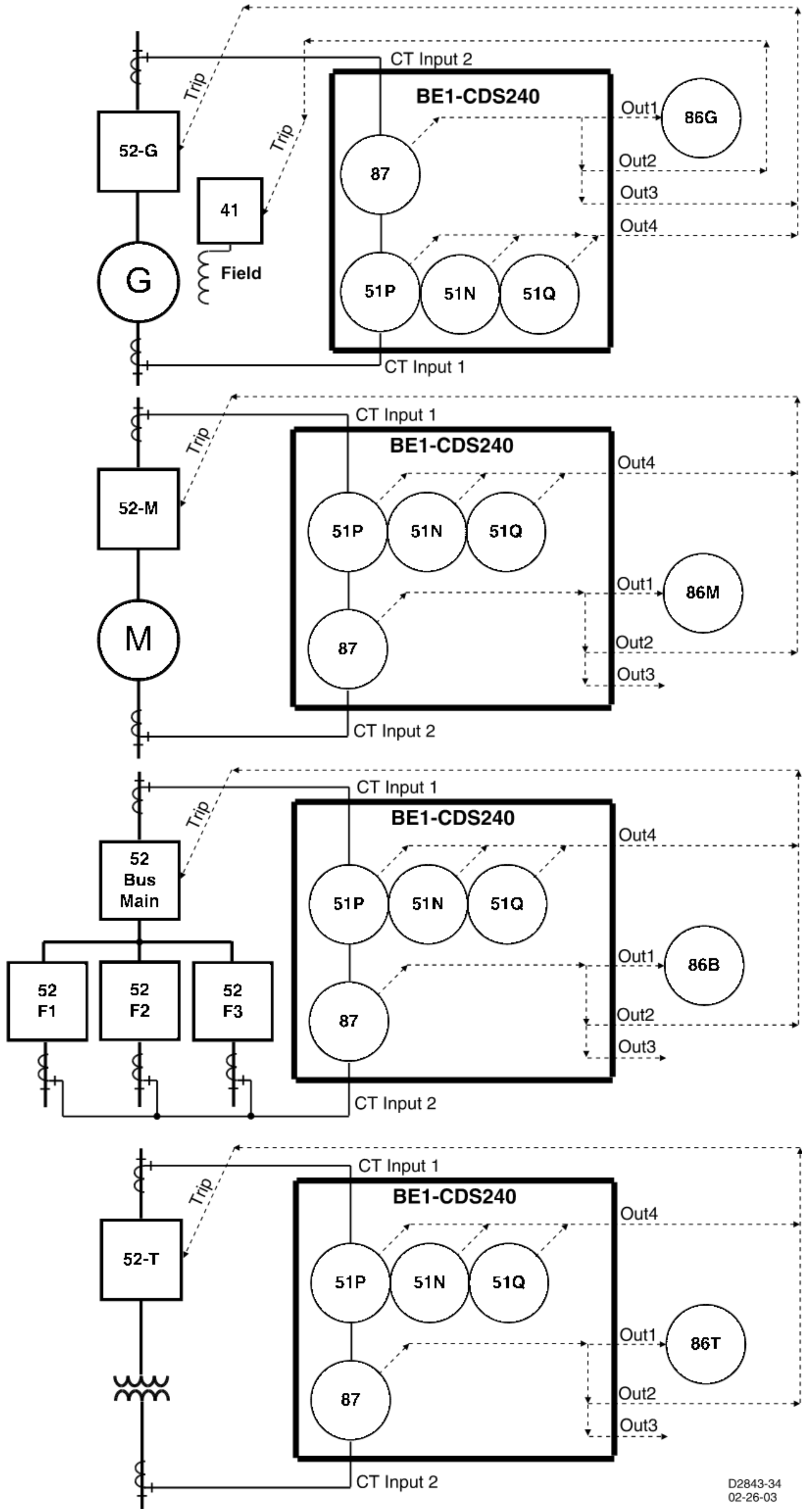

Figure 8-3. Typical One-line Diagram for CDS240-BA87-B-BE

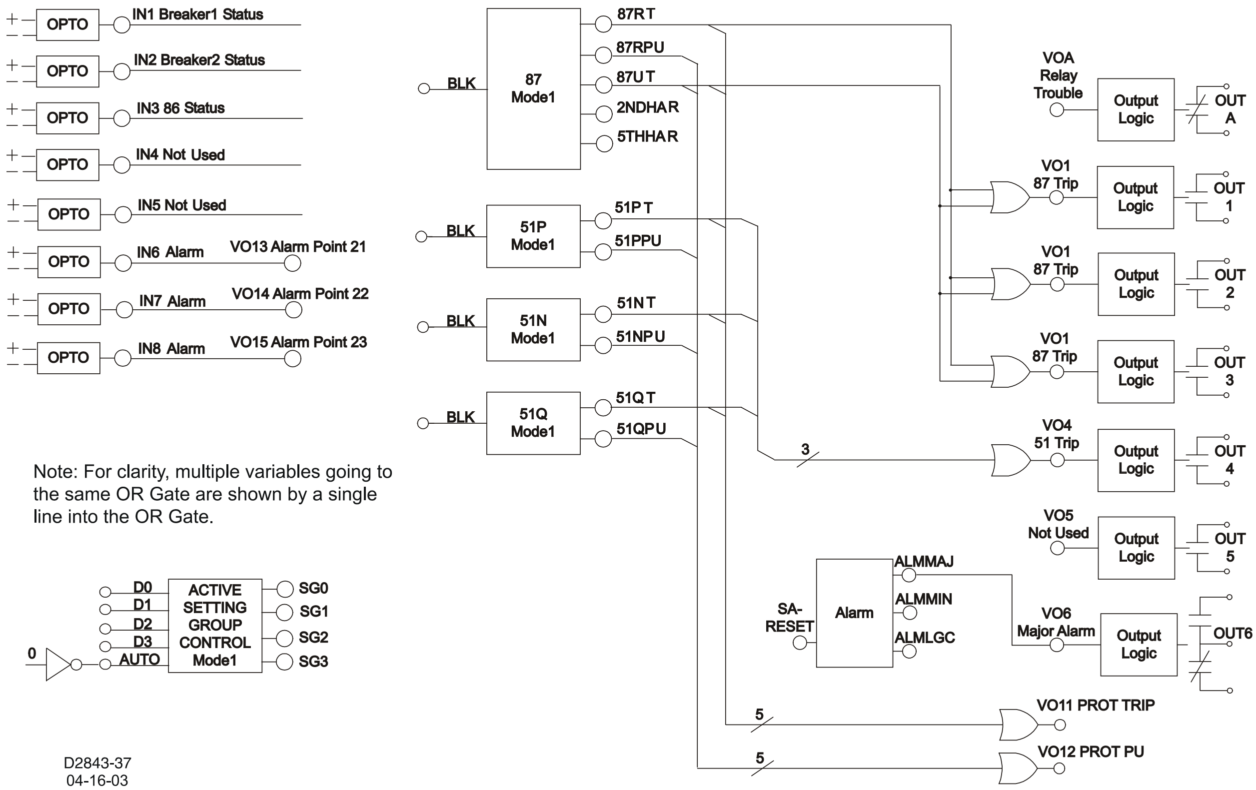

Figure 8-4. Typical Logic Diagram for CDS240-BA87-B-BE

Protection Elements

Referring to all four schemes (**G**enerator, **M**otor, **B**us, and **T**ransformer) in Figure 8-3, the 87 protection element is connected to CT input 1 and CT input 2. The 51 protection element is also connected to the CT input 1. The 87 and 51 protection elements are logic enabled by the programming shown in Table 8-3 to provide a trip through the BE1-CDS240 output contacts.

Typically, the 87 protection element provides high-speed percent restrained, phase and ground protection for faults inside the differential zone. For the generator, motor, and bus applications shown in Figure 8-3, the percent-restrained differential protection function is the only function of the 87 protection element required. Set the pickup of the 2^{nd}, 5^{th}, and 87 unrestrained functions to 0 (setting disabled). The 87 restrained function has a setting when the 2^{nd} and 5^{th} harmonic restraint functions are set for the transformer application shown in Figure 8-1 (refer to the discussion in *Overview Of Preprogrammed Logic Schemes*).

Typically, the 51 protection element is coordinated with down-line protection devices to provide overlapping Phase, Neutral, and Negative-Sequence timed backup protection for zones beyond the equipment being protected. In the low impedance, bus application, the 51 protection element must coordinate with the feeder protection of the circuits connected to the bus.

Integration of Protection, Control, and I/O Elements

The logic settings in Table 8-3 also include the logic equations that connect the various elements of the basic differential scheme. For example, the three underlined commands in the equations of Table 8-7 provide the electrical connection between the 87 element (trip enabled by the settings) and trip outputs 1, 2 and 3. Referring to Figures 8-3 and 8-4, the 87 protection element trips through Outputs 1, 2, and 3. The user can apply any or all of the outputs. The 51 protection element (also trip enabled by the settings) trips through Output 4. There are no virtual switches used in this application.

Control of the active setting group can be manual or automatic. For the CDS240-BA87-A-BE application, setting group control is programmed for continuous automatic operation because the /0 (not 0), logic 1 is applied to the AUTO input of the Active Setting Group Control Logic as shown in Figure 8-4.

Alarms

Three logic variables drive the front panel LEDs: Relay Trouble (ALMREL), Major Alarm (ALMMAJ), and Minor Alarm (ALMMIN). A fourth logic variable, Logic Alarm (ALMLGC), has no associated front panel LED. When the relay self-test detects a problem in the relay (ALMREL) as programmed for the CDS240-BA87-

A-BE scheme, the Relay Trouble LED lights, output A operates, and all other outputs are disabled. When a Major Alarm is detected (ALMMAJ), the associated LED lights and output six operates. When a Minor Alarm (ALMMIN) is detected, the associated LED lights, but in this scheme, no output relay is programmed to operate.

NOTE

Tables 8-8 through 8-12 provide detailed logic definitions for the inputs, outputs, protection, and control elements. Only those inputs, logic blocks, virtual switches, and outputs in use for the CDS240-BA87-B-BE preprogrammed logic are described in the following tables.

Table 8-8. CDS240-BA87-B-BE Contact Input Logic

Input	Purpose	Name Label	State Labels	
			Energized	De-Energized
IN1	Optional input. Used for CT input circuit 1 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-1	CLOSED	OPEN
IN2	Optional input. Used for CT input circuit 2 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-2	CLOSED	OPEN
IN3	Optional input. Used for 86 status indication in SER reports. TRUE when 86 is tripped.	86-TRIPPED	TRIPPED	NORMAL
IN6 - IN8	Optional inputs. Used for programmable alarms and SER reporting. For example, sudden pressure trip or transformer hot spot alarm, etc. Drives VO13 - VO15 that are programmable alarm points 21 - 23. Label inputs as appropriate.	INPUT_6, INPUT_7, INPUT_8	CLOSED	OPEN

Table 8-9. CDS240-BA87-B-BE Function Block Logic

Function	Purpose	BESTlogic Expression	Mode Setting
87	Used for percent-restrained differential protection with high-speed unrestrained instantaneous differential protection.	0	1 (enabled)
51P	Used for timed phase overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
51N	Used for timed neutral overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
51Q	Used for timed negative-sequence overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
GROUP	*Input 0 Logic:* No manual selection logic is used.	0	1 (Discrete Inputs)
	Input 1 Logic: No manual selection logic is used.	0	
	Input 2 Logic: No manual selection logic is used.	0	
	Input 3 Logic: No manual selection logic is used.	0	
	Auto/Manual Logic: Set to 1 (/0) to enable automatic selection. No manual selection is used.	/0	

Table 8-10. CDS240-BA87-B-BE Virtual Switch Logic

Switch	Purpose	Mode	Label	State Labels	
				True	False
N/A	No virtual switches used.	N/A	N/A	N/A	N/A

Table 8-11. CDS240-BA87-B-BE Virtual Output Logic

Output	Purpose	Description	Label	State Labels	
				True	False
VOA	Relay Trouble Alarm.	VOA TRUE if relay trouble alarm occurs.	RELAY-TROUBLE	ACTIVE	NORMAL
BESTlogic Expression: VOA=0					
VO1	Phase differential trip. OUT1 is a high-speed trip contact.	VO1 TRUE if restrained or unrestrained trip occurs.	87TRIP	TRIP	NORMAL
BESTlogic Expression: VO1=87RT+87UT					
VO4	Time overcurrent trip. May be used to direct trip main breaker or lockout.	VO4 TRUE if any time overcurrent (51P, N, or Q) trip occurs.	51TRIP	TRIP	NORMAL
BESTlogic Expression: VO4=51PT+51NT+51QT					
VO6	Used to annunciate an alarm.	VO6 TRUE when any programmed major alarm condition is TRUE.	MAJOR-ALARM	ALARM	NORMAL
BESTlogic Expression: VO6=ALMMAJ					
VO11	Protective Trip expression.	TRUE when any 87 or 51 element trips.	PROTECTIVE-TRIP	TRIP	NORMAL
BESTlogic Expression: VO11=87RT+87UT+51PT+51NT+51QT					
VO12	Protection Picked Up expression.	TRUE when any 87 or 51 element picks up.	PROT-PICKED-UP	PU	NORMAL
BESTlogic Expression: VO12=87RPU+87UT+51PPU+51NPU+51QPU (Note: 87UT is included to trigger the fault recorder because there is no unrestrained pickup output.)					
VO13	Optional. Use to annunciate an alarm when alarm point 21 is enabled.	VO13 is TRUE when IN6 is TRUE.	IN6-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO13=IN6					
VO14	Optional. Use to annunciate an alarm when alarm point 22 is enabled.	VO14 is TRUE when IN7 is TRUE.	IN7-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO14=IN7					
VO15	Optional. Use to annunciate an alarm when alarm point 23 is enabled.	VO15 is TRUE when IN8 is TRUE.	IN8-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO15=IN8					

Table 8-12. CDS240-BA87-B-BE Hardware Output Logic

Output	Purpose	Description
OUTA	Relay Trouble Alarm.	OUTA contact closes when relay trouble alarm occurs.
BESTlogic Expression: OUTA=VOA		
OUT1	Phase differential trip. OUT1 is a high-speed trip contact.	OUT1 contact closes if restrained or unrestrained trip occurs.
BESTlogic Expression: OUT1=VO1		
OUT2	Phase differential trip.	OUT2 contact closes if restrained or unrestrained trip occurs.
BESTlogic Expression: OUT2=VO1		
OUT3	Phase differential trip.	OUT3 contact closes if restrained or unrestrained trip occurs.
BESTlogic Expression: OUT3=VO1		
OUT4	Time overcurrent trip. May be used to direct trip main breaker or lockout.	OUT4 contact closes if any time overcurrent (51P, N, or Q) trip occurs.
BESTlogic Expression: OUT4=VO4		
OUT5	Spare output contact.	N/A
BESTlogic Expression: OUT5=0		
OUT6	Used to annunciate an alarm.	OUT6 contact closes when any programmed major alarm condition is TRUE.
BESTlogic Expression: OUT6=VO6		
OUT7 - 14	Spare output contacts.	N/A
BESTlogic Expression: OUT7-14 =0		

CDS240-TXCL-B-BE (Basic Transformer with Control) Logic Scheme

The Basic Transformer With Control Logic (CDS240-TXCL-B-BE) scheme was designed to provide a primary zone of differential relaying and three backup zones of time overcurrent relaying for phase and ground faults in two-winding transformer applications. This scheme also uses virtual control switch logic to eliminate the need for external control switches.

The control switch elements are referred to as virtual because they have no physical form. These elements exist only in logic form and they can only be operated via the ASCII command interface or by the front panel HMI. The virtual 101 switch is used to trip and close the transformer low-side breaker. Virtual Control Switches 43 and 143 are used to trip and close the transformer high-side breaker. Virtual Control Switch 243 turns off the 87 protection element and 343 selects whether the setting group control is automatic or manual.

Figure 8-5 is a one-line drawing and Figure 8-6 is a logic drawing that represents the logic settings shown in Table 8-13. In Table 8-13, the user can see the protection and control elements that are enabled for the CDS240-TXCL-B-BE application and how the elements are logically wired together (equations). If the user should decide to build on this scheme, all elements required for a more detailed application are available through programming. For programming details, refer to Section 7, *BESTlogic Programmable Logic.*

Table 8-13. CDS240-TXCL-B-BE Logic Settings and Equations

SL-N=CDS240-TXCL-B-BE,BASLER
SL-87=1,243
SL-87ND=0,0
SL-187ND=0,0
SL-50BF=0,0,0,0,0
SL-150BF=0,0,0,0,0
SL-250BF=0,0,0,0,0
SL-350BF=0,0,0,0,0
SL-50TP=0,0
SL-50TN=0,0
SL-50TQ=0,0
SL-150TP=0,0
SL-150TN=0,0
SL-150TQ=0,0
SL-250TP=0,0
SL-250TN=0,0
SL-250TQ=0,0
SL-350TP=0,0
SL-350TN=0,0
SL-350TQ=0,0
SL-450TP=0,0
SL-450TN=0,0
SL-550TP=0,0
SL-650TP=0,0
SL-750TP=0,0
SL-51P=0,0
SL-51N=G,0
SL-51Q=0,0
SL-151P=1,0
SL-151N=1,0
SL-151Q=1,0
SL-251P=2,0
SL-251N=2,0
SL-251Q=2,0
SL-351P=0,0
SL-351N=0,0
SL-351Q=0,0
SL-451N=0,0
SL-24=0,0
SL-27P=0,0
SL-127P=0,0
SL-47=0,0
SL-59P=0,0
SL-59X=0,0
SL-159P=0,0
SL-81=0,0
SL-181=0,0
SL-281=0,0
SL-381=0,0
SL-481=0,0
SL-581=0,0
SL-62=0,0,0
SL-162=0,0,0
SL-262=0,0,0
SL-362=0,0,0
SL-GROUP=1,0,0,0,0,/343
SL-43=3
SL-143=3
SL-243=2
SL-343=2
SL-443=0
SL-543=0
SL-643=0
SL-743=0
SL-101=1
SL-1101=0
SL-2101=0
SL-3101=0
SL-VOA=0
SL-VO1=87RT+87UT+151PT+51NT+151NT+151QT
SL-VO2=87RT+87UT+151PT+51NT+151NT+151QT+43
SL-VO3=/IN3*143
SL-VO4=87RT+87UT+101T+251PT+251NT+251QT
SL-VO5=/IN3*101C
SL-VO6=ALMMAJ
SL-VO7=0
SL-VO8=0
SL-VO9=0
SL-VO10=0
SL-VO11=87RT+87UT+151PT+251PT+51NT+151NT+251NT+151QT+251QT
SL-VO12=87RPU+87UT+151PPU+251PPU+51NPU+151NPU+251NPU+151QPU+251QPU
SL-VO13=243
SL-VO14=IN7
SL-VO15=IN8
SL-OUTA=VOA
SL-OUT1=VO1
SL-OUT2=VO2
SL-OUT3=VO3
SL-OUT4=VO4
SL-OUT5=VO5
SL-OUT6=VO6
SL-OUT7=0
SL-OUT8=0
SL-OUT9=0
SL-OUT10=0
SL-OUT11=0
SL-OUT12=0
SL-OUT13=0
SL-OUT14=0

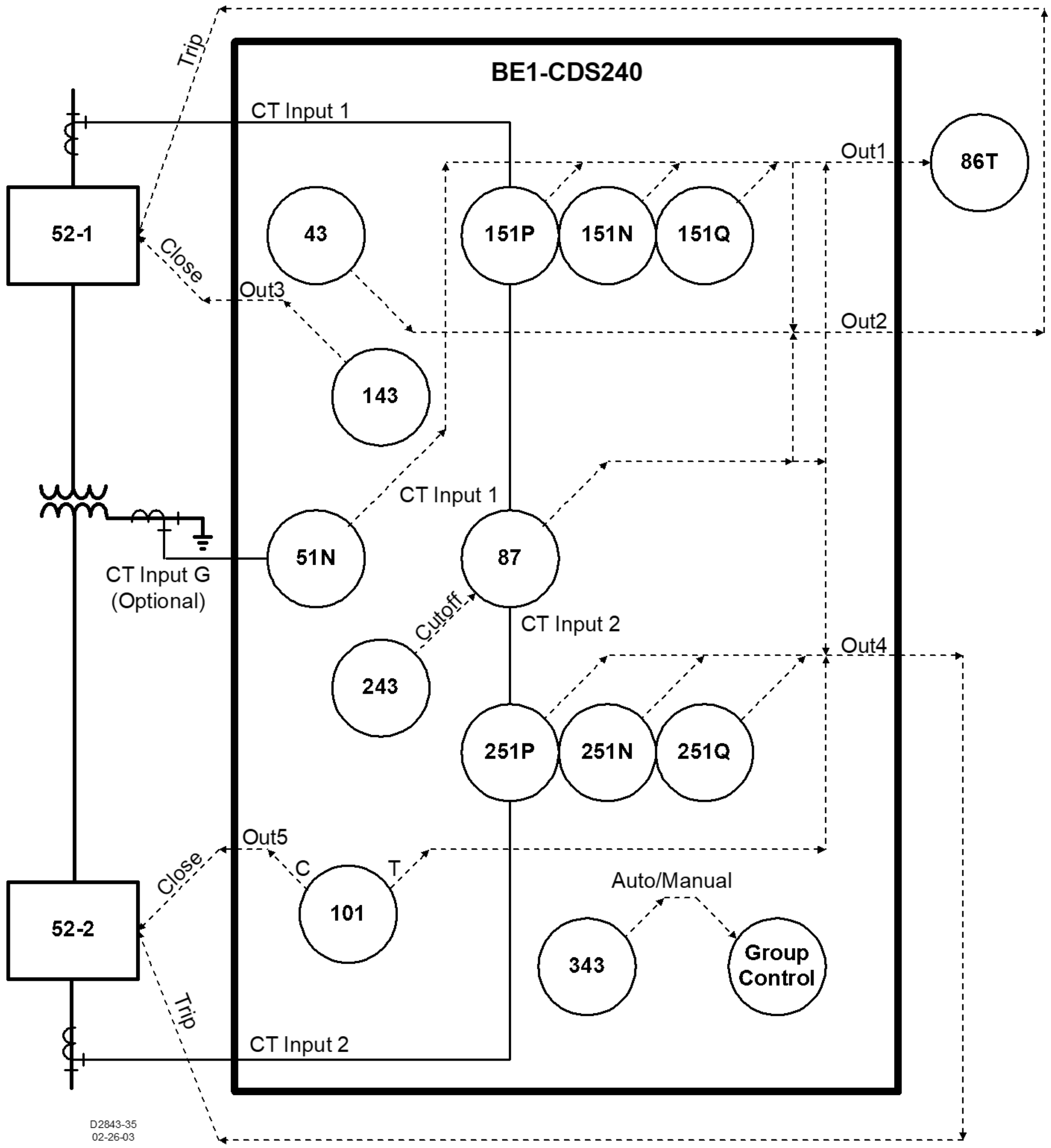

Figure 8-5. Typical One-line Diagram for CDS240-TXCL-B-BE

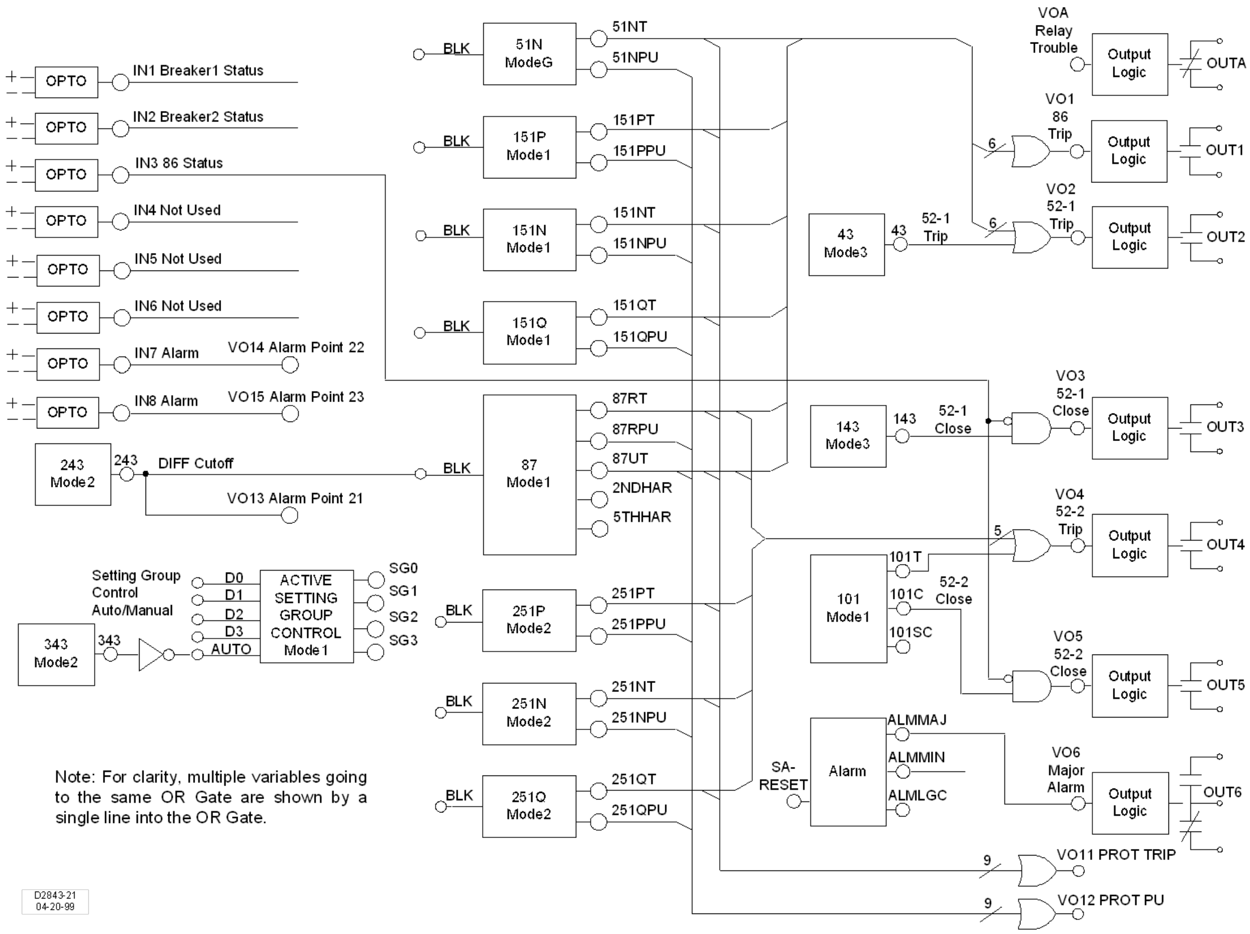

Figure 8-6. Typical Logic Diagram for CDS240-TXCL-B-BE

Protection Elements

Referring to Figure 8-5, the 87 and 151 protection elements are connected to the high-side CT, input 1. The 87 and 251 protection elements are connected to the low-side CT, input 2. The 51 protection element (N only) is connected to a ground CT at the grounded side of a delta-wye transformer. The ground input (G) is an option on the BE1-CDS240 and must be ordered. Paralleled CTs inside a delta tertiary (3Io) can also feed the 51N. The 87, 51, 151, and 251 protection elements are logic enabled to provide a trip through the BE1-CDS240 outputs. Protection elements set at 0 are setting disabled and will not provide a trip output, even if logic enabled.

Typically, the BE1-CDS240 would be applied with a BE1-851 or BE1-951 multifunction overcurrent relay to provide independent, overlapping, backup protection in the event of a common mode failure. The 87 protection element provides high-speed restrained differential and unrestrained differential phase and ground protection for faults inside the differential zone. At the same time, it provides security against mis-operations resulting from transformer inrush by restraining and preventing a trip in the presence of 2nd and 5th harmonics.

Typically, the 151 protection element is coordinated with the low-side bus protection to provide Phase, Neutral, and Negative Sequence timed backup protection for the low-side bus if the bus protection is out of service.

Typically, the 251 protection element is coordinated with the low-side feeder protection to provide Phase, Neutral, and Negative Sequence timed backup protection for feeder faults if the feeder protection is out of service.

Typically, the 51N protection element is coordinated with the low-side bus and feeder protection to provide Neutral (ground) timed backup protection for transformer low-side, bus, and feeder ground faults if any primary zone of protection is of service.

Integration of Protection, Control, and I/O Elements

The logic settings in Table 8-13 also include the logic equations that establish the control connections between elements of the CDS240-TXCL-B-BE scheme. For example, the three underlined commands in the logic equations of Table 8-13 provide the electrical connection between the 87 element (trip enabled by the settings) and trip outputs 1, 2, and 4. Referring to Figures 8-5 and 8-6, the 87 protection element trips through Outputs 1, 2, and 4. The 151 and 51N protection elements (also trip enabled by the settings) trip through Outputs 1 and 2 while the 251 protective element (also trip enabled by the settings) trips through Output 4. Protection elements set at 0 are setting disabled and will not provide a trip output even if logic enabled.

Virtual control switch elements enabled for use in this scheme are 101, 43, 143, 243, and 343. The 101 Control Switch trips the low-side breaker through Output 4 and closes the low-side breaker through Output 5 if IN3 (86 input) is not TRUE. The high-side breaker is tripped by 43 through Output 2 and closed by 143 through Output 3 if IN3 (86 input) is not TRUE. Control Switch 243 is used to turn the 87 function on or off.

Control of the active setting group can be manual or automatic. For the CDS240-TXCL-B-BE application, setting group control is enabled for discrete input and automatic or manual control as determined by the position of Virtual Switch 343.

Alarms

Three logic variables drive the front panel LEDs: Relay Trouble (ALMREL), Major Alarm (ALMMAJ), and Minor Alarm (ALMMIN). A fourth logic variable, Logic Alarm (ALMLGC), has no associated front panel LED. When the relay self-test detects a problem in the relay (ALMREL) as programmed for the CDS240-TXCL-A-BE scheme, the Relay Trouble LED lights, Output A operates and all outputs are disabled. When a Major Alarm is detected (ALMMAJ), the associated LED lights and Output 6 operates. When a Minor Alarm (ALMMIN) is detected, the associated LED lights. But in this scheme, no output relay is programmed to operate.

NOTE

Tables 8-14 through 8-18 provide detailed logic definitions for the inputs, outputs, protection, and control elements. Only those inputs, logic blocks, virtual switches, and outputs in use for the CDS240-TXCL-B-BE preprogrammed logic are described in the following tables.

Table 8-14. CDS240-TXCL-B-BE Contact Input Logic

Input	Purpose	Name Label	State Labels	
			Energized	De-Energized
IN1	Optional input. Used for CT input circuit 1 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-1	CLOSED	OPEN
IN2	Optional input. Used for CT input circuit 2 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-2	CLOSED	OPEN
IN3	Optional input. Used for 86 status indication and locks out the low-side and high-side breakers when TRUE. TRUE when 86 tripped.	86-TRIPPED	TRIPPED	NORMAL
IN7, IN8	Optional inputs. Used for programmable alarms and SER reporting. For example, sudden pressure trip or transformer hot spot alarm, etc. Drives VO14 and VO15 that are programmable alarm points 22 and 23. Label inputs as appropriate.	INPUT_7, INPUT_8	CLOSED	OPEN

Table 8-15. CDS240-TXCL-B-BE Function Block Logic

Function	Purpose	BESTlogic Expression	Mode Setting
87	Used for percent-restrained differential protection with high-speed unrestrained instantaneous differential protection. Differential function is blocked when Virtual Switch 243 is TRUE.	243	1 (enabled)
51N	Used for timed ground overcurrent protection for independent ground input circuit.	0	G (Ground Input)
151P	Used for timed phase overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
151N	Used for timed neutral overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
151Q	Used for timed negative-sequence overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
251P	Used for timed phase overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
251N	Used for timed neutral overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
251Q	Used for timed negative-sequence overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
GROUP	*Input 0 Logic:* No manual selection logic is used.	0	1 (Discrete Inputs)
	Input 1 Logic: No manual selection logic is used.	0	
	Input 2 Logic: No manual selection logic is used.	0	
	Input 3 Logic: No manual selection logic is used.	0	
	Auto/Manual Logic: Disable automatic selection when virtual switch 343 is in the MANUAL position.	/343	

Table 8-16. CDS240-TXCL-B-BE Virtual Switch Logic

Switch	Purpose	Mode	Label	State Labels	
				True	False
43	Trip high-side breaker (1).	3 (Off/Momentary On)	BREAKER1-TRIP	TRIP	NORMAL
143	Close low-side breaker (1)	3 (Off/Momentary On)	BREAKER1-CLOSE	CLOSE	NORMAL
243	Differential Cutoff switch. The 87 function is blocked when the switch is closed.	2 (On/Off)	87-CUTOFF	DISABLD	NORMAL
343	Automatic setting group change logic auto/manual switch.	2 (On/Off)	SETGRP-CONTROL	MANUAL	AUTO
101	Allows breaker to be tripped or closed manually from HMI or ASCII command interface.	1 (enabled)	N/A	N/A	N/A

Table 8-17. CDS240-TXCL-B-BE Virtual Output Logic

<table>
<tr><th rowspan="2">Output</th><th rowspan="2">Purpose</th><th rowspan="2">Description</th><th rowspan="2">Label</th><th colspan="2">State Labels</th></tr>
<tr><th>True</th><th>False</th></tr>
<tr><td>VOA</td><td>Relay Trouble Alarm.</td><td>VOA TRUE if relay trouble alarm occurs.</td><td>RELAY-TROUBLE</td><td>ACTIVE</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VOA=0</td></tr>
<tr><td>VO1</td><td>Phase differential trip. OUT1 is a high-speed trip contact.</td><td>VO1 TRUE if restrained, unrestrained, or time overcurrent trip occurs.</td><td>TRIP_86T</td><td>TRIP</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VO1=87RT+87UT+151PT+51NT+151NT+151QT</td></tr>
<tr><td>VO2</td><td>Breaker 1 Trip.</td><td>VO2 TRUE if restrained, unrestrained, 51, 151, or 43 virtual switch trip occurs.</td><td>TRIP-BKR1</td><td>TRIP</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VO2=87RT+87UT+151PT+51NT+151NT+151QT+43</td></tr>
<tr><td>VO3</td><td>Breaker 1 Close.</td><td>VO3 TRUE if virtual control switch is TRUE and 86 lockout is not tripped.</td><td>CLOSE-BKR1</td><td>CLOSE</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VO3=/IN3*143</td></tr>
<tr><td>VO4</td><td>Breaker 2 Trip.</td><td>VO4 TRUE if restrained, unrestrained, or any 251 time overcurrent trip occurs, or 101T (tripped) is TRUE.</td><td>TRIP-BKR2</td><td>TRIP</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VO4=87RT+87UT+101T+251PT+251NT+251QT</td></tr>
<tr><td>VO5</td><td>Breaker 2 Close.</td><td>VO5 TRUE if breaker control switch 101C is TRUE (closed) and 86 lockout is not tripped.</td><td>CLOSE-BKR2</td><td>CLOSE</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VO5=/IN3*101C</td></tr>
<tr><td>VO6</td><td>Used to annunciate an alarm by contact closure or opening if any of the conditions programmed as a major programmable alarm is TRUE.</td><td>VO6 TRUE when any programmed major alarm condition is TRUE.</td><td>MAJOR-ALARM</td><td>ALARM</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VO6=ALMMAJ</td></tr>
<tr><td>VO11</td><td>Protective Trip expression.</td><td>TRUE when any 87, 51N, 151, or 251 element trips.</td><td>PROTECTIVE-TRIP</td><td>TRIP</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VO11=87RT+87UT+151PT+251PT+51NT+151NT+251NT+151QT+251QT</td></tr>
<tr><td>VO12</td><td>Protection Picked Up expression.</td><td>TRUE when any 87, 51N, 151, or 251 element picks up.</td><td>PROT-PICKED-UP</td><td>PU</td><td>NORMAL</td></tr>
<tr><td colspan="6">BESTlogic Expression: VO12=87RPU+87UT+151PPU+251PPU+51NPU+151NPU+251NPU+151QPU+251QPU
(Note: 87UT is included to trigger the fault recorder because there is no unrestrained pickup output.)</td></tr>
</table>

Output	Purpose	Description	Label	State Labels	
				True	False
VO13	Alarm to indicate that differential cutoff switch operation is being blocked. This can be used as a programmable alarm by enabling alarm point 21. The programmable Variable Label will be displayed on the alarm report when TRUE.	VO13 is TRUE when Virtual Switch 243 is in the TRUE position.	87-BLOCKED	ACTIVE	NORMAL
BESTlogic Expression: VO13=243					
VO14	Optional. Use to annunciate an alarm when alarm point 22 is enabled.	VO14 is TRUE when IN7 is TRUE.	IN7-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO14=IN7					
VO15	Optional. Use to annunciate an alarm when alarm point 23 is enabled.	VO15 is TRUE when IN8 is TRUE.	IN8-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO15=IN8					

Table 8-18. CDS240- TXCL-B-BE Hardware Output Logic

Output	Purpose	Description
OUTA	Relay Trouble Alarm.	OUTA contact closes when relay trouble alarm occurs.
BESTlogic Expression: OUTA=VOA		
OUT1	Phase differential trip. OUT1 is a high-speed trip contact.	OUT1 contact closes if restrained, unrestrained, 51, or 151 trip occurs.
BESTlogic Expression: OUT1=VO1		
OUT2	Breaker 1 Trip.	OUT2 contact closes if restrained, unrestrained, 51, 151, or 43 virtual switch trip occurs.
BESTlogic Expression: OUT2=VO2		
OUT3	Breaker 1 Close.	OUT3 contact closes if virtual control switch is TRUE and 86 lockout is not tripped.
BESTlogic Expression: OUT3=VO3		
OUT4	Breaker 2 Trip.	OUT4 contact closes if restrained, unrestrained, or any 251 time overcurrent trip occurs, or 101T (tripped) is TRUE.
BESTlogic Expression: OUT4=VO4		
OUT5	Breaker 2 Close.	OUT5 contact closes if breaker control switch 101C is TRUE (closed) and 86 lockout is not tripped.
BESTlogic Expression: OUT5=VO5		
OUT6	Used to annunciate an alarm.	OUT6 contact closes when any programmed major alarm condition is TRUE.
BESTlogic Expression: OUT6=VO6		
OUT7 - 14	Spare output contacts.	N/A
BESTlogic Expression: OUT7-14 =0		

CDS240-TXBU-B-BE (Transformer Diff with Backup) Logic Scheme

The Transformer With Backup (CDS240-TXBU-B-BE) scheme was designed to provide high-speed phase and ground fault protection for a two-winding transformer and definite time backup protection for the associated low-side bus (similar to the BE1-851 BUS and BACKUP Logic Scheme). Figure 8-7 shows the interconnection of the BE1-851 or BE1-951 relays providing bus and feeder protection with a BE1-CDS240 (CDS240-TXBU-B-BE) providing backup transformer protection. The CDS240-TXBU-B-BE scheme also includes a low-side breaker BF (breaker failure) protection element with fast current reset. Current and contact supervised external breaker failure initiates (BFI) are included for the low-side breaker BF element. Virtual control switch logic is used for local or remote (SCADA) control and can be used to replace the equivalent panel control switch. See the paragraphs on *BUS WITH BACKUP SCHEME*, in this section for an interconnection of BE1-851 or BE1-951 relays providing feeder protection with BE1-CDS240 relays providing bus protection (CDS240-BSBU-A-BE) and transformer protection (CDS240-TXBU-B-BE).

The control switch elements are referred to as virtual because they have no physical form, they exist only in logic form, and they can only be operated via the ASCII command interface or the front panel HMI. The Virtual 101 Switch is used to trip and close the transformer low-side breaker, and 743 are used to select test mode enable. The user may choose to eliminate the use of external switches, as the virtual switches are fully functional equivalents of their physical counterparts.

Figure 8-7 is a logic drawing that represents the logic settings and equations shown in Table 8-19, Figure 8-8 is a Device Interconnection for Integrated Protection System, and Figure 8-9 is a one-line drawing. In Table 8-19, the user can see the protection and control elements that are enabled for the CDS240-TXBU-B-BE application and how the elements are logically wired together (equations). If the user should decide to build on this scheme, all elements required for a more detailed application are available through programming. For programming details, refer to Section 7, *BESTlogic Programmable Logic.*

Table 8-19. CDS240-TXBU-B-BE Logic Settings and Equations

SL-N=CDS240-TXBU-B-BE,BASLER	SL-351P=0,0
SL-87=1,43	SL-351N=0,0
SL-87ND=0,0	SL-351Q=0,0
SL-187ND=0,0	SL-451N=0,0
SL-50BF=0,0,0,0,0	SL-24=0,0
SL-150BF=1,VO10,0,IN2,VO15	SL-27P=0,0
SL-250BF=0,0,0,0,0	SL-127P=0,0
SL-350BF=0,0,0,0,0	SL-47=0,0
SL-50TP=2,0	SL-59P=0,0
SL-50TN=2,0	SL-59X=0,0
SL-50TQ=2,0	SL-159P=0,0
SL-150TP=0,0	SL-81=0,0
SL-150TN=0,0	SL-181=0,0
SL-150TQ=0,0	SL-281=0,0
SL-250TP=2,0	SL-381=0,0
SL-250TN=2,0	SL-481=0,0
SL-250TQ=2,0	SL-581=0,0
SL-350TP=0,0	SL-62=1,VO9,VO15
SL-350TN=0,0	SL-162=0,0,0
SL-350TQ=0,0	SL-262=0,0,0
SL-450TP=0,0	SL-362=0,0,0
SL-450TN=0,0	SL-GROUP=2,/IN5,0,0,0,0
SL-550TP=0,0	SL-43=2
SL-650TP=0,0	SL-143=0
SL-750TP=0,0	SL-243=0
SL-51P=0,0	SL-343=0
SL-51N=G,0	SL-443=0
SL-51Q=0,0	SL-543=0
SL-151P=1,0	SL-643=0
SL-151N=1,0	SL-743=2
SL-151Q=1,0	SL-101=1
SL-251P=2,0	SL-1101=0
SL-251N=2,0	SL-2101=0
SL-251Q=2,0	SL-3101=0
SL-VOA=0	SL-OUTA=VOA

SL-VO1=87RT+87UT+151PT+51NT+151NT+151QT
SL-VO2=250TPT+250TNT+250TQT
SL-VO3=BFT2+62
SL-VO4=87RT+87UT+BFRT2+VO9+101T+251PT+
251NT+251QT
SL-VO5=/IN3*/IN4*101C
SL-VO6=/IN5
SL-VO7=0
SL-VO8=0
SL-VO9=87RT*IN2*/VO15+IN2*87UT*/VO15+
IN2*IN6*/VO15
SL-VO10=VO11+50TPPU*IN7+50TNPU*IN7+
IN7*50TQPU
SL-VO11=250TPT+250TNT+87RT+87UT+250TQT+
151PT+251PT+51NT+151NT+251NT+151QT+251QT
SL-VO12=250TPPU+250TNPU+87RPU+87UT+
250TQPU+151PPU+251PPU+51NPU+151NPU+
251NPU+151QPU+251QPU
SL-VO13=43
SL-VO14=0
SL-VO15=/IN8+743

SL-OUT1=VO1
SL-OUT2=VO2
SL-OUT3=VO3
SL-OUT4=VO4
SL-OUT5=VO5
SL-OUT6=VO6
SL-OUT7=0
SL-OUT8=0
SL-OUT9=0
SL-OUT10=0
SL-OUT11=0
SL-OUT12=0
SL-OUT13=0
SL-OUT14=0

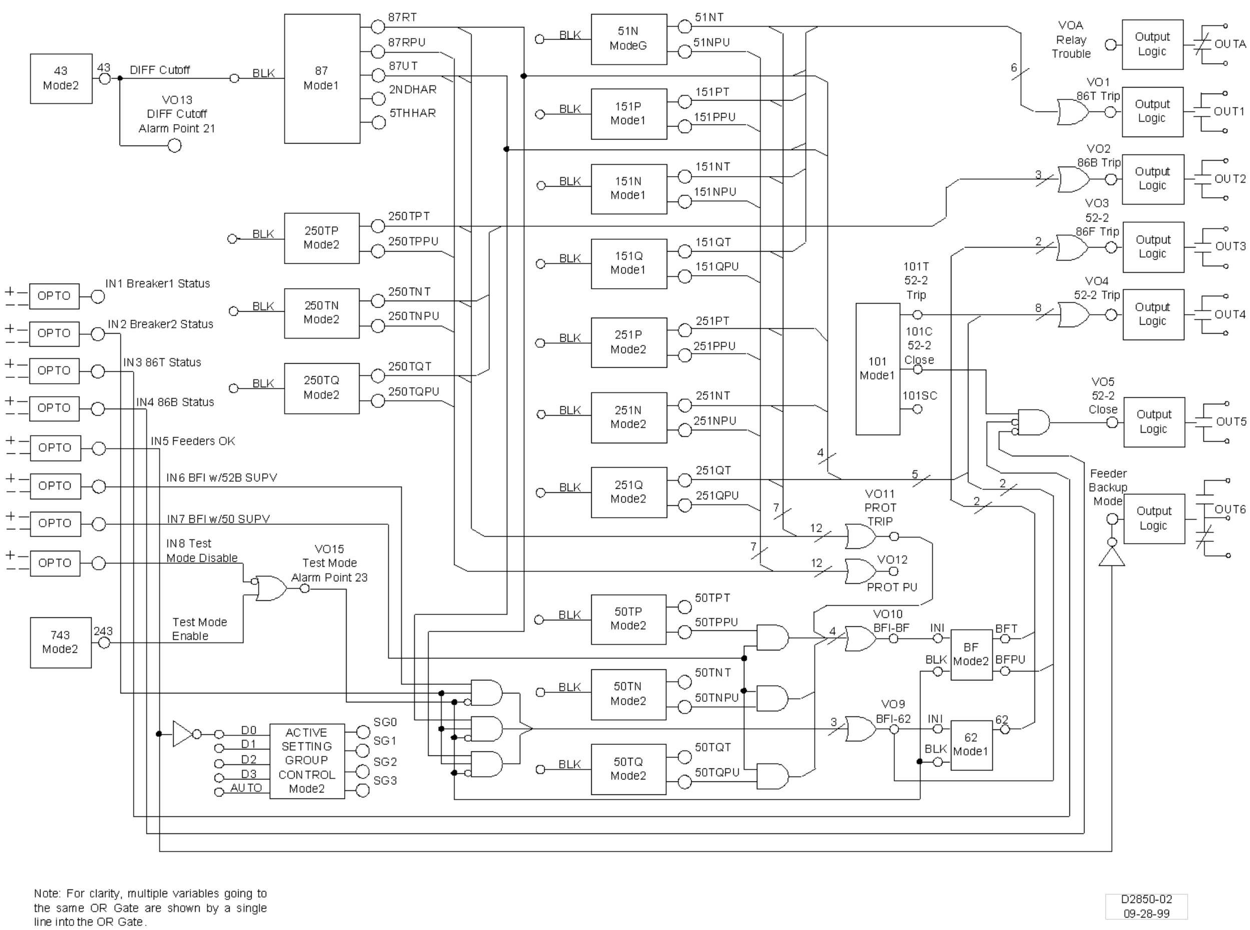

Figure 8-7. Typical Logic Diagram for CDS240-TXBU-B-BE

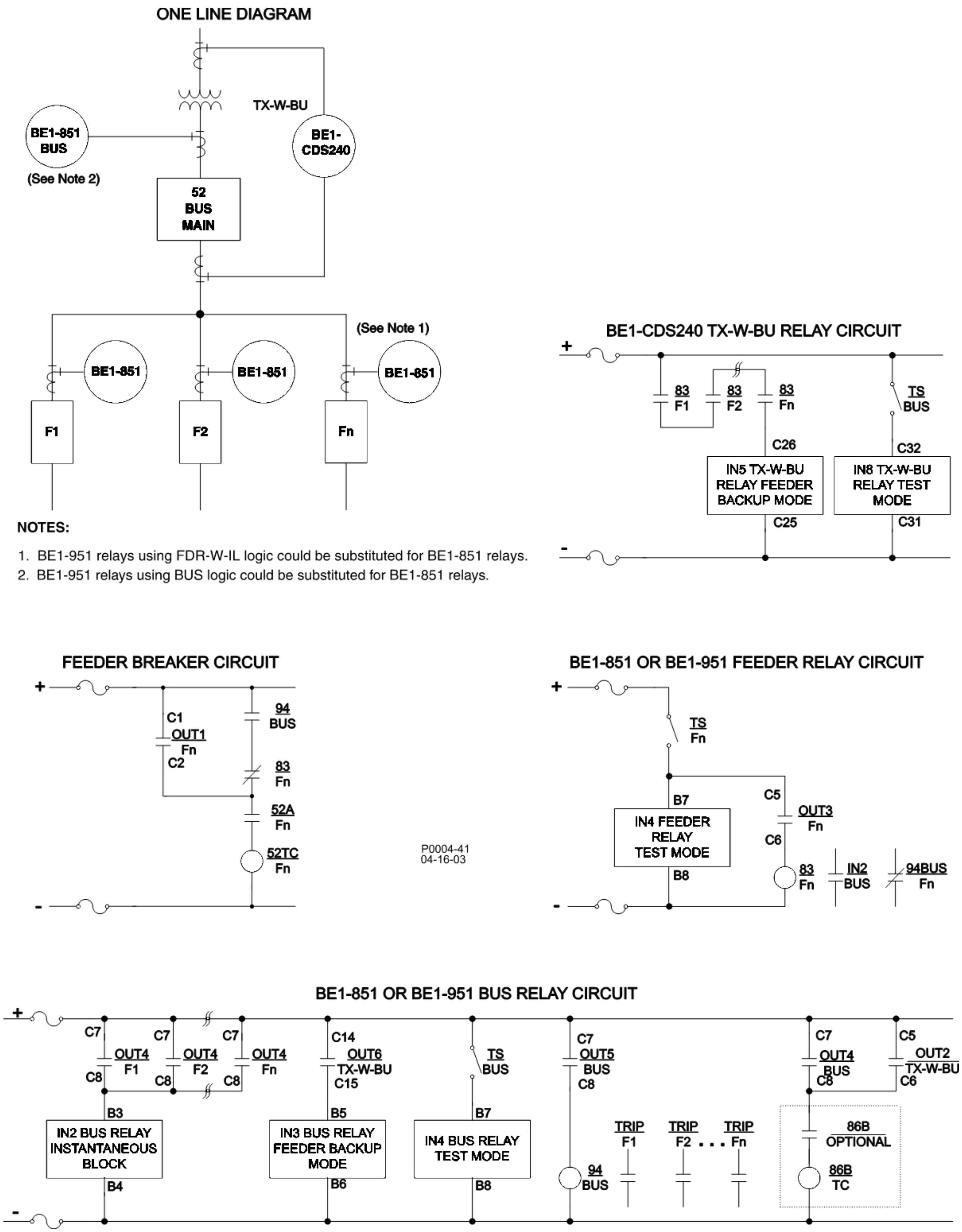

Figure 8-8. Device Interconnection for Integrated Protection System using BE1-CDS240 for Transformer Protection and BE1-851 or BE1-951 for Bus and Feeder Protection

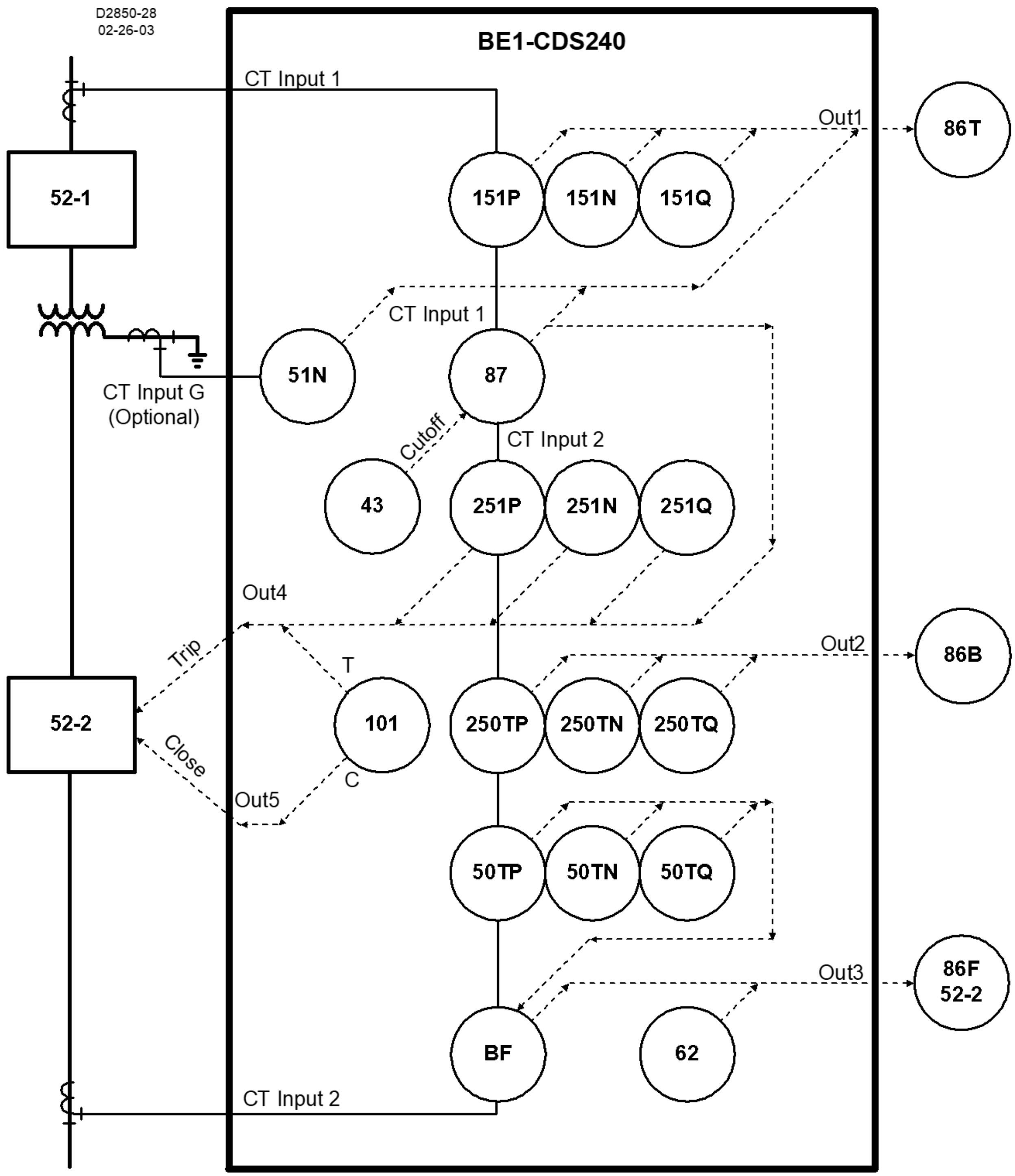

Figure 8-9. Typical One-line Diagram for CDS240-TXBU-B-BE

Protection Elements

Referring to Figure 8-9, the 87 and 151 protection elements are connected to the high-side CT, Input 1 and the 87 and 251 protection elements are connected to the low-side CT, Input 2. The 51 protection element (N only) is connected to a ground CT at the grounded side of a delta-wye transformer. The ground-input (G) is an option on the BE1-CDS240 and must be ordered. Paralleled CTs inside a delta tertiary (3Io) can also feed the 51N. The 87, 51, 151, and 251 protection elements are logic enabled to provide a trip by the settings shown in Table 8-19. Protection elements set at 0 are setting disabled and will not provide a trip output even if logic enabled.

Typically, the CDS240-TXBU-B-BE scheme would be applied with a BE1-851 on the feeder circuits and a BE1-851 or BE1-CDS240 on the bus main breaker interlocked with the feeder relay to provide high-speed, bus fault protection. This combination provides independent, overlapping backup protection in the event of a common mode failure.

Typically, the 87 protection element provides high-speed restrained differential and unrestrained differential phase and ground protection for faults inside the differential zone. At the same time, it provides security against misoperation resulting from transformer inrush by restraining and preventing a trip in the presence of 2^{nd} and 5^{th} harmonics.

Typically, the 151 protection element is coordinated with the low-side bus protection to provide Phase, Neutral, and Negative Sequence timed backup protection for the low-side bus if the bus protection is out of service.

Typically, the 251 protection element is coordinated with the low-side feeder protection to provide Phase, Neutral, and Negative Sequence timed backup protection for feeder faults if the feeder protection is out of service.

Typically, the 51N protection element is coordinated with the low-side bus and feeder protection to provide Neutral (ground) timed backup protection for transformer low side, bus, and feeder ground faults if any primary zone of protection is of service.

Typically, the 250T protection element is set to coordinate with a high-speed bus-interlocking scheme (851 or BE1-CDS240) to provide a definite time coordination interval of 18 to 20 cycles for bus fault backup protection. The 250T protection element should have a pickup setting greater than the highest feeder instantaneous element to ensure that it will not pickup before any feeder relay.

Typically, the 50T protection element is set to provide fault detection but not to be picked-up on load. This element provides current supervision for the external BFI input associated with the BF protection element.

Integration of Protection, Control, and I/O Elements

The logic settings in Table 8-19 also include the logic equations that establish the control connections between elements of the CDS240-TXBU-B-BE scheme. For example, the two underlined commands in the settings of Table 8-19 provide the electrical connection between the 87 element (trip enabled by the program) and Trip Outputs 1 and 4. Referring to Figures 8-7, 8-8, and 8-9, the 87 protection element trips through Outputs 1 and 4. The 151 and 51N protection elements (also trip enabled by the settings) trip through Output 1. The 251 protective element trips through Output 4. The 250 protection element trips through Output 2 and the BF element trips through Output 3. Protection elements set at 0 are setting disabled and will not provide a trip output even if logic enabled.

Input 5 of the CDS240-TXBU-B-BE scheme is hard wired from the feeder protection relays (851) (not shown on Figure 8-9) allowing the CDS240-TXBU-B-BE scheme to signal (through output 6) to the primary bus protection scheme (851 or CDS) to switch to Feeder Backup Mode. This signaling method was chosen because of limited 851 I/O. Input 6 of the CDS240-TXBU-A-BE scheme is a contact supervised BFI input and Input 7 is a current supervised BFI input.

Virtual control switch elements enabled for use in this scheme are 101, 43, and 743. The 101 Control Switch trips the low-side breaker through Output 4 and closes the low-side breaker through Output 5. Control Switch 43 is used to turn the 87 function on or off and 743 is used to enable Test Mode.

Setting group selection mode 2, binary coded selection, is used to recognize the group setting state. When Input D0 of the setting group selection element is high, it is interpreted as a binary 1 causing the logic to switch to group 1. For normal operation, setting group 0 is active for the CDS240-TXBU-B-BE scheme. Input 5 to the CDS240-TXBU-B-BE scheme indicates when a feeder relay is out of service and causes a switch from setting group 0 to setting group 1. At the same time, Output 6 of the CDS240-TXBU-B-BE scheme provides an input to the primary bus protection relay.

Test Mode

When Virtual Control Switch 743 is enabled, all breaker failure functions are defeated.

CAUTION
Test Mode Enable does not defeat the trip outputs of the relay. External trip test blades must be opened or the CDS240-TXBU-B-BE logic scheme must be modified to suit the user's test mode requirements. One option is to trip the breakers through an 86 device only. Typically, 86 devices are installed with test blades in the breaker trip circuit so that the protection scheme can be safely operational checked while the primary equipment is in service. Another option is to inhibit all trip outputs when test mode is enabled. However, external devices such as auxiliary relays and 86 devices would no longer be included in the operational test.

Alarms

Three logic variables drive the front panel LEDs: Relay Trouble (ALMREL), Major Alarm (ALMMAJ), and Minor Alarm (ALMMIN). A fourth logic variable, Logic Alarm (ALMLGC), has no associated front panel LED. When the relay self-test detects a problem in the relay (ALMREL) as programmed for the CDS240-TXBU-A-BE scheme, the Relay Trouble LED lights, output A operates and all outputs are disabled. When a Major Alarm is detected (ALMMAJ), the associated LED lights, but in this scheme, no output relay is programmed to operate. When a Minor Alarm (ALMMIN) is detected, the associated LED lights, but in this scheme, no output relay is programmed to operate.

NOTE
Tables 8-20 through 8-24 provide detailed logic definitions for the inputs, outputs, protection, and control elements. Only those inputs, logic blocks, virtual switches, and outputs in use for the CDS240-TXBU-B-BE preprogrammed logic are described in the following tables.

Table 8-20. CDS240-TXBU-B-BE Contact Input Logic

Input	Purpose	Name Label	State Labels	
			Energized	De-Energized
IN1	Optional input. Used for CT input circuit 1 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-1	CLOSED	OPEN
IN2	Optional input. Used for CT input circuit 2 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-2	CLOSED	OPEN
IN3	Optional input. Used for 86T status indication and locks out the low-side and high-side breakers when TRUE. TRUE when 86T is tripped.	86T-TRIPPED	TRIPPED	NORMAL
IN4	Optional Input. Used for 86B status indication and locks out the low-side breaker when TRUE. TRUE when 86B is tripped.	86B-TRIPPED	TRIPPED	NORMAL
IN5	Puts transformer and bus relays in feeder backup mode when feeder relay out-of-service is detected by an open contact. Feeder relays such as BE1-851 or BE1-951 using one of the preprogrammed schemes with interlock logic.	FEEDERS_OK	NORMAL	FDR_OOS
IN6	Breaker Failure Initiate by external relays with breaker status supervision. Typically used for differential or sudden pressure tripping.	EXT-BFI-52B-SUPV	INI	NORMAL
IN7	Breaker Failure Initiate by external relays with fault detector supervision. Typically used for overcurrent tripping relays.	EXT-BFI-50-SUPV	INI	NORMAL

Input	Purpose	Name Label	State Labels	
			Energized	De-Energized
IN8	Puts the relay in test mode so that the breaker failure is disabled when Input 8 is de-energized.	TEST-MODE-DISABL	NORMAL	TSTMODE

Table 8-21. CDS240-TXBU-B-BE Function Block Logic

Function	Purpose	BESTlogic Expression	Mode Setting
87	Used for percent-restrained differential protection with high-speed unrestrained instantaneous differential protection. Differential function is blocked when Virtual Switch 43 is TRUE.	43	1 (enabled)
51N	Used for timed ground overcurrent protection for independent ground input circuit.	0	G (Ground Input)
151P	Used for timed phase overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
151N	Used for timed neutral overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
151Q	Used for timed negative-sequence overcurrent protection for CT input circuit 1.	0	1 (Circuit 1)
251P	Used for timed phase overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
251N	Used for timed neutral overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
251Q	Used for timed negative-sequence overcurrent protection for CT input circuit 2.	0	2 (Circuit 2)
50TP	Used as fault detector for Breaker 2 external BFI (IN7) supervision.	0	2 (Circuit 2)
50TN	Used as fault detector for Breaker 2 external BFI (IN7) supervision.	0	2 (Circuit 2)
50TQ	Used as fault detector for Breaker 2 external BFI (IN7) supervision.	0	2 (Circuit 2)
250TP	Used for bus backup overcurrent protection, CT Circuit 2.	0	2 (Circuit 2)
250TN	Used for bus backup overcurrent protection, CT Circuit 2.	0	2 (Circuit 2)
250TQ	Used for bus backup overcurrent protection, CT Circuit 2.	0	2 (Circuit 2)
150BF	*BFI50 Logic:* Used for CT Circuit 2 breaker failure protection. Initiated by BFI with fault detector supervision expression.	VO10	1 (enable)
	BFI52 Logic: Not used.	0	
	52 STATUS Logic: Not used.	0	
	BLK Logic: Block breaker failure protection when relay is in test mode.	VO15	
62	*INI Logic:* Used for breaker failure tripping with no current supervision.	VO9	1 (PU/DO)
	BLK Logic: Block breaker failure protection when relay is in test mode.	VO15	
GROUP	*Input 0 Logic:* Switch to setting group 1 if feeder relay is out of service as indicated by open contact (IN5).	/IN5	2 (Binary Inputs)
	Input 1 Logic: No manual selection logic is used.	0	
	Input 2 Logic: No manual selection logic is used.	0	
	Input 3 Logic: No manual selection logic is used.	0	
	Auto/Manual Logic: No automatic selection.	0	

Table 8-22. CDS240-TXBU-B-BE Virtual Switch Logic

Switch	Purpose	Mode	Label	State Labels	
				True	False
43	Used as differential cutoff. The 87 is blocked when the switch is in the closed state.	2 (On/Off)	87-CUTOFF	DISABLD	NORMAL
743	Selects test mode so that reclosing and BF are disabled when virtual switch is closed.	2 (On/Off)	TEST-MODE-ENABLE	TSTMODE	NORMAL
101	Allows breaker to be tripped or closed manually from HMI or ASCII command interface.	1 (enabled)	N/A	N/A	N/A

Table 8-23. CDS240-TXBU-B-BE Virtual Output Logic

Output	Purpose	Description	Label	State Labels	
				True	False
VOA	Relay Trouble Alarm.	VOA TRUE if relay trouble alarm occurs.	RELAY-TROUBLE	ACTIVE	NORMAL
BESTlogic Expression: VOA=0					
VO1	Transformer fault trip (86T for example).	VO1 TRUE if restrained, unrestrained, 51, or 151 time overcurrent trip occurs.	TRIP_86T	TRIP	NORMAL
BESTlogic Expression: VO1=87RT+87UT+151PT+51NT+151NT+151QT					
VO2	Transformer fault trip (86B for example).	VO2 TRUE, Trip bus breaker via lockout for bus faults (250T w/ 18-20 cycles delay).	TRIP-86B	TRUE	FALSE
BESTlogic Expression: VO2=250TPT+250TNT+250TQT					
VO3	Breaker 2 breaker failure trip (86F, for example).	TRUE when BFT or 62 times out.	TRIP-86F	TRUE	FALSE
BESTlogic Expression: VO3=BFT2+62					
VO4	Breaker 2 Trip.	VO4 TRUE if 87R or 87U trip output of the phase differential protection function is TRUE. Or for 251 bus backup overcurrent trip. Or for control switch trip. Or when BF is initiated.	TRIP-BKR2	TRIP	NORMAL
BESTlogic Expression: VO4=87RT+87UT+BFRT2+VO9+101T+251PT+251NT+251QT					
VO5	Breaker 2 Close.	VO5 TRUE if virtual control switch is TRUE and 86T or 86B LO is not tripped.	CLOSE-BKR2	CLOSE	NORMAL
BESTlogic Expression: VO5=/IN3*/IN4*101C					
VO6	Signal relay on bus source that is using BUS logic that a feeder relay is out of service.	VO6 TRUE, Feeder relay is out of service as indicated by contact open from the feeder relays.	FDR-BACKUP-MODE	BACKUP	NORMAL
BESTlogic Expression: VO6=/IN5					

Output	Purpose	Description	Label	State Labels	
				True	False
VO9	52b supervised breaker failure initiate expression.	Initiate BF timing (62 Timer) when 87R or 87U trip is TRUE or when external BFI contact (IN6) is sensed. Stop BF timing when breaker opens (52a status contact). Prevent initiate when in test mode (VO15).	BFI-62	INI	NORMAL
BESTlogic Expression: VO9=87RT*IN2*/VO15+IN2*87UT*/VO15+IN2*IN6*/VO15					
VO10	Current supervised breaker failure initiate expression.	Initiate BF timing when protective trip expression is TRUE. Or when external initiate contact (IN7) is sensed and any of the fault detectors is picked up.	BFI-BF	INI	NORMAL
BESTlogic Expression: VO10=VO11+50TPPU*IN7+50TNPU*IN7+IN7*50TQPU					
VO11	Protective Trip expression.	TRUE when any 87, 250T, 51, 151, or 251 element has timed out.	PROTECTIVE-TRIP	TRIP	NORMAL
BESTlogic Expression: VO11=250TPT+250TNT+87RT+87UT+250TQT+151PT+251PT+51NT+151NT+251NT+151QT+251QT					
VO12	Protection Picked Up expression.	TRUE when any 87, 250T, 51, 151, or 251 element picks up.	PROT-PICKED-UP	PU	NORMAL
BESTlogic Expression: VO12=250TPPU+250TNPU+87RPU+87UT+250TQPU+151PPU+251PPU+51NPU+151NPU+251NPU+151QPU+251QPU (Note: 87UT is included to trigger the fault recorder because there is no unrestrained pickup output.)					
VO13	Alarm to indicate that the differential cutoff switch is in the block operation position.	TRUE if Virtual Switch 43 is in the closed position.	87-BLOCKED	ACTIVE	NORMAL
BESTlogic Expression: VO13=43					
VO15	Alarm bit #23 indication that the relay is in test mode and that breaker failure is disabled.	TRUE if IN8 is de-energized or if Virtual Switch 743 is closed.	IN8-ALARM	ACTIVE	NORMAL
BESTlogic Expression: VO15=/IN8+743					

Table 8-24. CDS240-TXBU-B-BE Hardware Output Logic

Output	Purpose	Description
OUTA	Relay Trouble Alarm.	OUTA contact closes when relay trouble alarm occurs.
BESTlogic Expression: OUTA=VOA		
OUT1	Transformer fault trip (86T for example).	OUT1 contact closes if restrained, unrestrained, 51, or 151 time overcurrent trip occurs.
BESTlogic Expression: OUT1=VO1		
OUT2	Transformer fault trip (86B for example).	OUT2 contact closes when Trip bus breaker via lockout for bus faults (250T w/ 18-20 cycles delay).
BESTlogic Expression: OUT2=VO2		

Output	Purpose	Description
OUT3	Breaker 2 failure trip. (86F for example).	OUT3 closes when BFT or 62 times out.
BESTlogic Expression: OUT3=VO3		
OUT4	Breaker 2 Trip.	OUT4 contact closes 87R or 87U trip output of the phase differential protection function is TRUE. Or for 251 bus backup overcurrent trip. Or for control switch trip. Or when BF is initiated.
BESTlogic Expression: OUT4=VO4		
OUT5	Breaker 2 Close.	OUT5 contact closes when virtual control switch is TRUE and 86T or 86B LO is not tripped.
BESTlogic Expression: OUT5=VO5		
OUT6	Signal relay on bus source that is using BUS logic that a feeder relay is out of service.	OUT6 contact closes when Feeder relay is out of service as indicated by contact open from the feeder relays.
BESTlogic Expression: OUT6=VO6		
OUT7 - 14	Spare output contacts.	N/A
BESTlogic Expression: OUT7-14 =0		

CDS240-BSBU-A-BE (Bus with Backup) Logic Scheme

The BUS With Backup (CDS240-BSBU-A-BE) scheme was designed to provide low impedance, high-speed phase, and ground bus fault protection for distribution buses. This scheme also includes a high-speed bus-interlocking scheme that provides a second level of bus protection and "Feeder Relay Out of Service" backup protection. Figure 8-10 shows the interconnection of a BE1-CDS240 (CDS240-TXBU-B-BE) for backup protection, a BE1-851 or BE1-951 for feeder protection, and the BE1-CDS240 for bus protection. When interconnected with feeder relays using preprogrammed feeder logic (FDR-W-IL), the CDS240-BSBU-A-BE scheme provides complete backup, except for reclosing, for the feeder relays if relay failure occurs or when they are out of service for testing or maintenance. Virtual control switch logic is used for local or remote (SCADA) control and can be used to replace the equivalent panel control switches.

The control switch elements are referred to as virtual because they have no physical form, they exist only in logic form, and they can only be operated via the ASCII command interface or the front panel. The Virtual 101 Switch is used to trip and close the bus main breaker, Virtual Control Switch 43 is used to turn off the 87 protection element and 743 is used to select test mode enable. The user may choose to eliminate the use of external switches, as the virtual switches are fully functional equivalents of their physical counterparts.

Figure 8-11 is a one-line drawing and Figure 8-12 is a logic drawing. Both represent the logic settings shown in Table 8-25. In Table 8-25, the user can see the protection and control elements that are enabled for the CDS240-BSBU-A-BE application and how the elements are logically wired together (equations). If the user should decide to build on this scheme, all elements required for a more detailed application are available through programming. For programming details, refer to Section 7, *BESTlogic Programmable Logic.*

Table 8-25. CDS240-BSBU-A-BE Logic Settings and Equations

SL-N=CDS240-BSBU-A-BE,BASLER
SL-87=1,43
SL-87ND=0,0
SL-187ND=0,0
SL-50BF=0,0,0,0,0
SL-150BF=0,0,0,0,0
SL-250BF=0,0,0,0,0
SL-350BF=0,0,0,0,0
SL-50TP=1,IN5
SL-50TN=1,IN5
SL-50TQ=1,IN5
SL-150TP=1,0
SL-150TN=1,0
SL-150TQ=1,0
SL-250TP=0,0
SL-250TN=0,0
SL-250TQ=0,0
SL-350TP=0,0
SL-350TN=0,0
SL-350TQ=0,0
SL-450TP=0,0
SL-450TN=0,0
SL-550TP=0,0
SL-650TP=0,0
SL-750TP=0,0
SL-51P=1,0
SL-51N=1,0
SL-51Q=1,0
SL-151P=1,0
SL-151N=1,0
SL-151Q=1,0
SL-251P=0,0
SL-251N=0,0
SL-251Q=0,0
SL-351P=0,0
SL-351N=0,0
SL-351Q=0,0
SL-451N=0,0
SL-24=0,0
SL-27P=0,0
SL-127P=0,0
SL-47=0,0
SL-59P=0,0
SL-59X=0,0
SL-159P=0,0
SL-81=0,0
SL-181=0,0
SL-281=0,0
SL-381=0,0
SL-481=0,0
SL-581=0,0
SL-62=0,0,0
SL-162=0,0,0
SL-262=0,0,0
SL-362=0,0,0
SL-GROUP=2,IN7,0,0,0,0
SL-43=2
SL-143=0
SL-243=0
SL-343=0
SL-443=0
SL-543=0
SL-643=0
SL-743=2
SL-101=1
SL-1101=0
SL-2101=0
SL-3101=0
SL-VOA=0
SL-VO1=87RT+VO8*/VO14
SL-VO2=250TPT+250TNT+250TQT
SL-VO3=VO9*VO14
SL-VO4=87RT+VO9*/VO14+VO10+101T
SL-VO5=/IN3*/IN4*101C
SL-VO6=VO7*/VO15
SL-VO7=87RT+VO9*/VO14+VO10
SL-VO8=50TPT+50TNT+50TQT
SL-VO9=50TPT+50TNT+50TQT+51PT+51NT+51QT
SL-VO10=150TPT+150TNT+150TQT+151PT+151NT+151QT
SL-VO11=50TPT+150TPT+50TNT+150TNT+87RT+50TQT+150TQT+51PT+151PT+51NT+151NT+51QT+151QT
SL-VO12=50TPPU+150TPPU+50TNPU+150TNPU+87RPU+50TQPU+150TQPU+51PPU+151PPU+51NPU+151NPU+51QPU+151QPU
SL-VO13=43
SL-VO14=SG1
SL-VO15=/IN8+743
SL-OUTA=VOA
SL-OUT1=VO1
SL-OUT2=VO2
SL-OUT3=VO3
SL-OUT4=VO4
SL-OUT5=VO5
SL-OUT6=VO6
SL-OUT7=0
SL-OUT8=0
SL-OUT9=0
SL-OUT10=0
SL-OUT11=0
SL-OUT12=0
SL-OUT13=0
SL-OUT14=0

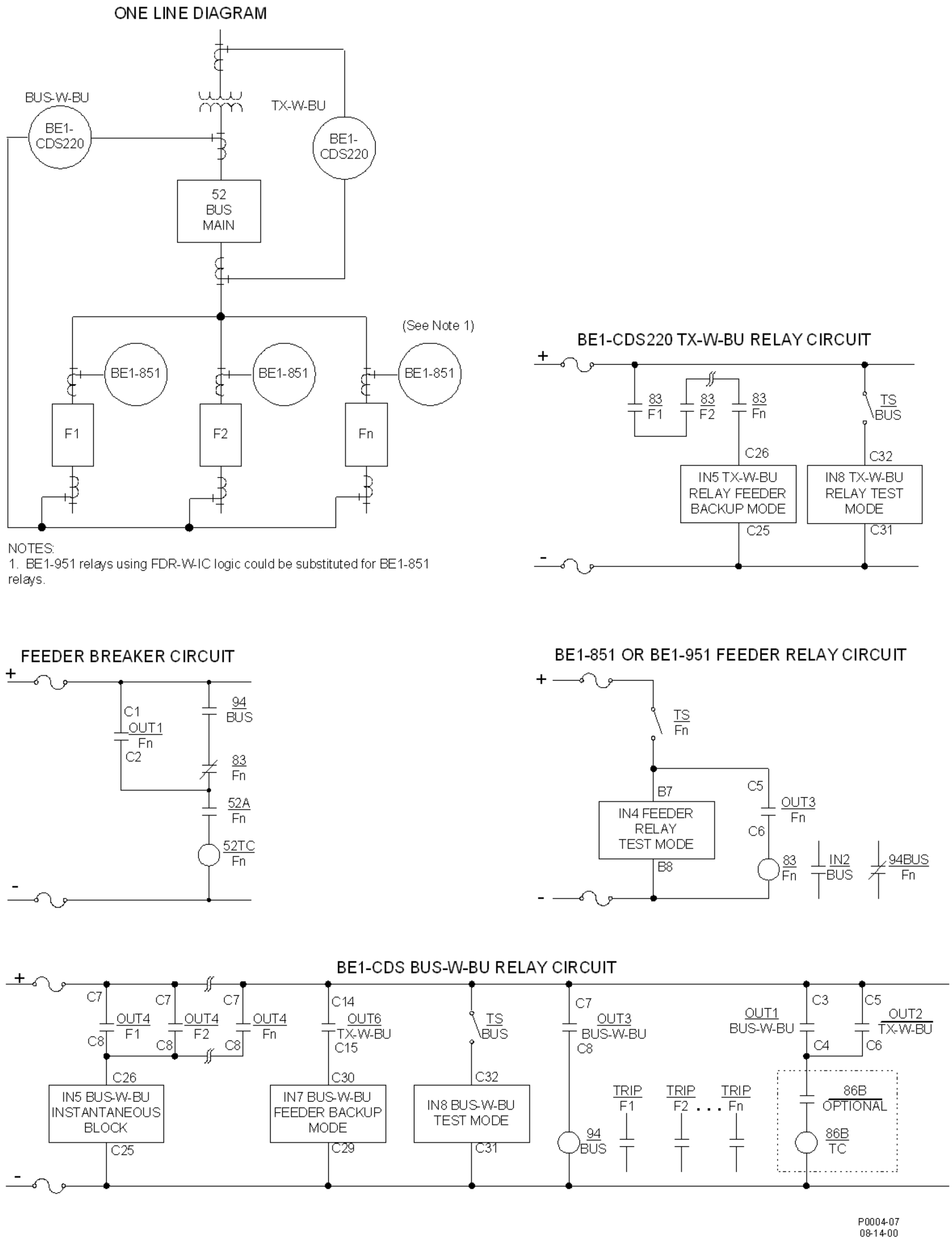

Figure 8-10. Device Interconnection for Integrated Protection System Using BE1-CDS240 for Transformer and Bus Protection and BE1-851 Or BE1-951 for Feeder Protection

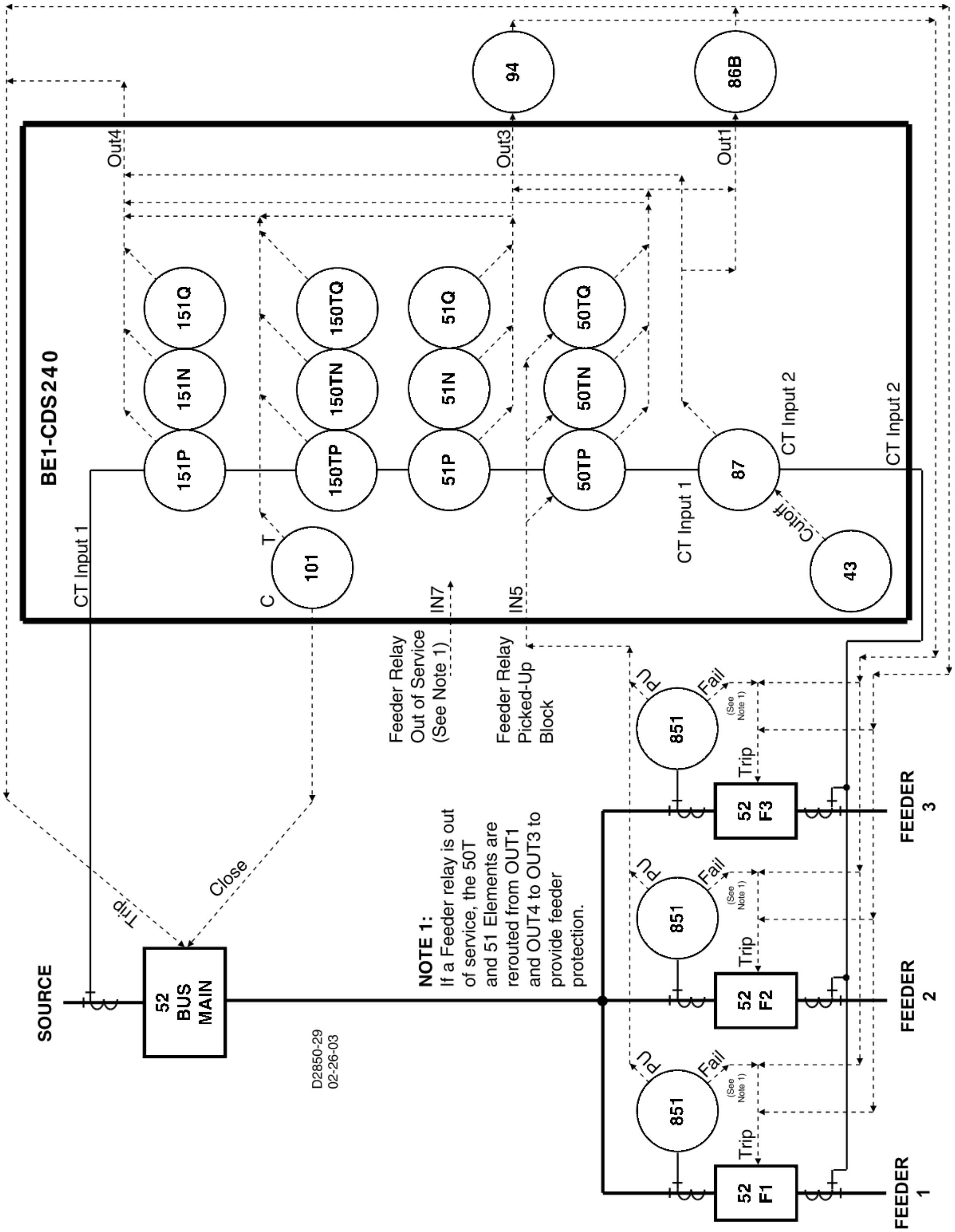

Figure 8-11. Typical One-line Diagram for CDS240-BSBU-A-BE

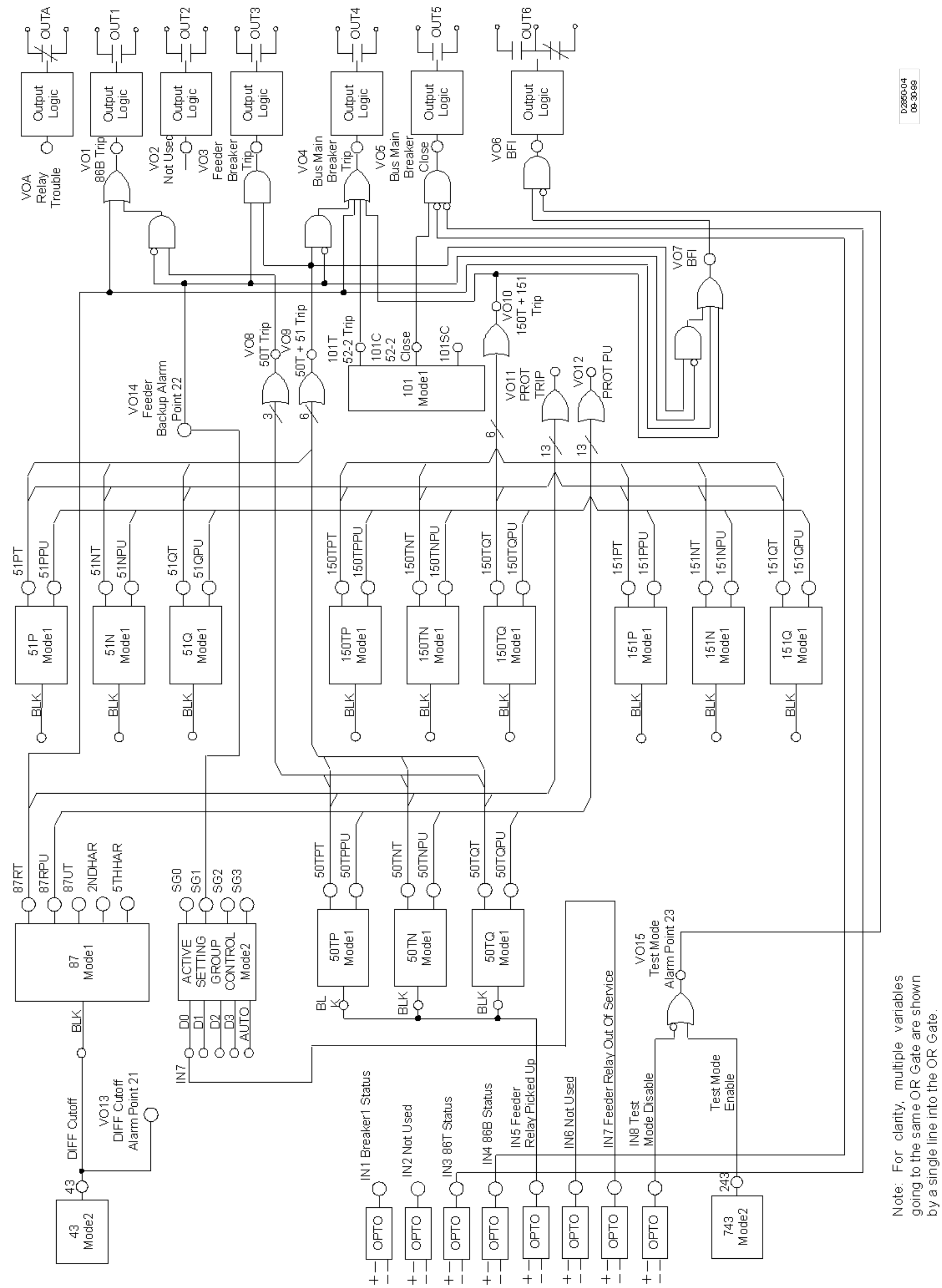

Figure 8-12. Typical Logic Diagram for CDS240-BSBU-A-BE

Protection Elements

Referring to Figure 8-11, the 87, 150/151, 50/51 protection elements are connected to CT Input 1 and the Feeder Side of the 87 protection element is connected to Input 2. The 87, 150/151, and 50/51 protection elements are logic enabled to provide a trip by the settings shown in Table 8-11. Protection elements set to 0 are setting disabled and will not provide a trip output even if logic enabled.

As shown in Figure 8-11, the CDS240-BSBU-A-BE scheme is typically applied with a BE1-851 on the feeder circuits and a BE1-CDS240 on the transformer (not shown) supplying the bus. The transformer BE1-CDS240 provides an independent backup for bus faults with a coordination interval of 18 to 20 cycles. This combination provides independent, overlapping backup protection in the event of a common mode failure (refer to the discussion in *Details Of Preprogrammed Logic Schemes*).

Typically, the 87 protection element provides high-speed percent restrained, phase, and ground protection for faults inside the differential zone. For the CDS240-BSBU-A-BE application shown in Figure 8-11, the percent-restrained differential protection function is the only function of the 87 protection element required. Set the pickup of the 2nd, 5th, and 87U functions to 0 (setting disabled). The 87U function has a setting only when the 2nd and 5th harmonic restraint functions are set for transformers (refer to the discussion in *Overview Of Preprogrammed Logic Schemes*).

Typically, the 150 and 151 protection elements are coordinated with the bus and feeder protection to provide Phase, Neutral, and Negative Sequence instantaneous and timed backup protection for bus and feeder faults.

Typically, the 51 protection element is coordinated with the low-side feeder protection to provide Phase, Neutral, and Negative Sequence timed backup protection for feeder faults should feeder protection be out of service. When a **Feeder Relay Out of Service** signal is detected through IN7 of the BE1-CDS CDS240-BSBU-A-BE scheme, the relay switches from normal mode to feeder backup mode. The 251 protection element is reset from setting group 0 to setting group 1 to provide time overcurrent feeder replacement protection.

Typically, the 50T protection element is set to provide high-speed bus fault protection (2-4 cycles coordination interval) when used with 851 feeder protection inputs as part of a bus-interlocking scheme (IN5 of the Bus BE1-CDS240). For normal mode, the 250T protection element should have a pickup setting greater than the highest feeder instantaneous element to ensure that it will not pickup before any feeder relay. When a **Feeder Relay Out of Service** signal is detected through IN7 of the BE1-CDS240 CDS240-BSBU-A-BE, the relay switches from normal mode to feeder backup mode. The 250T protection element is reset from setting group 0 to setting group 1 to provide instantaneous overcurrent feeder replacement protection.

Integration of Protection, Control, and I/O Elements

The logic settings in Table 8-25 also include the logic equations that establish the control connections or logic wiring between elements of the CDS240-BSBU-A-BE scheme. For example, the two underlined equations in the settings of Table 8-25 provide the electrical connection between the 87 element (trip enabled by the settings) and trip outputs 1 and 4. Referring to Figures 8-11 and 8-12, during the normal mode, the 87, 50, and 51 protection elements (each trip enabled by the settings) trip through Outputs 1 and 4. The 150 and 151 protection elements and the 101 Virtual Switch element (also trip enabled by the settings) trip through Output 4. During the feeder backup mode, the 50T and 51 protection elements are rerouted from Output 1 and Output 4, to Output 3 to provide feeder protection. Protection elements set at 0 are setting disabled and will not provide a trip output even if logic enabled.

As shown in Figure 8-11, IN7 of the CDS240-BSBU-A-BE signals the scheme that a feeder relay is out of service. This input instructs the BE1-CDS240 relay to switch from the normal mode of interlocked bus protection to the feeder backup mode.

As shown in Figure 8-11, IN5 of the CDS240-BSBU-A-BE scheme is hard wired to the feeder protection relays (BE1-851). This signal path provides the intelligence that allows the CDS240-BSBU-A-BE to determine if a fault is on the bus or on a feeder circuit. When any feeder overcurrent elements are picked up and timing, a signal at IN5 of the BE1-CDS240 bus blocks the 50T protection elements. The pickup of the 50T protection element is delayed 2 to 4 cycles to allow time for the feeder protection to detect, pickup, and start timing. If the fault is not on a feeder, the 50T protection element of the BE1-CDS240 bus is not blocked and trips in 2 to 4 cycles through Outputs 1 and 4 as previously discussed. The overlapping 250T protection element from the transformer BE1-CDS240 (not shown in Figure 8-11) does not get blocked when the feeder relays are picked up. Therefore, the 250T protection element must be set with a time delay long enough to allow the feeder breaker to interrupt the fault.

Virtual control switch elements enabled for use in this scheme are 101, 43, and 743. The 101 Control Switch trips the low-side breaker through output 4 and closes the low-side breaker through Output 5. Control Switch 43 is used to turn the 87 function on or off and 743 us used to enable Test Mode.

Test Mode

When Virtual Control Switch 743 is enabled, breaker failure initiate through Output 6 is defeated.

CAUTION
Test Mode Enable does not defeat the trip outputs of the relay. External trip test blades must be opened or the CDS240-BSBU-A-BE logic scheme must be modified to suit the user's test mode requirements. One option is to trip the breakers through an 86 device only. Typically, 86 devices are installed with test blades in the breaker trip circuit so that the protection scheme can be safely operational checked while the primary equipment is in service. Another option is to inhibit all trip outputs when test mode is enabled. However, external devices such as auxiliary relays and 86 devices would no longer be included in the operational test.

Setting Group

For normal operation, setting group 0 is active for the CDS240-BSBU-A-BE scheme. IN7 to the BE1-CDS240 identifies when a feeder relay (851) is out of service. At the same time, IN5 of the transformer BE1-CDS240 scheme gets the same signal. Both relays then switch to setting group 1. Setting group selection mode 2, binary coded selection, is used to recognize the group setting state. When input D0 to the setting group selection element is a one, it is interpreted as a binary 1 causing the logic to switch to group 1.

When the bus BE1-CDS240 is in setting group 1, it is operating in feeder backup mode. This expression is programmed to Virtual Output 14 that drives alarm bit #22 in the programmable alarm mask. It can be masked to drive an alarm LED and alarm display to indicate when the relay is in feeder backup mode and to trip a feeder breaker instead of the bus breaker.

Alarms

Three logic variables drive the front panel LEDs: Relay Trouble (ALMREL), Major Alarm (ALMMAJ), and Minor Alarm (ALMMIN). A fourth logic variable, Logic Alarm (ALMLGC), has no associated front panel LED. When the relay self-test detects a problem in the relay (ALMREL) as programmed for the CDS240-BSBU-A-BE scheme, the Relay Trouble LED lights, Output A operates and all outputs are disabled. When a Major Alarm is detected (ALMMAJ), the associated LED lights, but in this scheme, no output relay is programmed to operate. When a Minor Alarm (ALMMIN) is detected, the associated LED lights, but in this scheme, no output relay is programmed to operate.

NOTE
Tables 8-26 through 8-30 provide detailed logic definitions for the inputs, outputs, protection, and control elements. Only those inputs, logic blocks, virtual switches, and outputs in use for the CDS240-BSBU-A-BE preprogrammed logic are described in the following tables.

Table 8-26. CDS240-BSBU-A-BE Contact Input Logic

Input	Purpose	Name Label	State Labels	
			Energized	**De-Energized**
IN1	Optional input. Used for CT input circuit 1 breaker status indication in SER reports. TRUE when breaker is closed.	BREAKER-1	CLOSED	OPEN
IN3	Used for 86 status indication in SER reports. TRUE when Transformer 86 tripped. Also blocks virtual breaker close switch close until 86 is reset.	86T-TRIPPED	TRIPPED	NORMAL
IN4	Optional Input. Used for 86B status indication and locks out the low-side breaker when TRUE. TRUE when 86B is tripped.	86B-TRIPPED	TRIPPED	NORMAL
IN5	Block instantaneous when feeder relay is picked up. Feeder relays such as BE1-851 or BE1-951 using one of the preprogrammed schemes with interlock logic.	FDR-RLY-PICKEDUP	PICKDUP	NORMAL
IN7	Signal from relay on bus source that is using BACKUP logic that a feeder relay is out of service. BE1-851, BE1-951, or BE1-CDS240 using preprogrammed logic scheme BACKUP.	BACKUP-FDR-RELAY	BACKUP	NORMAL
IN8	Puts the relay in test mode so that the breaker failure is disabled when Input 8 is de-energized.	TEST-MODE-DISABL	NORMAL	TSTMODE

Table 8-27. CDS240-BSBU-A-BE Function Block Logic

Function	Purpose	BESTlogic Expression	Mode Setting
87	Used for percent-restrained differential protection with high-speed unrestrained instantaneous differential protection. Differential function is blocked when Virtual Switch 43 is TRUE.	43	1 (enabled)
51P	Applied to bus main (CT 1). Normally for bus time OC protection coordinated with feeder relay time OC. When in feeder relay backup mode, provides primary time OC protection for feeder. SG1 settings must coordinate with other feeder 51 elements.	0	1 (Circuit 1)
51N	Applied to bus main (CT 1). Normally for bus time OC protection coordinated with feeder relay time OC. When in feeder relay backup mode, provides primary time OC protection for feeder. SG1 settings must coordinate with other feeder 51 elements.	0	1 (Circuit 1)
51Q	Applied to bus main (CT 1). Normally for bus time OC protection coordinated with feeder relay time OC. When in feeder relay backup mode, provides primary time OC protection for feeder. SG1 settings must coordinate with other feeder 51 elements.	0	1 (Circuit 1)
151P	Applied to bus main (CT 1). Used for backup bus time OC trip. Provides primary time OC protection when 51 elements are used for feeder relay backup.	0	1 (Circuit 1)
151N	Applied to bus main (CT 1). Used for backup bus time OC trip. Provides primary time OC protection when 51 elements are used for feeder relay backup.	0	1 (Circuit 1)
151Q	Applied to bus main (CT 1). Used for backup bus time OC trip. Provides primary time OC protection when 51 elements are used for feeder relay backup.	0	1 (Circuit 1)

Function	Purpose	BESTlogic Expression	Mode Setting
50TP	Applied to bus main (CT 1). Normally for fast bus OC protection (2-4 cycles delay) as backup to 87. When in feeder relay backup mode, provides near instantaneous for feeder. Block when feeder relay is picked up indicating that the fault is on a feeder.	IN5	1 (Circuit 1)
50TN	Applied to bus main (CT 1). Normally for fast bus OC protection (2-4 cycles delay) as backup to 87. When in feeder relay backup mode, provides near instantaneous for feeder. Block when feeder relay is picked up indicating that the fault is on a feeder.	IN5	1 (Circuit 1)
50TQ	Applied to bus main (CT 1). Normally for fast bus OC protection (2-4 cycles delay) as backup to 87. When in feeder relay backup mode, provides near instantaneous for feeder. Block when feeder relay is picked up indicating that the fault is on a feeder.	IN5	1 (Circuit 1)
150TP	Applied to bus main (CT 1). Used for backup bus OC trip. 18-20 cycles delay (no feeder picked up interlock). Provides primary OC protection when 50T elements are used for feeder relay backup.	0	1 (Circuit 1)
150TN	Applied to bus main (CT 1). Used for backup bus OC trip. 18-20 cycles delay (no feeder picked up interlock). Provides primary OC protection when 50T elements are used for feeder relay backup.	0	1 (Circuit 1)
150TQ	Applied to bus main (CT 1). Used for backup bus OC trip. 18-20 cycles delay (no feeder picked up interlock). Provides primary OC protection when 50T elements are used for feeder relay backup.	0	1 (Circuit 1)
GROUP	*Input 0 Logic:* Switch to setting group 1 if feeder relay is out of service as indicated by closed contact from relay with BACKUP logic such as BE1-851, BE1-951, or BE1-CDS240.	IN7	2 (Binary Inputs)
	Input 1 Logic: No manual selection logic is used.	0	
	Input 2 Logic: No manual selection logic is used.	0	
	Input 3 Logic: No manual selection logic is used.	0	
	Auto/Manual Logic: No automatic selection.	0	

Table 8-28. CDS240-BSBU-A-BE Virtual Switch Logic

Switch	Purpose	Mode	Label	State Labels	
				True	False
43	Used as differential cutoff. The 87 is blocked when the switch is in the closed state.	2 (On/Off)	87-CUTOFF	DISABLD	NORMAL
743	Selects test mode so that reclosing and BF are disabled when virtual switch is closed.	2 (On/Off)	TEST-MODE-ENABLE	TSTMODE	NORMAL
101	Allows breaker to be tripped or closed manually from HMI or ASCII command interface.	1 (enabled)	N/A	N/A	N/A

Table 8-29. CDS240-BSBU-A-BE Virtual Output Logic

Output	Purpose	Description	Label	State Labels	
				True	False
VOA	Relay Trouble Alarm.	VOA TRUE if relay trouble alarm occurs.	RELAY-TROUBLE	ACTIVE	NORMAL
BESTlogic Expression: VOA=0					

Output	Purpose	Description	Label	State Labels	
				True	False
VO1	Bus fault trip (86B for example).	TRUE if bus fault by restrained differential trip or for high-speed bus OC trip (50T) and not in feeder backup mode (VO14).	TRIP_86B	TRIP	NORMAL
BESTlogic Expression: VO1=87RT+VO8*/VO14					
VO2	Transformer fault trip (86B for example).	VO2 TRUE, Trip bus breaker via lockout for bus faults (250T with 18-20 cycles delay).	TRIP-86B	TRUE	FALSE
BESTlogic Expression: VO2=250TPT+250TNT+250TQT					
VO3	Feeder breaker trip.	VO3 TRUE, Trip feeder breaker via auxiliary relay (94) for 50/51 (VO9) trip when in feeder relay backup mode (VO14).	FEEDER-BKR-TRIP	TRIP	NORMAL
BESTlogic Expression: VO3=VO9*VO14					
VO4	Breaker 1 Trip.	VO4 TRUE, Trip for bus diff, 87 is TRUE. Or, high-speed bus OC with interlock, 50T, or bus time OC trip, 51 is TRUE and not in feeder backup mode (VO14). Or, for 150T & 151 bus backup overcurrent trip. Or, for control switch trip.	TRIP-BKR1	TRIP	NORMAL
BESTlogic Expression: VO4=87RT+VO9*/VO14+VO10+101T					
VO5	Breaker 1 Close.	VO5 TRUE if virtual control switch is TRUE and 86T or 86B LO is not tripped.	CLOSE-BKR1	CLOSE	NORMAL
BESTlogic Expression: VO5=/IN3*/IN4*101C					
VO6	Breaker Failure Initiate output. Initiate breaker failure protection in relay using backup logic.	VO6 TRUE, Initiate breaker failure if BFI expression is TRUE (VO7) and not in test mode.	BFI	INI	NORMAL
BESTlogic Expression: VO6=VO7*/VO15					
VO7	Breaker failure initiate expression.	Initiate breaker failure for all bus breaker protective tripping elements. 87RT, 50/51 (when not in feeder backup mode), or 150/151 (101T is excluded).	BFI	INI	NORMAL
BESTlogic Expression: VO7=87RT+VO9*/VO14+VO10					
VO8	Intermediate logic expression for 50T Trip. Used for high-speed bus OC trip in normal mode or feeder breaker inst. Trip in feeder backup mode.	TRUE if any 50T with feeder pickup interlock is TRUE. Elements have 2-4 cycle delay due to interlock with feeder relay pickups.	50T-INTERLKD-OC	TRIP	NORMAL
BESTlogic Expression: VO8=50TPT+50TNT+50TQT					

Output	Purpose	Description	Label	State Labels	
				True	False
VO9	Intermediate logic expression for 50T and 51 Trip. Used for bus OC trip in normal mode or for feeder relay backup trip in feeder backup mode.	TRUE for any primary OC trip (50T or 51).	50T-51-TRIP	TRUE	FALSE
BESTlogic Expression: VO9=50TPT+50TNT+50TQT+51PT+51NT+51QT					
VO10	Intermediate logic expression for 150T Trip. Used for backup bus OC trip.	TRUE for any backup overcurrent trip (150T or 151).	150T-151-TRIP	TRUE	FALSE
BESTlogic Expression: VO10=150TPT+150TNT+150TQT+151PT+151NT+151QT					
VO11	Protective trip expression.	TRUE when any 87, 50T, 150T, 51, or 151 element has timed out.	PROTECTIVE-TRIP	TRIP	NORMAL
BESTlogic Expression: VO11=50TPT+150TPT+50TNT+150TNT+87RT+50TQT+150TQT+51PT+151PT+51NT+151NT+51QT+151QT					
VO12	Protective pickup expression.	TRUE when any 87, 50T, 150T, 51, or 151 element has picked up.	PROT-PICKED-UP	PU	NORMAL
BESTlogic Expression: VO12=50TPPU+150TPPU+50TNT+150TNPU+87RPU+50TQPU+150TQPU+51PPU+151PPU+51NPPU+151NPU+51QPU+151QPU					
VO13	Alarm to indicate that the differential cutoff switch is in the block operation position.	TRUE if Virtual Switch 43 is in the closed position.	87-BLOCKED	ACTIVE	NORMAL
BESTlogic Expression: VO13=43					
VO14	Alarm that relay is in feeder backup mode.	TRUE if in setting group 1.	FDR-BU-ENABLED	BACKUP	NORMAL
BESTlogic Expression: VO14=SG1					
VO15	Alarm bit #23 indication that the relay is in test mode and that breaker failure is disabled.	TRUE if IN8 is de-energized or if Virtual Switch 743 is closed.	TEST_MODE	ACTIVE	NORMAL
BESTlogic Expression: VO15=/IN8+743					

Table 8-30. CDS240-BSBU-A-BE Hardware Output Logic

Output	Purpose	Description
OUTA	Relay Trouble Alarm.	OUTA contact closes when relay trouble alarm occurs.
BESTlogic Expression: OUTA=VOA		
OUT1	BUS fault trip (86B for example).	OUT1 contact closes if restrained differential trip or for high-speed bus OC trip (50T) and not in feeder backup mode (VO14).
BESTlogic Expression: OUT1=VO1		

Output	Purpose	Description
OUT2	Transformer fault trip (86B for example).	OUT2 contact closes when Trip bus breaker via lockout for bus faults (250T with 18-20 cycles delay).
BESTlogic Expression: OUT2=VO2		
OUT3	Feeder breaker trip.	OUT3 closes when Trip feeder breaker via auxiliary relay (94) for 50/51 (VO9) trip when in feeder relay backup mode (VO14).
BESTlogic Expression: OUT3=VO3		
OUT4	Breaker 1 trip.	OUT4 contact closes when Trip for bus diff, 87 is TRUE. Or, high-speed bus OC with interlock, 50T, or bus time OC trip, 51 is TRUE and not in feeder backup mode (VO14). Or, for 150T & 151 bus backup overcurrent trip. Or, for control switch trip.
BESTlogic Expression: OUT4=VO4		
OUT5	Breaker 1 Close.	Close breaker 1 (main) if virtual control switch is TRUE and 86B LO is not tripped.
BESTlogic Expression: OUT5=VO5		
OUT6	Breaker Failure Initiate output. Initiate breaker failure protection in relay using backup logic.	Initiate breaker failure if BFI expression is TRUE (VO7) and not in test mode.
BESTlogic Expression: OUT6=VO6		
OUT7 - 14	Spare output contacts.	N/A
BESTlogic Expression: OUT7-14 =0		

CDS240-MOTR-A-BE Motor Protection Logic

The Motor Protection (CDS240-MOTR-A-BE) scheme provides high-speed differential and multiple layers of instantaneous and time overcurrent protection for large motors. This scheme protects against stator phase and ground faults, locked rotor, jam, thermal overload, and unbalanced current. Basic frequent starting protection is also provided. Virtual control switch logic is used for local or remote control and can be used to replace the equivalent panel control switches.

The control switch elements are referred to as virtual because they have no physical form, they exist only in logic form, and they can only be operated via the ASCII command interface or the front panel. When Virtual Control Switch 143 is on or enabled, motor starting is determined by speed switch. When off or disabled, starting is determined by current detector set at 85% of locked rotor current. The Virtual Control Switch 243 is used to customize the protection for high or low starting inertia applications. When high is selected, 150TP is blocked, and 151P is enabled for locked rotor protection. The user may choose to eliminate the use of external switches, as the virtual switches are fully functional equivalents of their physical counterparts.

Figure 8-13 is a one-line drawing and Figure 8-14 is a logic drawing. Both represent the settings shown in Table 8-31. In Table 8-31, the user can see the protection and control elements that are enabled for the CDS240-MOTR-A-BE application and how the elements are logically wired together (equations). If the user should decide to build on this scheme, all elements required for a more detailed application are available through programming. For programming details, refer to Section 7, *BESTlogic Programmable Logic.*

Table 8-31. CDS240-MOTR-A-BE Logic Settings and Equations

SL-N=CDS240-MOTR-A-BE,BASLER
SL-87=1,0
SL-87ND=0,0
SL-187ND=0,0
SL-50BF=0,0,0,0,0
SL-150BF=0,0,0,0,0
SL-250BF=0,0,0,0,0
SL-350BF=0,0,0,0,0
SL-50TP=1,0
SL-50TN=1,0
SL-50TQ=1,0
SL-150TP=1,250TPT+243
SL-150TN=0,0
SL-150TQ=0,0
SL-250TP=1,0
SL-250TN=0,0
SL-250TQ=0,0
SL-350TP=0,0
SL-350TN=0,0
SL-350TQ=0,0
SL-450TP=0,0
SL-450TN=0,0
SL-550TP=0,0
SL-650TP=0,0
SL-750TP=0,0
SL-51P=1,0
SL-51N=0,0
SL-51Q=1,0
SL-151P=1,/VO7+/243
SL-151N=0,0
SL-151Q=0,0
SL-251P=1,VO8
SL-251N=0,0
SL-251Q=0,0
SL-351P=0,0
SL-351N=0,0
SL-351Q=0,0
SL-451N=0,0
SL-24=0,0
SL-27P=0,0
SL-127P=0,0
SL-47=0,0
SL-59P=0,0
SL-59X=0,0
SL-159P=0,0
SL-81=0,0
SL-181=0,0
SL-281=0,0
SL-381=0,0
SL-481=0,0
SL-581=0,0
SL-62=0,0,0
SL-162=0,0,0
SL-262=0,0,0
SL-362=0,0,0
SL-GROUP=0,0,0,0,0,/0
SL-43=0
SL-143=2
SL-243=2
SL-343=0
SL-443=0
SL-543=0
SL-643=0
SL-743=0
SL-101=0
SL-1101=0
SL-2101=0
SL-3101=0
SL-VOA=0
SL-VO1=VO11
SL-VO2=0
SL-VO3=0
SL-VO4=VO14
SL-VO5=VO15
SL-VO6=0
SL-VO7=250TPPU*IN2*143+50TPPU*/143
SL-VO8=250TPPU*/250TPT
SL-VO9=IN3+VO13
SL-VO10=0
SL-VO11=150TPT+50TNT+87RT+VO13+50TQT+51PT+151PT+251PT+51QT
SL-VO12=150TPPU+50TNPU+87RPU+50TQPU+51PPU+151PPU+251PPU+51QPU
SL-VO13=VO9*/ARSTKEY
SL-VO14=250TPT*51PPU
SL-VO15=51QPU
SL-OUTA=VOA
SL-OUT1=VO1
SL-OUT2=VO2
SL-OUT3=VO3
SL-OUT4=VO4
SL-OUT5=VO5
SL-OUT6=VO6
SL-OUT7=0
SL-OUT8=0
SL-OUT9=0
SL-OUT10=0
SL-OUT11=0
SL-OUT12=0
SL-OUT13=0
SL-OUT14=0

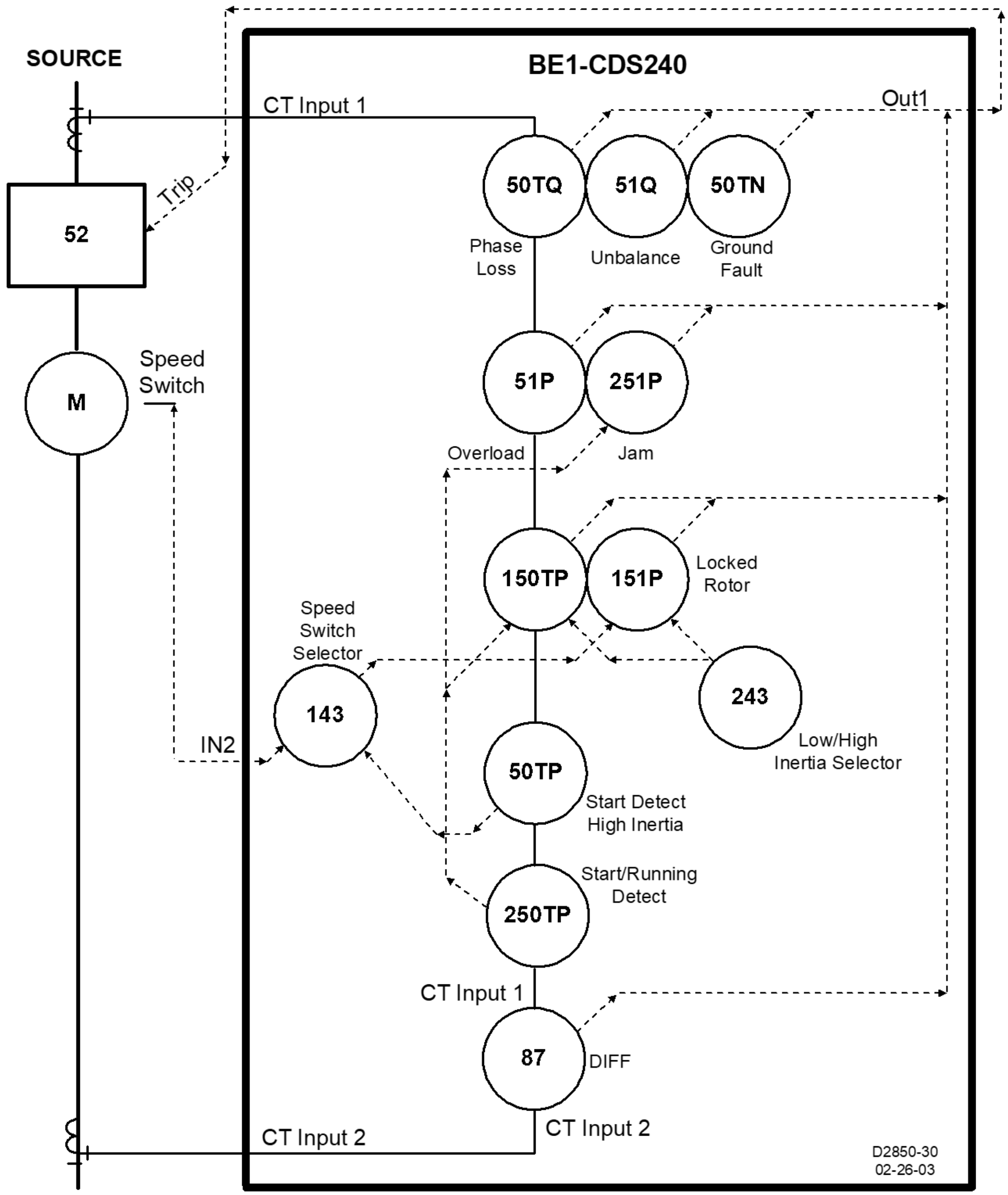

Figure 8-13. Typical One-line Diagram for CDS240-MOTR-A-BE

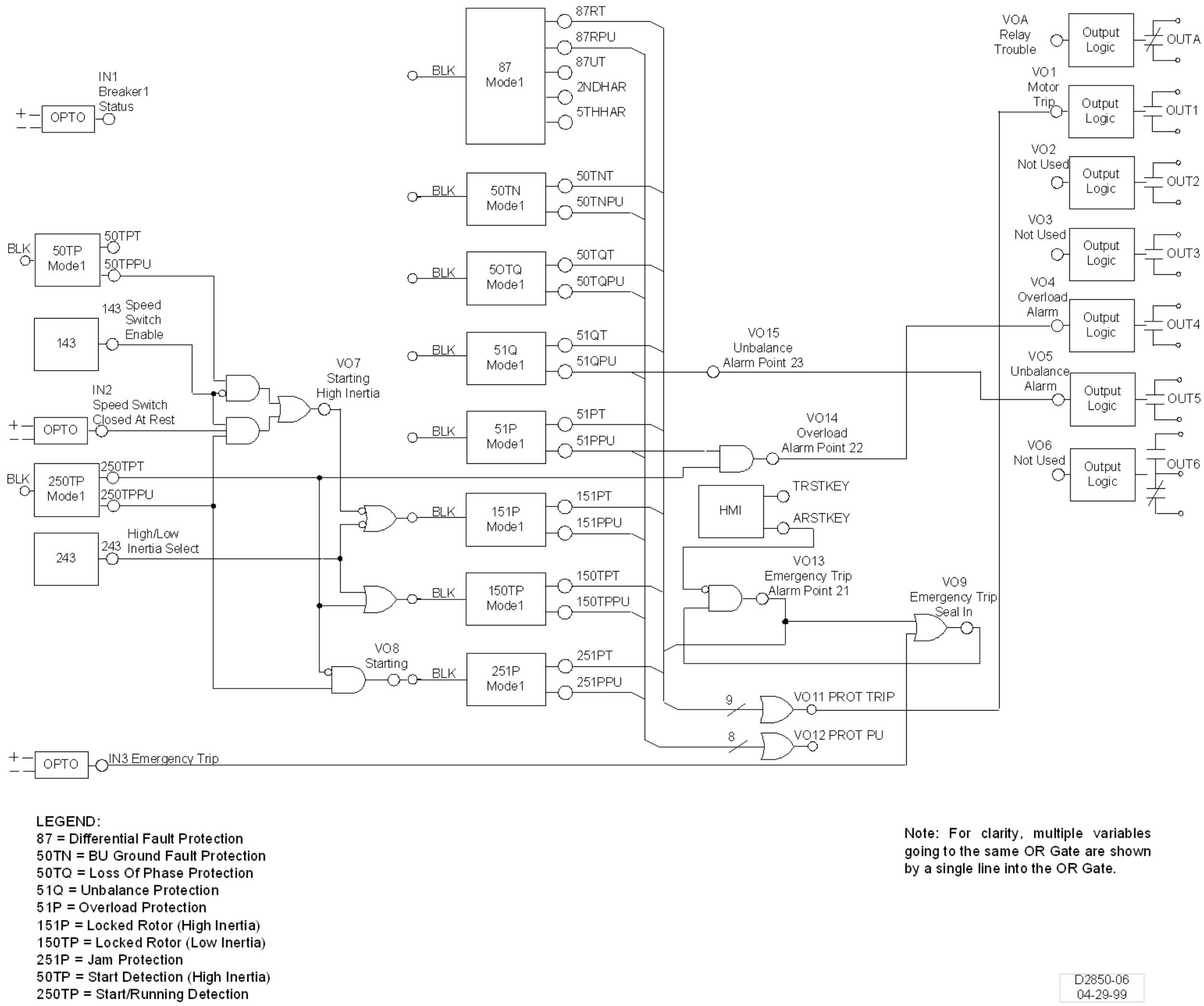

Figure 8-14. Typical Logic Diagram for CDS240-MOTR-A-BE

Protection Elements

Referring to Figure 8-13, the 87, 50/51, 150/151, and 250 protection elements are connected to CT Input 1, and the motor side of the 87 protection element is connected to Input 2. The 87, 50/51, 150/151, and 250 protection elements are logic enabled to provide a trip by the settings shown in Table 8-31. Protection elements set at 0 are setting disabled, and will not provide a trip output even if logic enabled.

Typically, the 87 protection element provides high-speed, percent restrained, phase and ground protection, for faults inside the differential zone. For the CDS240-MOTR-A-BE application shown in Figure 8-14, the percent-restrained differential protection function is the only function of the 87 protection element required. Set the pickup of the 2nd, 5th, and 87U functions to 0 (setting disabled). The unrestrained differential function has a setting only when the 2nd and 5th harmonic restraint functions are set for transformer applications (refer to the discussion in *Overview Of Preprogrammed Logic Schemes*).

In the CDS240-MOTR-A-BE scheme, the 50TQ protection element is used for loss of phase detection, the 51Q protection element is used for unbalance protection (46), and the 50TN protection element is used for ground fault backup protection.

In the CDS240-MOTR-A-BE scheme, the 51P protection element is used for motor overload protection. Blocking during starting is not required since this element is slower than the locked rotor protection. It also serves as backup during starting. The 251P protection element is used to protect for a jam or stall condition. It is blocked while the motor is starting as determined by VO8.

In the CDS240-MOTR-A-BE scheme, the 150TP protection element provides locked rotor protection for low inertia motors. It is blocked when the motor is running (after the 250TP time setting expires) or when Virtual Control Switch 243 is set to high inertia mode. The 151P protection element provides locked rotor protection for high inertia motors. It is blocked when Virtual Control Switch 243 is set to low inertia mode. If high Inertia is selected, it is unblocked when starting as determined by intermediate logic VO7. Virtual Control Switch 143 selects whether high inertia motor starting is determined by speed switch or by current detection (50TP protection element set at 85% of locked rotor current).

In the CDS240-MOTR-A-BE scheme, the 50TP protection element is used for motor start detection (50S). The 250TP protection element is used to detect when the motor is running. It supervises the 150TP locked rotor protection for low inertia motor applications and the 251P jam or stall protection. Targets should not be enabled with the SG-TARG setting for either the 50TP or the 250TP function.

Integration of Protection, Control, and I/O Elements

The logic settings in Table 8-31 also include the logic equations that establish the control connections or logic wiring between elements of the CDS240-MOTR-A-BE scheme. For example, the two underlined equations in the settings of Table 8-31 provide the electrical connection between the 87 element (trip enabled by the settings) and trip output 1. Referring to Figures 8-13 and 8-14, all protection elements in the CDS240-MOTR-A-BE scheme are enabled to trip. All protection elements, with the exception of 250TP start/run detection, are connected to trip through Output 1. Motor phase unbalance alarms are connected through Output 5 and motor overload alarms through output 4. Protection elements set at 0 are setting disabled and will not provide a trip output even if logic enabled.

The 87, 50TN, 50TQ, 51P, and 251P protection elements provide primary and backup fault/open phase protection including stall protection for a running motor. The remainder of the protection is associated with starting the motor. High and low inertia locked rotor protection is provided by 150TP and 151P protection elements. Start/run current detection for low inertia motors is provided by the 250TP protection element and start detection for high inertia motors is provided by either speed switch input or current detection from the 50TP protection element.

High Inertia Motor Start

As shown on Figure 8-13, the first thing the user must do is select the high inertia position of Virtual Control Switch 243 and then select between motion detection by external speed switch or motion detection by current sensing. This is accomplished by the position of Virtual Switch 143. If we assume current sensing was selected, then, when the breaker is closed, 50TP picks up forcing VO7 high and removing the block from 151P locked rotor protection. Locked rotor 151P picks up and starts timing. If the motor current drops below the 50TP setting before 151P times out, the locked rotor protection is blocked and the motor start was successful. However, if the motor current stays high until 151P times out, the motor is tripped through Output 1 and the Major Alarm LED on the front panel lights.

If speed switch input is selected by the position of Virtual Switch 143, then, when the breaker is closed, 250TP picks up and a closed external speed sensing contact at Input 2 unblocks the locked rotor protection. If the speed sensing contact opens, or the 250TP drops out, locked rotor protection is blocked and the motor successfully starts.

For high or low inertia starts, 251P jam or stall protection is blocked by V08 until 250T drops out or times out.

For high inertia motors, the distance between the burn-up curve and the knee point of the start/run plot is typically close. Locked rotor protection will reset when the motor comes up to speed but abnormally high run current could still be present but not high enough to trip on overload. If the abnormal run current is allowed to persist, motor life will be shortened through accelerated thermal aging. To alert the user to this condition, when 250TP has timed out and 51P is picked up, Virtual Output 14 is programmed to go high which drives alarm bit #22 in the programmable alarm mask and alarms through Output 4 to the outside world. It can also be masked to drive an alarm LED, and the alarm display to indicate when the overload condition exists. If the overload is high enough to time out 51P, the breaker is tripped through Output 1.

Phase imbalance can lead to stator and rotor overheating resulting in the same scenario as previously discussed. For this reason, a circuit similar to the overload alarm is included for phase imbalance. When 51Q picks up, Virtual Output 15 is programmed to go high which drives alarm bit #23 in the programmable alarm mask and alarms through Output 5 to the outside world. It can also be masked to drive an alarm LED and the alarm display to indicate when the imbalance condition exists. If the imbalance is high enough to time out 51Q, the breaker is tripped through Output 1.

Low Inertia Motor Start

Selecting the low inertia protection through Virtual Control Switch 243 disables the 151P high inertia locked rotor protection. When the breaker is closed, 250TP, start/run current detection and 150TP low inertia locked rotor protection, start timing. If the motor comes up to speed before time out of the 150TP element, start is successful. If 150TP times out first, the motor is tripped through Output 1. As described under high inertia start, a motor could successfully start but still have abnormally high run currents. If 250TP, start/run current detection times out, 150TP (low inertia locked rotor protection) is defeated and the same motor overload protection discussed above takes over.

Emergency Trip

An external emergency trip sensed at IN3 will initiate a trip of the breaker through Output 1 and seals the trip path through V09. Virtual Output 13 goes high which drives alarm bit #21 in the programmable alarm mask. The breaker cannot be closed until the seal-in is cleared by the Alarm Reset Key (ARSTKEY).

Alarms

Three logic variables drive the front panel LEDs: Relay Trouble (ALMREL), Major Alarm (ALMMAJ), and Minor Alarm (ALMMIN). There is a fourth logic variable, Logic Alarm (ALMLGC) but there is no associated front panel LED. When the relay self-test detects a problem in the relay (ALMREL) as programmed for the CDS240-MOTR-A-BE scheme, the Relay Trouble LED lights, Output A operates and all outputs are disabled. When a Major Alarm is detected (ALMMAJ), the associated LED lights. But in this scheme, no output relay is programmed to operate. When a Minor Alarm (ALMMIN) is detected, the associated LED lights, but in this scheme, no output relay is programmed to operate.

NOTE

Tables 8-32 through 8-36 provide detailed logic definitions for the inputs, outputs, protection, and control elements. Only those inputs, logic blocks, virtual switches, and outputs in use for the CDS240-MOTR-A-BE preprogrammed logic are described in the following tables.

Table 8-32. CDS240-MOTR-A-BE Contact Input Logic

Input	Purpose	Name Label	State Labels	
			Energized	De-Energized
IN1	Optional input. Used for CT Input Circuit 1 Breaker status indication in SER reports. TRUE when breaker closed.	BREAKER-1	CLOSED	OPEN
IN2	Speed switch, closed at reset. Used to block the 51S locked rotor protection (for high inertia motors) during running.	SPEED-SWITCH	RUNNING	STOPPED
IN3	Emergency trip. This is an optional input.	EMERG-TRIP	TRIP	NORMAL

Table 8-33. CDS240-MOTR-A-BE Function Block Logic

Function	Purpose	BESTlogic Expression	Mode Setting
87	Used for percent-restrained differential protection with high-speed unrestrained instantaneous differential protection.	0	1 (enabled)
51P	51P is used for motor overload protection. Blocking during starting is not required since this element is slower than the LR protection. It serves as backup during starting.	0	G (Ground Input)
51Q	51Q is used for unbalance protection (46).	0	1 (Circuit 1)
151P	The 151P element provides locked rotor protection for high inertia motors. Blocked when low inertia is selected by Switch 243. If high Inertia is selected, it is unblocked when starting as determined by intermediate logic VO7.	/VO7+/243	1 (Circuit 1)
251P	This element protects for a jam condition. It is blocked while the motor is starting as determined by VO8.	VO8	1 (Circuit 1)

Function	Purpose	BESTlogic Expression	Mode Setting
50TP	50TP is used for motor start detection (50S). Target should not be enabled with the SG-TARG setting for this function.	0	1 (Circuit 1)
50TN	50TN is used for ground fault backup protection.	0	1 (Circuit 1)
50TQ	50TQ is used for loss of phase detection.	0	1 (Circuit 1)
150TP	This element provides LR protection for low inertia motors. It is blocked when the motor is running (after the 250TP time setting expires) or when the high inertia mode is selected.	250TPT+243	1 (Circuit 1)
250TP	The 250TP is used to detect when the motor is running. It supervises the 150TP locked rotor protection for low inertia motor applications and the 251P jam protection. Target should not be enabled with the SG-TARG setting for this function.	0	1 (Circuit 1)

Table 8-34. CDS240-MOTR-A-BE Virtual Switch Logic

Switch	Purpose	Mode	Label	State Labels	
				True	False
143	Speed Switch selector. When enabled, the motor starting is determined by speed switch. When None, starting is determined by current detector set at 85% of locked rotor current.	2 (On/Off)	SPEED-SWITCH	ENABLED	NONE
243	Selector Switch to customize the protection for high or low inertia applications. When high is selected, blocks 150TP and enables 151P for locked rotor protection.	2 (On/Off)	INERTIA-MODE	HIGH	LOW

Table 8-35. CDS240-MOTR-A-BE Virtual Output Logic

Output	Purpose	Description	Label	State Labels	
				True	False
VOA	Relay Trouble Alarm.	VOA TRUE if relay trouble alarm occurs.	RELAY-TROUBLE	ACTIVE	NORMAL
BESTlogic Expression: VOA=0					
VO1	Breaker trip.	TRUE when protective trip expression is TRUE.	MOTOR_TRIP	TRIP	NORMAL
BESTlogic Expression: VO1=VO11					
VO4	VO4 TRUE, Overload protection (51P) is picked up and timing to trip.	TRUE when Overload protection (51P) is picked up and timing to trip.	OVERLOAD	ALARM	NORMAL
BESTlogic Expression: VO4=VO14					
VO5	Unbalance alarm output contact.	VO5 TRUE, Unbalance protection (51Q) is picked up and timing to trip.	UNBALANCE	TRIP	NORMAL
BESTlogic Expression: VO5=VO15					

Output	Purpose	Description	Label	State Labels	
				True	False
VO7	Intermediate logic variable that determines if a high inertia motor application is starting. (Not yet up to speed).	SW 143 selects whether starting is determined by monitoring speed switch or current. TRUE if motor energized 250TPPU and speed switch (IN2) closed. Or, 50TP is picked up. Used to unblock 151P for Locked Rotor protection.	STARTING-HIGH-I	TRUE	FALSE
BESTlogic Expression: VO7=250TPPU*IN2*143+50TPPU*/143					
VO8	Intermediate logic variable that determines if the motor is starting. (Time set for about 120% of maximum start time.)	TRUE if 250TP is picked up but not yet timed out. Used to unblock jam (251P) protection.	STARTING	TRUE	FALSE
BESTlogic Expression: VO8=250TPPU*/250TPT					
VO9	Emergency Trip intermediate logic expression for external trip alarm seal-in.	TRUE if IN3 is energized causing a trip or if emergency trip alarm point is TRUE.	EMER-TRIP-SEALIN	TRUE	FALSE
BESTlogic Expression: VO9=IN3+VO13					
VO11	Protective trip expression.	Restrained diff trip, 50TN ground fault, 50TQ loss of phase, 150TP low inertia locked rotor, 51P overload, 51Q unbalance, 151P high inertia locked rotor, 251P Jam, or VO13 Emergency Trip.	PROTECTIVE-TRIP	TRIP	NORMAL
BESTlogic Expression: VO11=150TPT+50TNT+87RT+VO13+50TQT+51PT+151PT+251PT+51QT					
VO12	Protective pickup expression.	Restrained and unrestrained diff trip, 50TN ground fault, 50TQ loss of phase, 150TP low inertia locked rotor, 51P overload, 51Q unbalance, 151P high inertia locked rotor, 251P Jam.	PROT-PICKED-UP	PU	NORMAL
BESTlogic Expression: VO12=150TPPU+50TNPU+87RPU+50TQPU+51PPU+151PPU+251PPU+51QPU					
VO13	Emergency trip alarm.	TRUE if emergency trip input is energized causing a motor trip. The alarm condition is sealed in for annunciation on the HMI until the alarm reset key is pressed on the HMI. Note: Seal-in condition cannot be broken unless optional HMI is purchased.	EMER-TRIP-RESET	ALARM	NORMAL
BESTlogic Expression: VO13=VO9*/ARSTKEY					
VO14	Overload alarm.	TRUE if overload (51P) protection is picked up. This condition will trip the motor if allowed to time out. The alarm point is supervised by the 250TP timing out to prevent a spurious alarm during starting.	OVERLOAD	ALARM	NORMAL
BESTlogic Expression: VO14=250TPT*51PPU					

Output	Purpose	Description	Label	State Labels	
				True	False
VO15	Unbalance alarm.	TRUE if unbalance (51Q) protection is picked up. This condition will trip the motor if allowed to time out.	UNBALANCE	ALARM	NORMAL
BESTlogic Expression: VO15=51QPU					

Table 8-36. CDS240-MOTR-A-BE Hardware Output Logic

Output	Purpose	Description
OUTA	Relay Trouble Alarm.	OUTA contact closes when relay trouble alarm occurs.
BESTlogic Expression: OUTA=VOA		
OUT1	Breaker trip.	OUT1 contact closes when protective trip expression is TRUE.
BESTlogic Expression: OUT1=VO1		
OUT4	Overload alarm output contact.	OUT4 contact closes when Overload protection (51P) is picked up and timing to trip.
BESTlogic Expression: OUT4=VO4		
OUT5	Unbalance alarm output contact.	OUT5 contact closes when Unbalance protection (51Q) is picked up and timing to trip.
BESTlogic Expression: OUT5=VO5		
OUT7 - 14	Spare output contacts.	N/A
BESTlogic Expression: OUT7-14 =0		

Miscellaneous Logic Expressions

Several logic expressions are classified as miscellaneous. That is, they are not included in the BESTlogic settings and are not set through the ASCII command interface using the SL (set logic) commands. Several of the Reporting And Alarm Functions provided in the relay require programmable logic expressions to determine their functionality. These logic expressions are included with the settings associated with each function. Table 8-37 cross-references the manual Sections and commands associated with each miscellaneous logic expression.

Each of the preprogrammed logic schemes is designed to be compatible with the factory default logic expression settings for these Reporting And Alarm Functions. However, when copying a preprogrammed scheme for modification or direct use, it is important to recognize that these miscellaneous logic expressions will not be effected. These miscellaneous logic settings must be reviewed to ensure desired performance for these functions.

Table 8-37. Miscellaneous Logic Expressions

Command	Reference
SA-RESET	Section 6, *Reporting and Alarms, Alarms Function*
SB-DUTY	Section 6, *Reporting and Alarms, Breaker Monitoring*
SB-LOGIC	Section 6, *Reporting and Alarms, Breaker Monitoring*
SG-TARG	Section 6, *Reporting and Alarms, Fault Reporting*
SG-TRIGGER	Section 6, *Reporting and Alarms, Fault Reporting*
ST-DUTY	Section 6, *Reporting and Alarms, Transformer Monitoring*

Trip Circuit Continuity and Voltage Monitor

The trip circuit monitor drives logic variable CKTMON. This variable can be used to improve breaker failure logic or to automatically enhance security during testing.

If the relay detects a loss of voltage or continuity in the breaker trip circuit, it is possible to speed up fault clearing time by bypassing the breaker failure timer. Since relay failure and breaker failure are covered by different backup actions, it is desirable to reduce common mode failure mechanisms. It is recommended that the feeder breaker and feeder protection circuits be supplied by separate control power fuses or breakers. The equation for the Breaker Failure Trip logic (VO5) in Figure 8-15 can be modified by ORing the Breaker Failure Trip output with the expression VO10∗CKTMON. VO10 is designated as the Breaker Failure Initiate expression. Example 1 illustrates how the BFT logic expression is modified. It is important that the breaker failure timer bypass logic also be disabled in test mode. Example 2 shows the expression for blocking the upstream instantaneous element. Figure 8-15 illustrates using the trip circuit continuity monitor in breaker failure logic.

Example 1.

Breaker failure trip expression: SL-VO5=BFT+VO10*CKTMON*IN4*/343

Example 2.

Block upstream instantaneous expression: SL-VO4=VO12*/VO5*/CKTMON*IN4*/343

If the internal breaker failure function block is not being used, the trip circuit continuity and voltage monitor alarm can be used to detect when the test switches have been opened. This will automatically place the relay in test mode. Each of the preprogrammed logic schemes has logic to detect when the relay is out of service for test. This enables the backup logic and enhances security. It should be noted that if the test mode logic is modified in this manner, it is not possible to differentiate between the relay being out of service for test and a problem in the circuit breaker trip circuit. Otherwise, the internal breaker failure function block would be disabled during a known problem in the trip circuit.

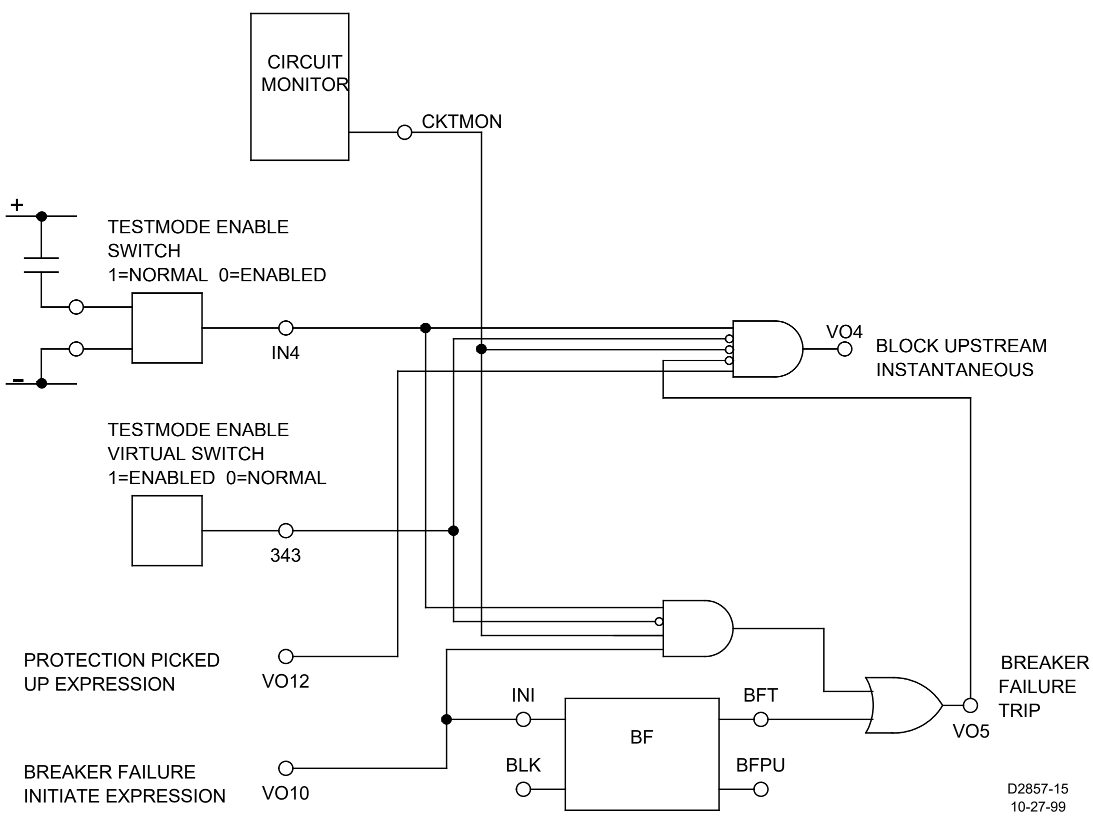

Figure 8-15. Trip Circuit Continuity and Voltage Monitor

Close-Circuit Monitor

A close-circuit monitor is not included in any of the preprogrammed logic schemes. This function may be added by using a 62 function block and a contact sensing input (INX) to monitor the close circuit. The logic is shown in Figure 8-16. The output of the 62 protection block will close the designated output contact (VOY) when an open breaker and an open close-circuit condition exist. The S<g>-62 command is used to provide a 500-millisecond time delay to inhibit the momentary alarm that will occur due to the timing difference between the two signals.

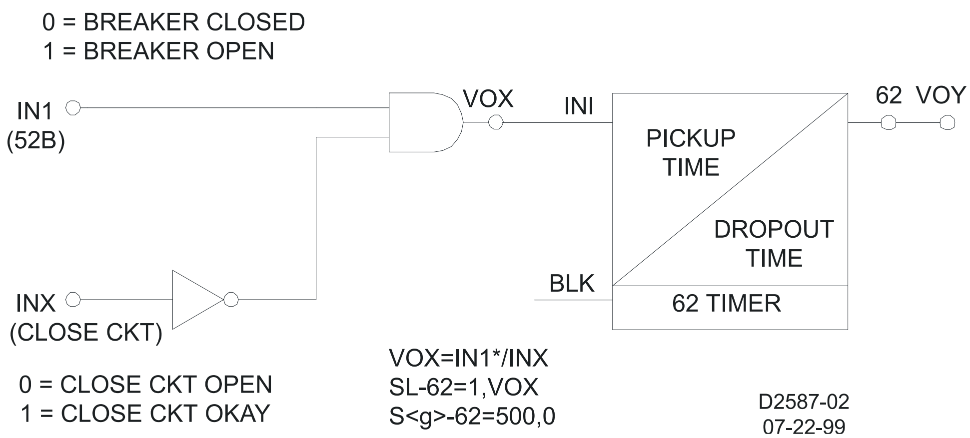

Figure 8-16. Close Circuit Monitor Logic

Block Neutral and Negative Sequence Protection

The neutral and negative sequence overcurrent elements provide greater sensitivity to unbalanced faults than the phase overcurrent elements because they can be set to pickup below balanced three-phase load. This can lead to a misoperation during periods of load imbalance. The BE1-CDS240 provides a neutral and negative sequence demand function that allows monitoring and alarming to prevent load imbalances. However, distribution systems with single-pole fault clearing and switching devices or long single-phase laterals, may have misoperation during switching activities.

Some of the preprogrammed logic schemes provide for the use of a cutoff switch to block the ground and negative sequence 50T (used for low set instantaneous) and the 51 (inverse time) function blocks during switching activities. This is the most conservative approach. The protection engineer may wish to evaluate this strategy based on his system, his/her operating practices, and his/her setting practices. For instance, on systems with wye-connected loads, the ground units are most sensitive to this situation. On systems with delta connected loads the negative sequence units are most sensitive to this situation. It may not be necessary to block the instantaneous units if their settings prevent them from tripping for a switching imbalance.

To maintain proper coordination, the logic of the feeder relays may be interconnected with the upstream bus relay to block the equivalent ground and/or negative sequence function blocks in the upstream relay.

Setting Group Selection

The BE1-CDS240 Current Differential System provides multiple settings groups for adaptive relaying. The preprogrammed logic schemes barely demonstrate the flexibility available. The following examples illustrate how the setting groups can be adapted for different conditions and how different setting groups can be used to vary the system logic.

Example 1: Adapting the relay settings for different conditions.

In overcurrent protection systems, the source conditions can have a major impact on sensitivity, coordination intervals, and clearing times. Generally, the pickup and time dial settings are a compromise between a normal condition and a worst-case condition. Contact logic from the position of the source breakers can select which settings group is active. To do this, assign input D0 or D1 to a contact sensing input. Set the setting group selection mode at 2 for binary coded selection. If D0 is set, group 0 will be selected when the input is off (binary code 00). Group 1 will be selected when the input is on (binary code 01). Similarly, if D1 is set, group 2 will be selected when the input is on (binary coded 10).

This logic is useful in a situation where two transformers feed a single bus or two busses have a bus tie between them. The feeder and bus relays must be coordinated for the situation where only one source is in service (bus tie open or one transformer out of service). However, when both sources are in service, such as when the bus tie is closed, each bus relay sees only half of the current for a fault. This results in poor sensitivity and slow clearing time for the bus relays.

Example 2: Adapting the logic in different setting groups.

The logic in most of the preprogrammed logic schemes can be varied in each of the different setting groups. This is accomplished by disabling functions by setting their primary settings at zero. More sophisticated modification of the logic in each of the different setting groups is possible by using the active setting group logic variables SG0, SG1, SG2, and SG3 in the BESTlogic expressions.

Output Contact Seal-in

Trip contact seal-in circuits have historically been provided with electromechanical relays. These seal-in circuits consisted of a dc coil in series with the relay trip contact and a seal-in contact in parallel with the trip contact. The seal-in feature serves several purposes for the EM relays. One is to provide mechanical energy to drop the target. Second is to carry the dc tripping current from the induction disk contact that may not have significant closing torque for a low resistance connection. The third is to prevent the relay contact from dropping out until the current has been interrupted by the 52a contacts in series with the trip coil. If the tripping contact opens before the dc current is interrupted, the contact may be damaged. The first two of these items are not an issue for solid-state relays, but the third item is an issue.

To prevent the output relay contacts from opening prematurely, a 200 millisecond hold timer can be selected with the SG-HOLDn=1 command. (See Table 8-38.) Refer to Section 3, *Input and Output Functions, Outputs, Programmable Hold Timer,* for more information on this feature. If the protection engineer desires seal-in logic with feedback from the breaker position logic, he/she can provide this feature by modifying the BESTlogic expression for the tripping output. To do this, use one of the general purpose timers, 62, or 162 and set it for mode 1 (Pickup/Dropout Timer). Set the timer logic so that it is initiated by the breaker position input, and set the timer for two cycles pickup and two cycles dropout. Then AND the timer output with the tripping output (VO1) and OR it into the expression for the tripping output. The same can be done for the closing output. See Figure 8-17 for the seal-in logic diagram and Seal-in Logic Table 8-38 that follows. This table is based on the CDS240-BATX-A-BE preprogrammed logic scheme.

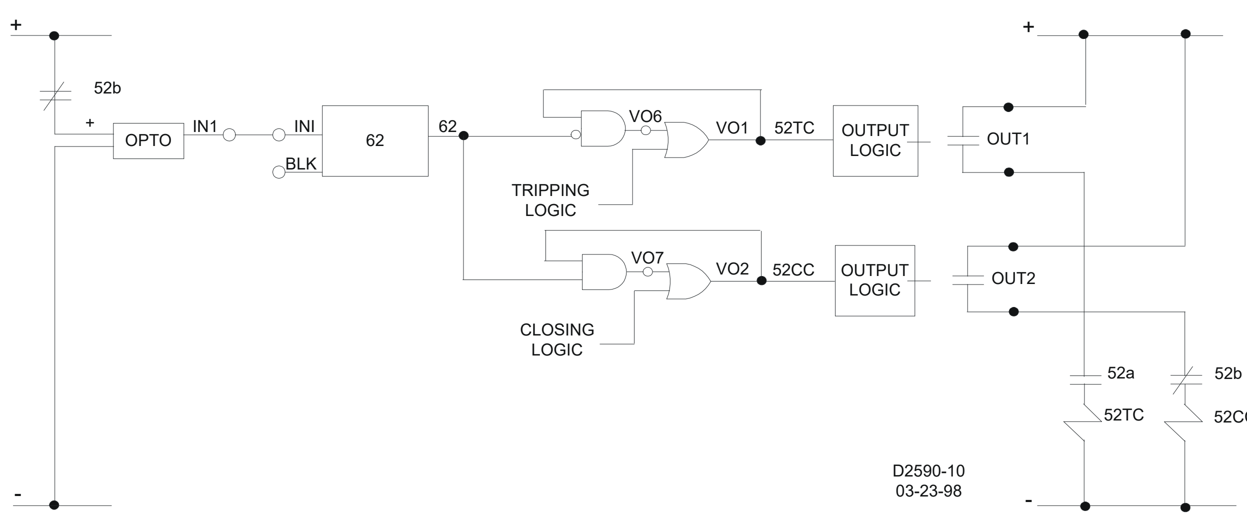

Figure 8-17. Output Seal-in Logic Diagram

Table 8-38. Output Contact Seal-in Logic

Command	Purpose
SG-HOLD1=0	Turn off the hold timer for output 1.
SL-62=1,IN1,0	Set the timer logic to mode 1 (pickup/dropout), IN1 to initiate, no blocking.
S#-62=2c,2c	Set the pickup (2 cycles) and dropout (2 cycles) times.
VO1=87RT+87UT+VO1∗/62	Set the tripping logic for restrained 87 or unrestrained 87 or Virtual Output 1 and not 62.
VO2=87RT+87UT+VO7	Set the closing logic for restrained 87 or unrestrained 87 or Virtual Output 7.
VO6=VO1∗/62	Set the Virtual Output 6 logic to VO1 and not 62.
VO7=VO2∗62	Set the Virtual Output 7 logic to VO2 and 62.
E	Exit.
Y	Save settings.

Latching a Tripping Contact

On occasion, an application will call for latching an output contact. As an example, assume that a BE1-CDS240 is used for protection of a radial transformer as shown in Figure 8-18. The user wants to trip and lockout the high-side circuit switcher for a differential trip but not for an overcurrent trip. He/she does not want the transformer to be re-energized until someone locally checks and resets the relay.

Referring to Figure 8-13, which is an adaptation of CDS240-BA87-B-BE logic, an 87 trip will cause VO7 to go TRUE. This causes OUT1, OUT2, and OUT3 to close and OUT5 that would be wired in the close circuit, to open. VO7 is sealed in via VO8 and holds the outputs in this condition. The optional front panel HMI LCD automatically goes to the *Targets* screen per the automatic display priority function. When the operator presses the *Reset* key while the display is on the *Targets* screen, the TRSTKEY logic variable goes high and breaks the seal-in of logic expressions VO7 and VO8. Outputs OUT1, OUT2, and OUT3 will then open and OUT5 will close.

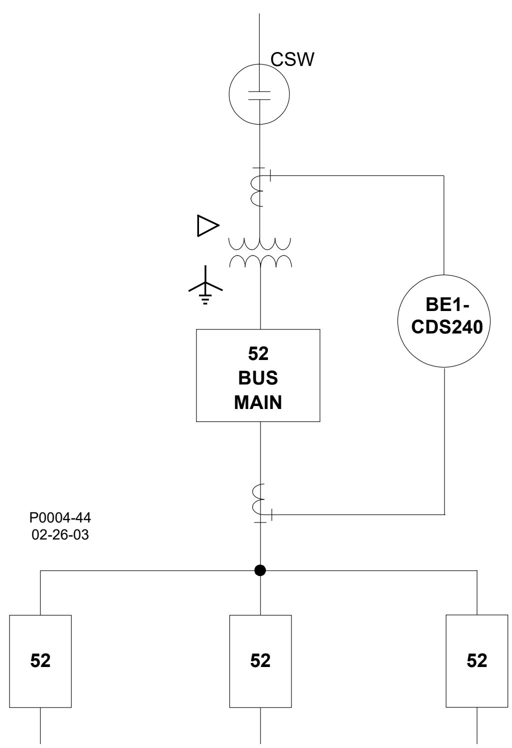

Figure 8-18. Station One-line Drawing

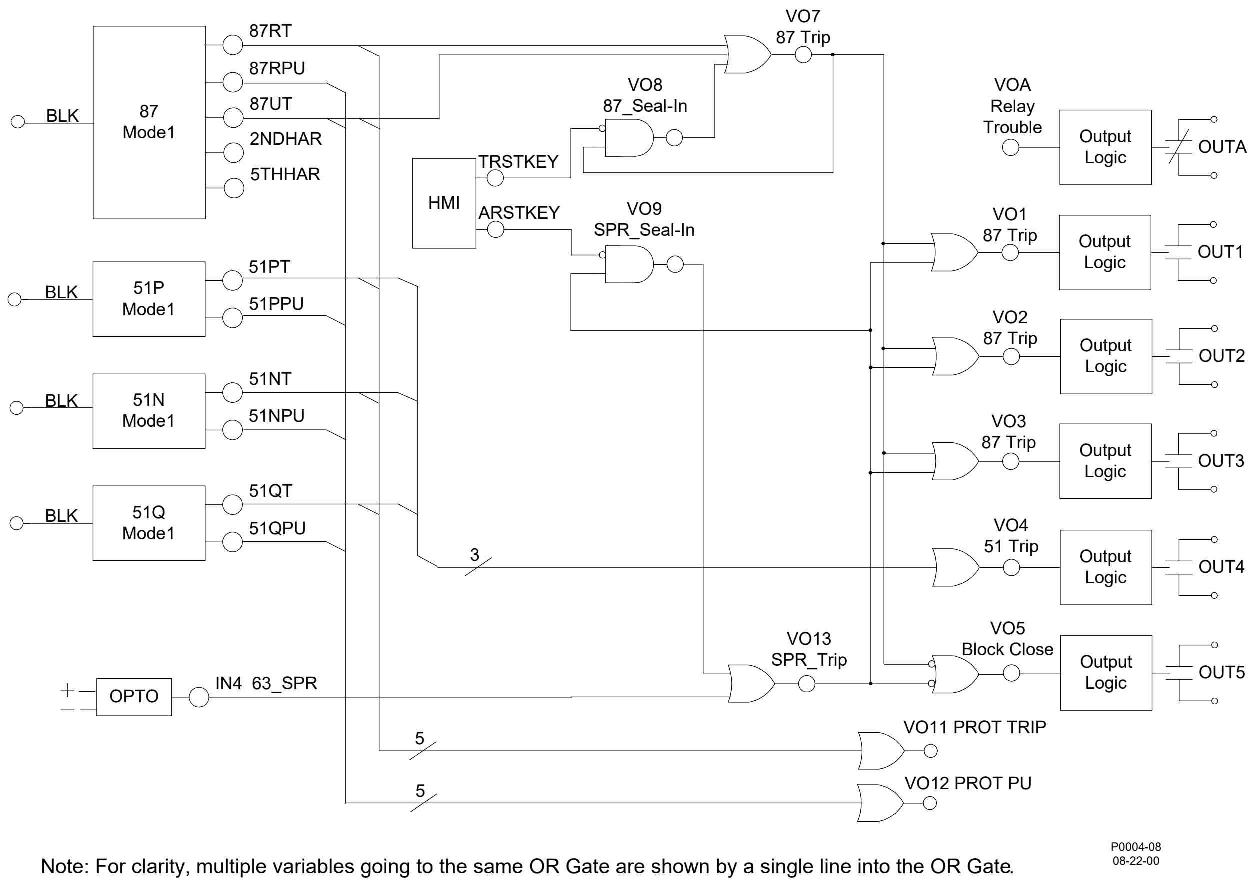

Figure 8-19. Latching a Tripping Contact Example

Latching a Programmable Logic Alarm or Creating a Pseudo Target

Sometimes, a user may want the relay to annunciate and latch for a user-defined condition originating internally or externally to the relay. This can be accomplished using the user programmable labels functionality and the virtual outputs VO13, VO14, or VO15. These virtual outputs are also programmable alarm variables. If one of these three logic expressions is true and is also programmed as a major or minor alarm point, the programmable label will appear on the *Alarms* screen of the optional front panel HMI display.

The application of this is best illustrated with an example. Use the application shown in Figures 8-18 and 8-19. The user wants to trip and lockout the high side circuit switcher (CSW) for a Sudden Pressure Relay (63_SPR) trip. The SPR trip is to be supervised and sealed in via the BE1-CDS240 relay. Since this is an external function, it is desired that the relay annunciate that the trip came from the SPR instead of an internal protective element.

Referring to Figure 8-19, when the SPR contact closes, IN4 will cause VO13 to go TRUE. This causes OUT1, OUT2, and OUT3 to close and OUT5 that would be wired in the close circuit to open. VO13 is sealed in through VO9 that holds the outputs in this condition. The HMI LCD automatically goes to the *Alarms* screen if VO13 is programmed as a major or minor alarm per the automatic display priority function. The LCD displays the user programmable label for VO13 which in this example might be programmed to be SN-VO13=SPR_TRIP.

When the operator presses the *Reset* key while the display is on the *Alarms* screen, the ARSTKEY logic variable goes high and breaks the seal in of logic expressions VO13 and VO9. Outputs OUT1, OUT2, and OUT3 will then open and OUT5 will close.

Refer to Section 6, *Reporting and Alarms,* for more information on programmable alarms. Refer to Section 10, *Human Machine Interface,* for more information on Automatic Display Priorities.

Logic settings associated with Figure 8-19 are provided in Table 8-39.

Table 8-39. Logic Settings Associated with Figure 8-19

SL-87=1,0
SL-51P=1,0; SL-51N=1,0; SL-51Q=1,0
SL-VO1=VO7+VO13
SL-VO2=VO7+VO13
SL-VO3=VO7+VO13
SL-VO4=51PT+51NT+51QT
SL-VO5=/VO7+/VO13
SL-VO6=ALMMAJ
SL-VO7=87RT+87UT+VO8
SL-VO8=VO7*/TRSTKEY
SL-VO9=VO13*/ARSTKEY
SL-VO11=51PT+51NT+51QT+87RT+87UT
SL-VO12=87UT+51PPU+51NPU+51QPU+87RPU
SL-VO13=IN4+VO9
SL-OUT1=VO1
SL-OUT2=VO2
SL-OUT3=VO3
SL-OUT4=VO4
SL-OUT5=VO5
SL-OUT6=VO6

SECTION 9 • SECURITY

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SECTION 9 • SECURITY

Introduction

In this section, security, in the form of multilevel password protection, is discussed along with the information required for protecting specific function groups and user interface components against unauthorized access.

Passwords provide access security for three distinct functional access areas: Settings, Reports, and Control. Each functional area can be assigned a unique password or one password can be assigned to multiple areas. A global password is used to access all three of the functional areas. BE1-CDS240 passwords are not case sensitive; either lowercase or uppercase letters may be entered. Password security only limits write operations; passwords are never required to read information from any area.

Additional security is provided by controlling the functional areas that can be accessed from a particular communication port. For example, security can be configured so that access to control commands from the rear RS-232 port (COM1) is denied. An attempt to issue a Control command through COM1 will cause the relay to respond with an ACCESS DENIED and/or INVALID PASSWORD message. This will occur whether a valid password is entered or not. When configuring communication port access areas, you should be aware that the front RS-232 port (COM0) and the front panel human-machine interface (HMI) are treated as the same port.

The communication ports and password parameters act as a two-dimensional control to limit changes. In order for a command to be accepted, the entered password must be correct and the command must be entered through a valid port. Only one password can be active at one time for any area or port. For example, if a user gains write access at COM1, then users at other areas (COM0, front panel human-machine interface (HMI) and COM2) will not be able to gain write access until the user at COM1 uses the EXIT command to release access control.

If a port holding access privileges sees no activity (command entered or HMI key pressed) for approximately five minutes, access privileges and any pending changes will be lost. This feature ensures that password protection cannot be accidentally left in a state where access privileges are enabled for one area and other areas locked out for an indefinite period.

If password protection is disabled, then entering ACCESS= followed by no password or any alphanumeric character string will obtain access to the unprotected area(s).

Setting Password Protection

Password protection is configured for each access area port and communication port using BESTCOMS™. Alternately, password protection can be configured using the GS-PW ASCII command.

To configure password protection using BESTCOMS, select General Operation from the *Screens* pull-down menu. Then select the *Global Security* tab. Refer to Figure 9-1.

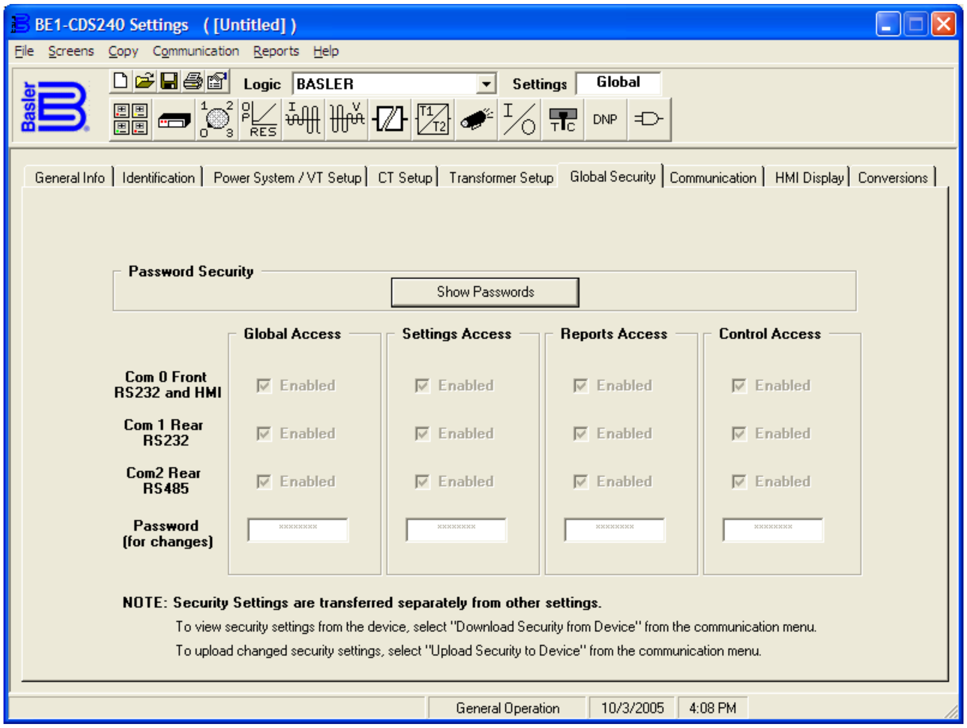

Figure 9-1. General Operation Screen, Global Security Tab

If a change is required and the *Password Security* box reads *Show Passwords*, press *Show Passwords*. Passwords may be entered in the text boxes for Global Access, Settings Access, Reports Access, and Control Access. See Figure 9-2. Each access level may be enabled (or not enabled) for COM 0 Front RS-232 and HMI, COM 1 Rear RS-232, and COM 2 Rear RS-485. Access levels may also be enabled for multiple ports.

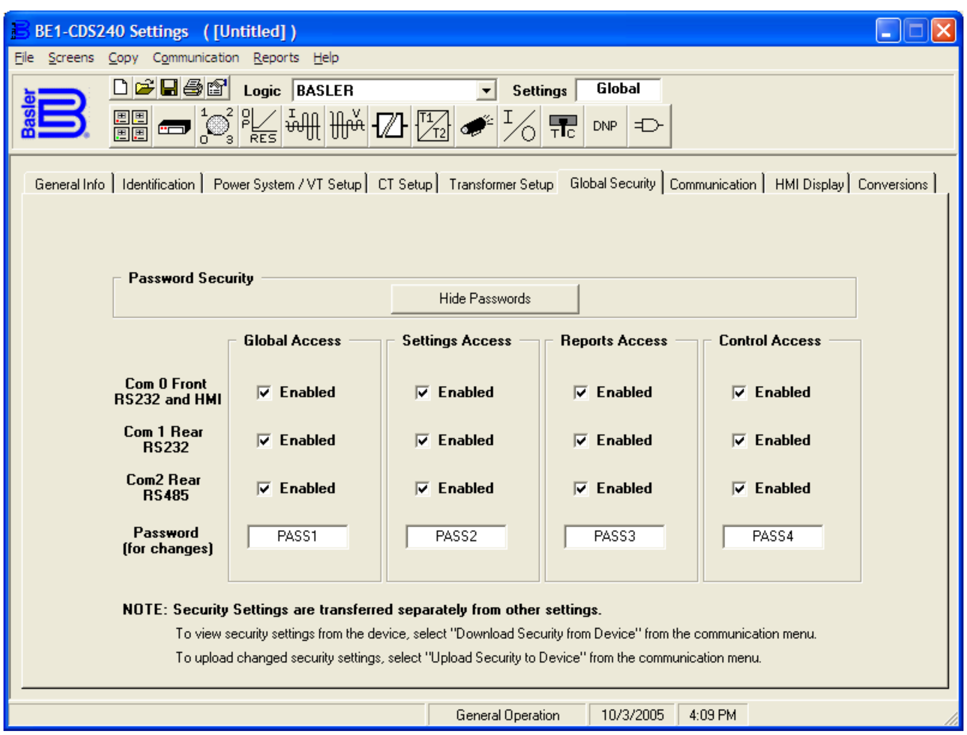

Figure 9-2. General Operation Screen, Global Security Tab with Passwords Shown

Table 9-1 lists password protection settings.

Table 9-1. Password Protection Settings

Setting	Range/Purpose
Password	User defined alphanumeric string with a maximum of 8 characters. A setting of 0 (zero) disables password protection.
Com ports	0 = Front RS-232 port 1 = Rear RS-232 port 2 = Rear RS-485 port

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SECTION 10 • HUMAN-MACHINE INTERFACE

General

This section describes the BE1-CDS240 Current Differential System optional human-machine interface (HMI) and illustrates the front panel display menu tree branches.

Front Panel Display

Figure 10-1 shows the optional front panel HMI for a horizontal mount BE1-CDS240 Current Differential System. The vertical mount relay layout has identical functionality. The locators and descriptions of Table 10-1 correspond to the locators shown in Figure 10-1.

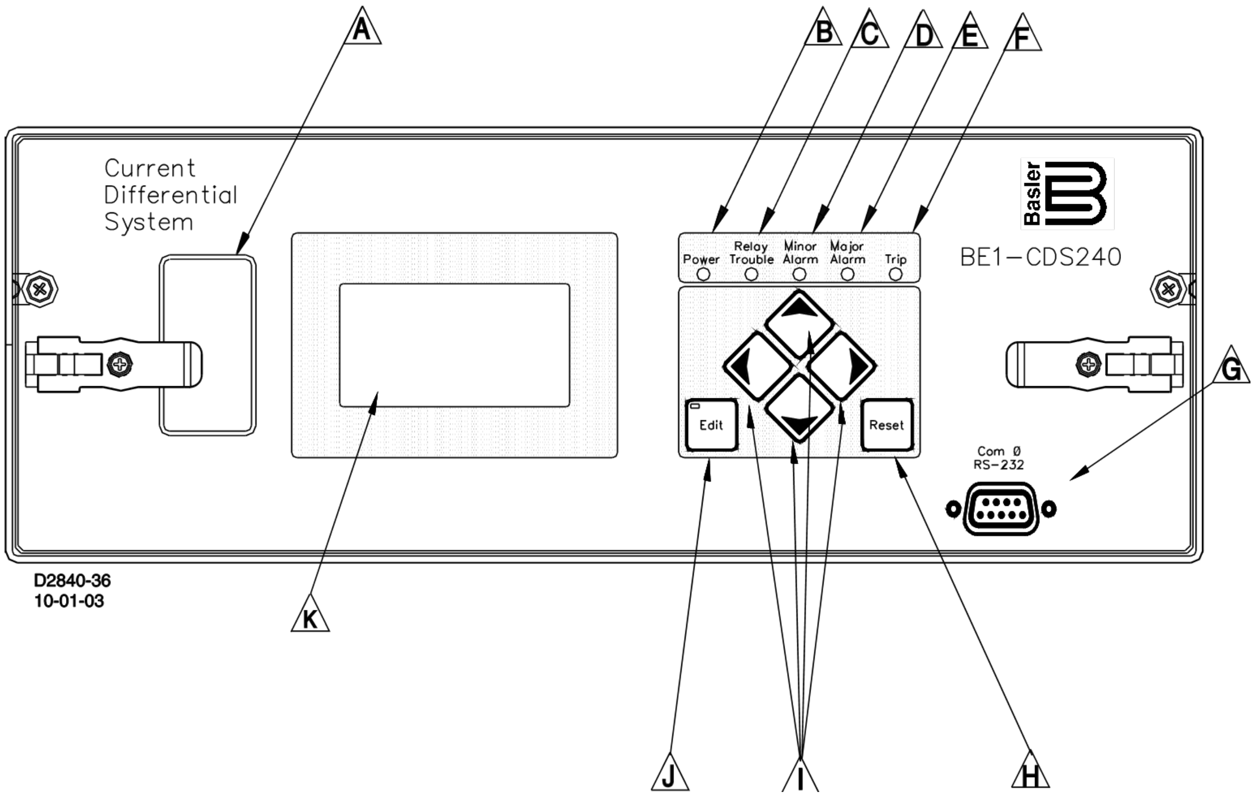

Figure 10-1. BE1-CDS240 Current Differential System with Optional HMI

Table 10-1. Front Panel HMI Descriptions

Locator	Description
A	*Identification Label* – This label lists the style number, serial number, sensing input current and voltage range, and power supply input voltages.
B	*Power Indicator* – This green LED lights when operating power is applied to the relay.
C	*Relay Trouble Indicator* – This red LED lights momentarily during start-up and lights continuously when a relay failure is detected. Section 6, *Reporting and Alarms*, provides a complete description of all relay failure alarm diagnostics.
D, E	*Minor Alarm, Major Alarm Indicators* – These red LEDs light to indicate that a programmable alarm has been set. Each indicator can be programmed to annunciate one or more conditions. Section 6, *Reporting and Alarms*, provides detailed information about programming alarms.
F	*Trip Indicator* – A flashing Trip LED indicates that a protective element is picked up. A continuously lit LED indicates that a trip output is closed. This red LED is sealed in if a protective trip has occurred and targets are displayed.

Locator	Description
G	*Communication Port 0* – This RS-232 serial port can be used to communicate with the relay using simple ASCII command language. A computer terminal or PC running terminal emulation software (such as Windows® HyperTerminal) is required to send commands to the relay or receive information from the relay.
H	*Reset Pushbutton* – Pushing this switch will reset the Trip LED, sealed-in Trip Targets, Peak Demand Currents, and Alarms.
I	*Scrolling Pushbuttons* – Use these four switches to navigate *(UP/DOWN/LEFT/RIGHT)* through the LCD's menu tree. When in Edit mode, the *LEFT* and *RIGHT* scrolling pushbuttons select the variable to be changed. The *UP* and *DOWN* scrolling pushbuttons change the variable.
J	*Edit Pushbutton* – Settings changes can be made at the front panel using this switch. When pushed, this switch lights to indicate that Edit mode is active. When you are finished making settings changes (using the scrolling pushbuttons) and the *Edit* switch is pressed again, the switch light turns off to indicate that your settings changes have been saved. If changes aren't completed and saved within five minutes, the relay will automatically exit the Edit mode without saving any changes.
K	*Display* – 64 by 128 pixel graphic liquid crystal display (LCD) with backlighting. The LCD is the primary source for obtaining information from the relay or when locally setting the relay. Information such as targets, metering values, demand values, communication parameters, the active logic scheme name, and diagnostic information is provided by the LCD. Information and settings are displayed in a menu with branches. The *Menu Tree* subsection provides more information about the menu branches.

Menu Tree

A menu tree with six branches can be accessed through the front panel controls and display. The *LEFT* and *RIGHT* scrolling pushbuttons are used to view each of the six branches. A greater level of detail in a menu branch is accessed using the *DOWN* scrolling pushbutton. The branch path is located in the upper left hand corner. This path is like a computer file path and indicates the current branch and level in the menu tree structure. This path helps so that you do not loose track of where you are in the menu tree. Each time you go to a lower level in the menu tree, another branch is added to the screen path and is separated by a backslash. The *UP* scrolling pushbutton is used to return to the top of the menu branch.

The six branches of the menu tree are illustrated in Figure 10-2 and summarized in the following paragraphs.

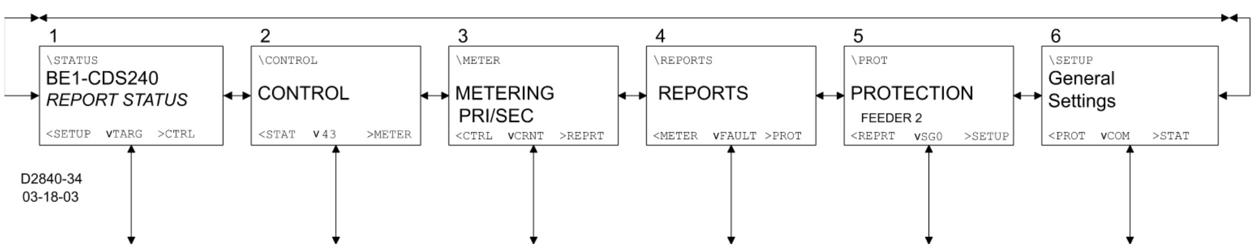

Figure 10-2. BE1-CDS240 Menu Tree (Top Level, All Branches)

1. REPORT STATUS – Provides display and resetting of general status information such as targets, alarms, and recloser status. Figure 10-3 illustrates the structure of the Report Status menu branch.
2. CONTROL – Accesses control function operation of virtual switches, active setting group selection, and others. Control menu branch structure is illustrated in Figure 10-4.
3. METERING – Displays real time metering values. Figure 10-5 illustrates the structure of the Metering menu branch.

4. REPORTS – Provides display and resetting of report information such as time and date, demand registers, and breaker duty statistics. Reports menu branch structure is illustrated in Figures 10-6 and 10-7.
5. PROTECTION LOGIC – Provides display and setting of protective functions such as pickups and time delays. Figure 10-8 illustrates the structure of the Protection Logic menu branch.
6. GENERAL SETTINGS – Provides display and setting of relay configuration settings such as communication, LCD contrast, transformer ratios, and system frequency. General Settings menu branch structure is illustrated in Figure 10-9.

In the following figures, notice near the upper left hand corner of each screen display, one, two, three, or four digit numbers with decimal points between each digit. These numbers are reference numbers to the screens in the menu tree. They are frequently referred to in the text of this manual and are necessary for programming the SG-SCREEN command as described in this section.

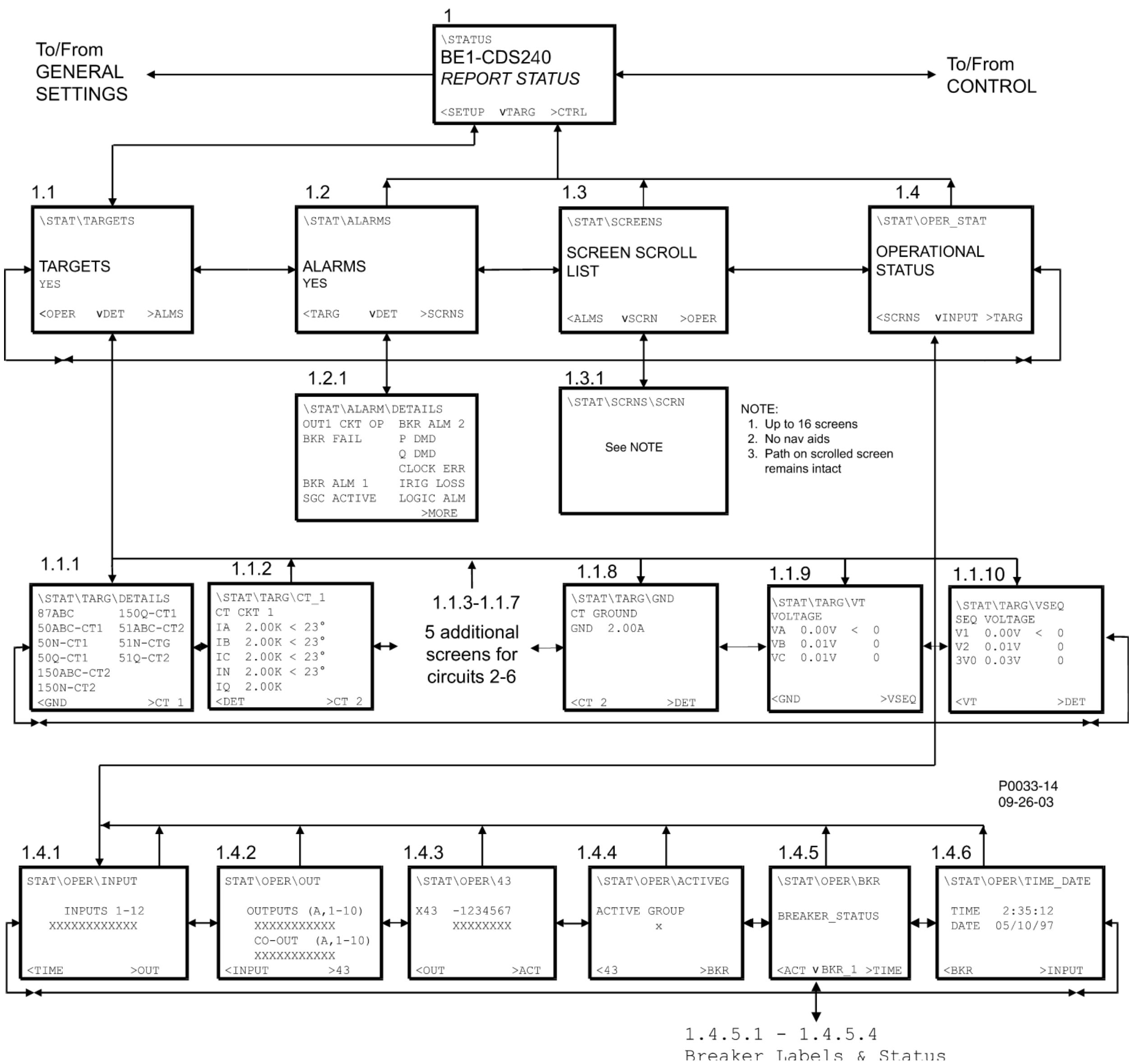

Figure 10-3. BE1-CDS240 Menu Tree (Report Status)

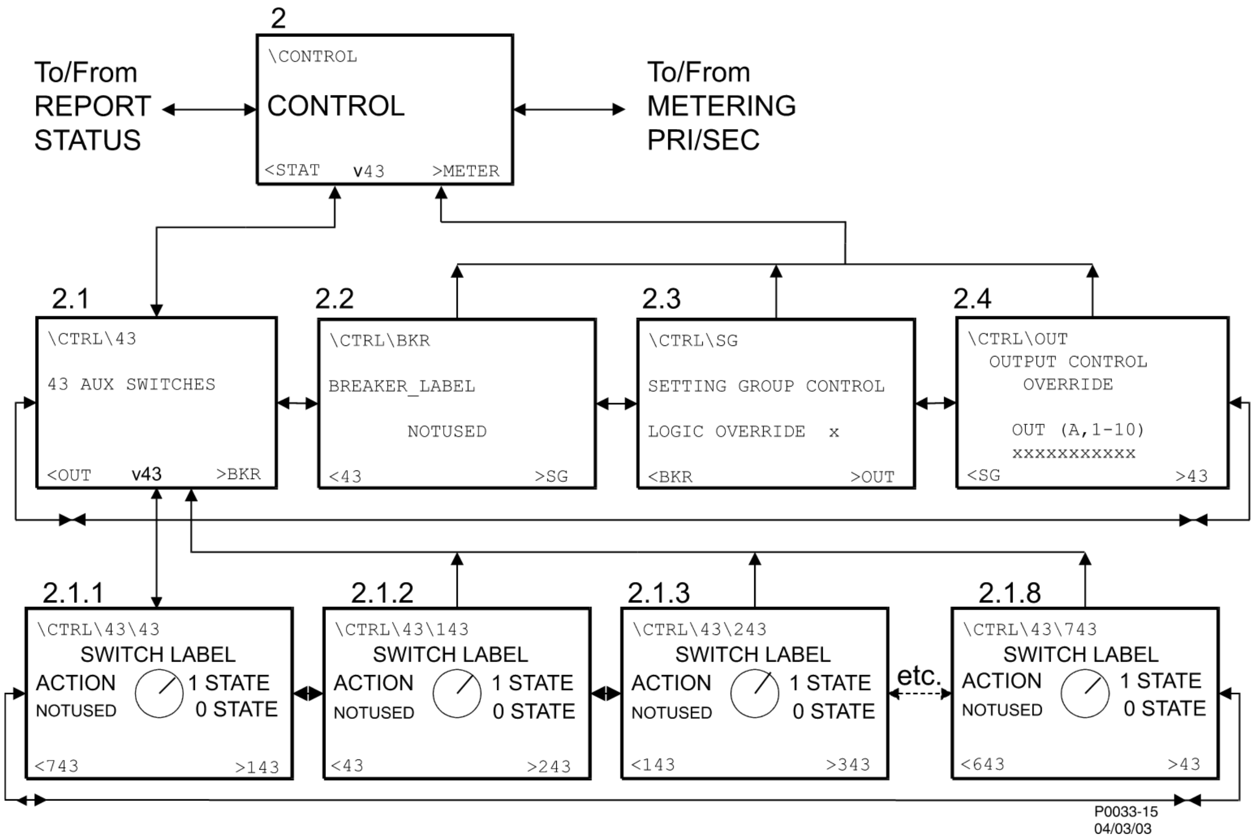

Figure 10-4. BE1-CDS240 Menu Tree (Control Branch)

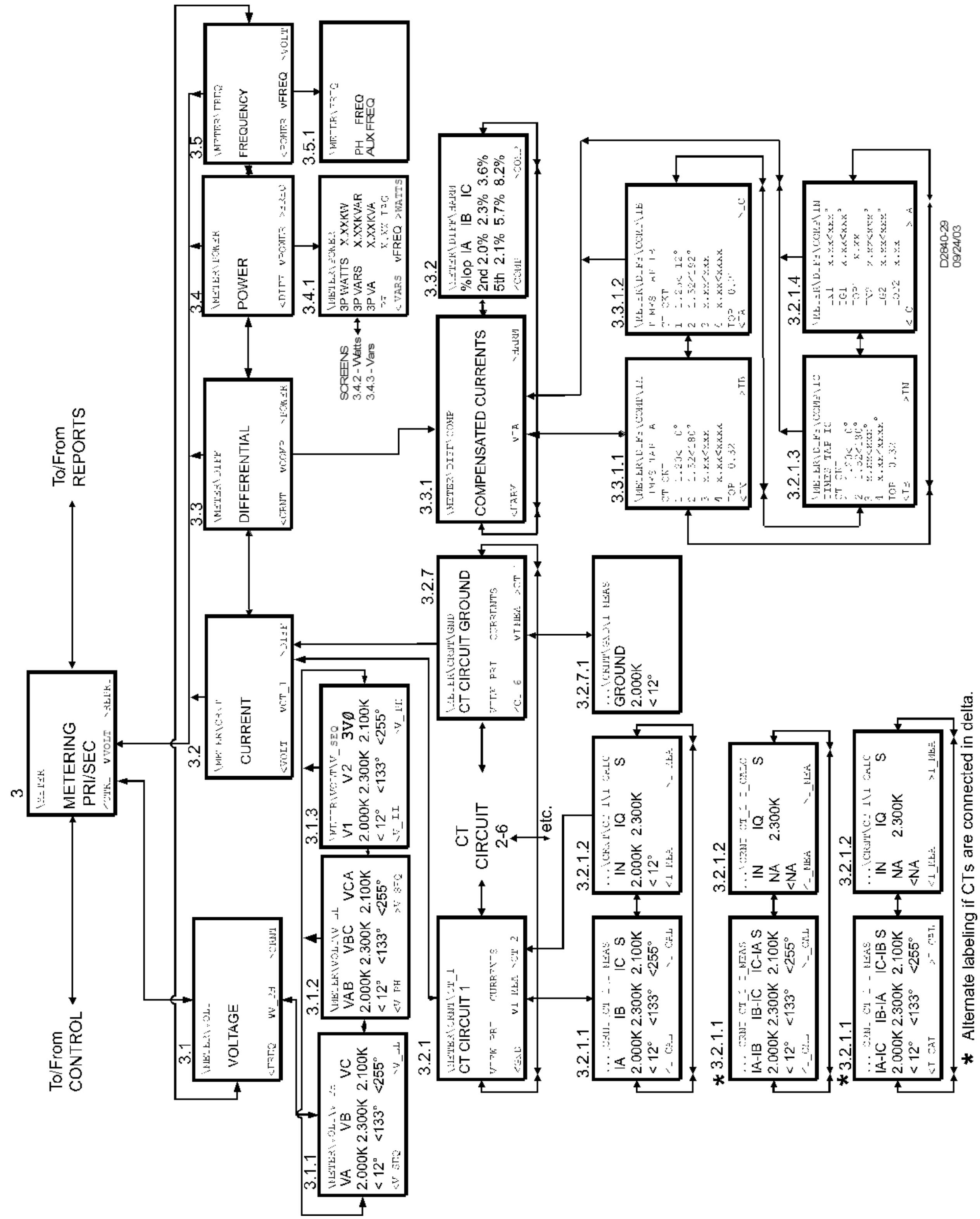

Figure 10-5. BE1-CDS240 Menu Tree (Metering PRI/SEC Branch)

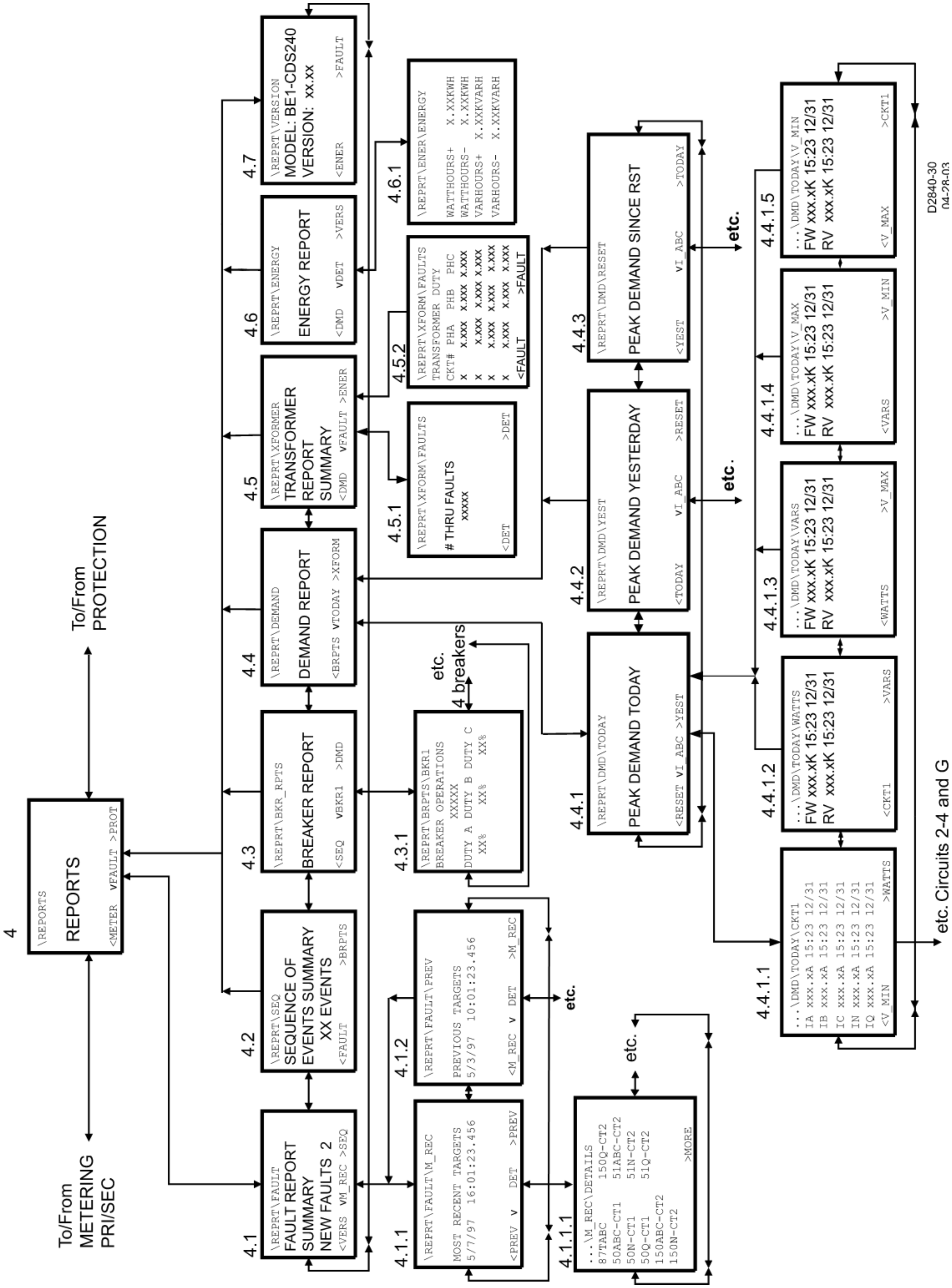

Figure 10-6. BE1-CDS240 Menu Tree (Reports Branch)

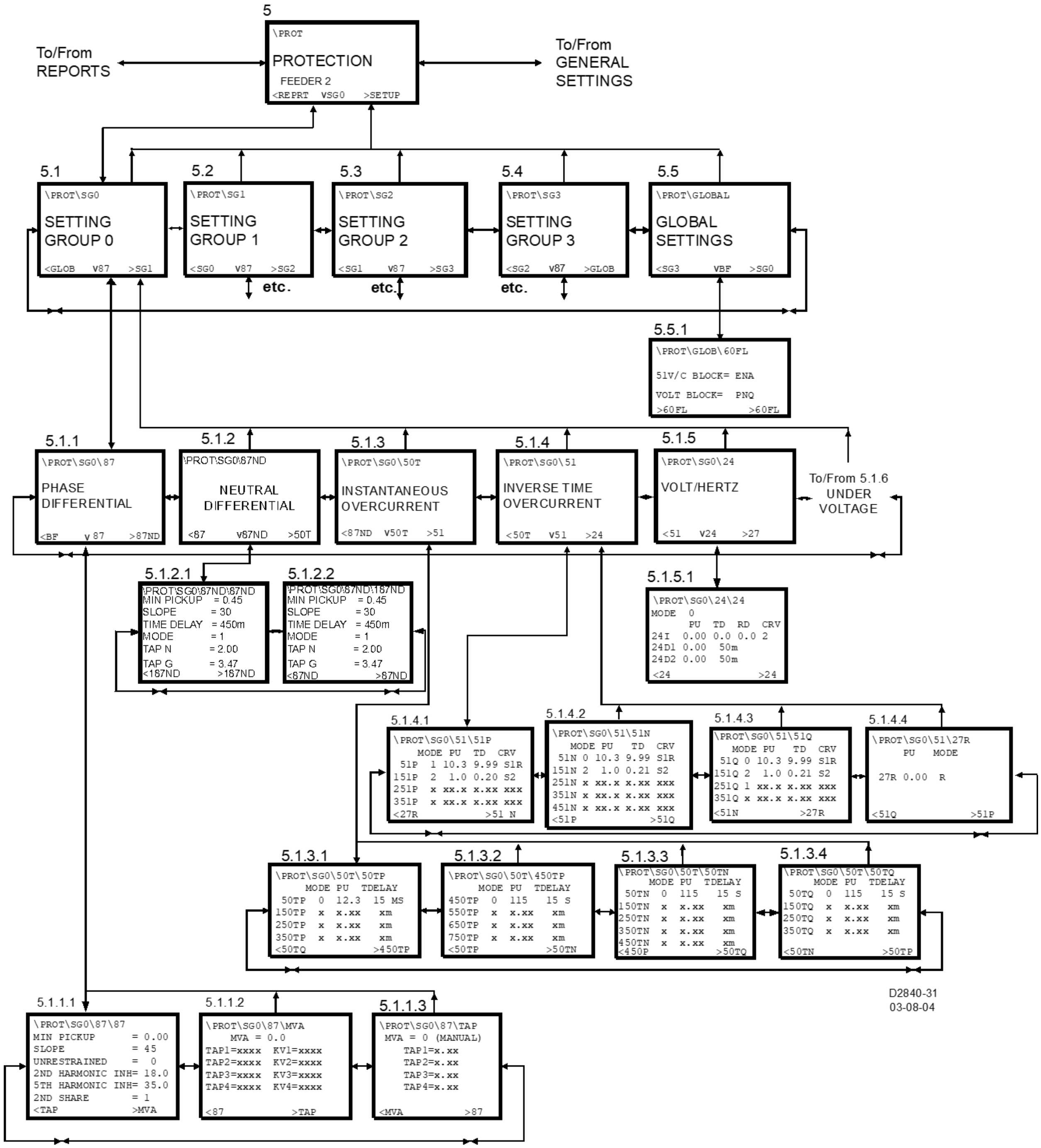

Figure 10-7. BE1-CDS240 Menu Tree (Protection Branch) (1 of 2)

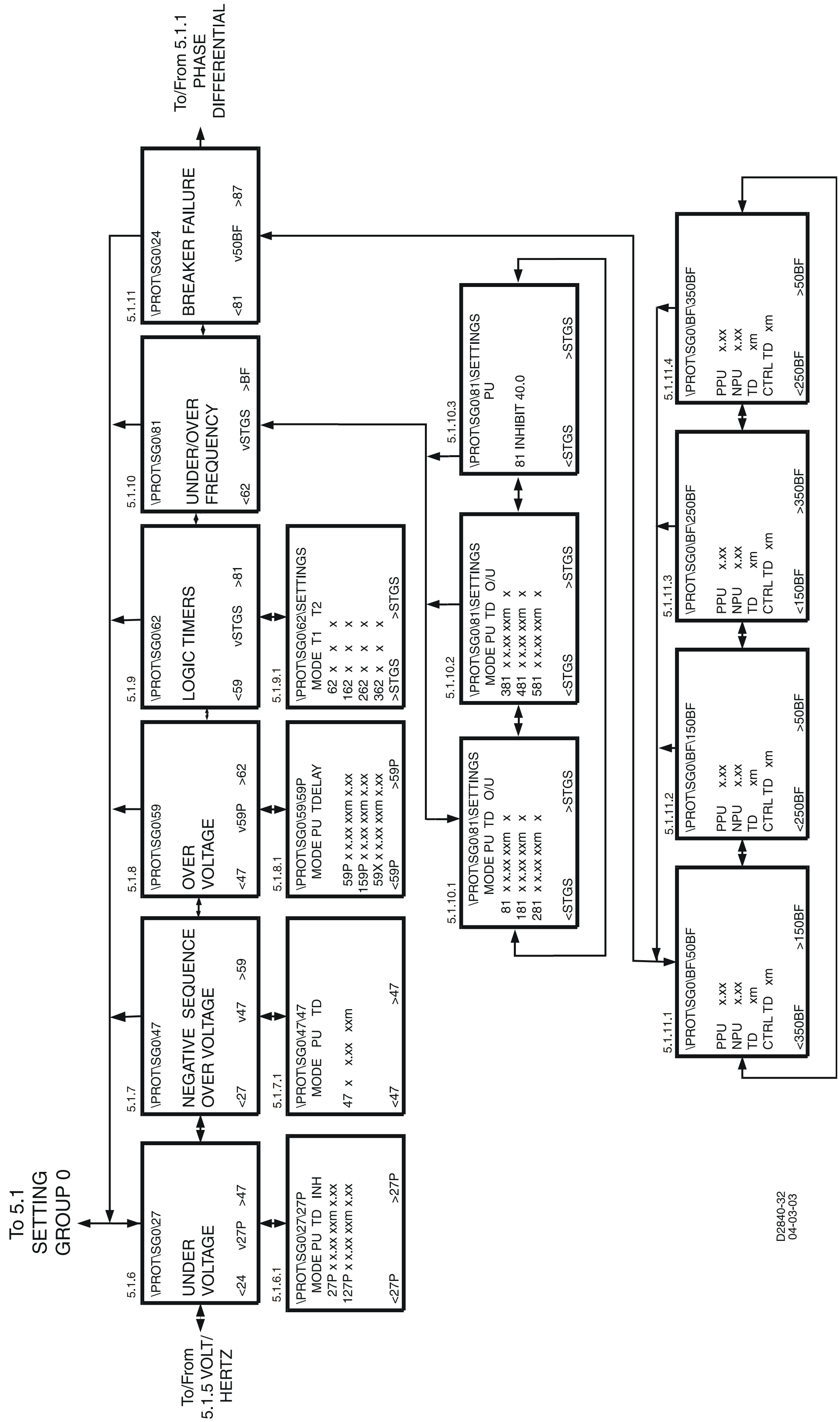

Figure 10-8. BE1-CDS240 Menu Tree (Protection Branch) (2 of 2)

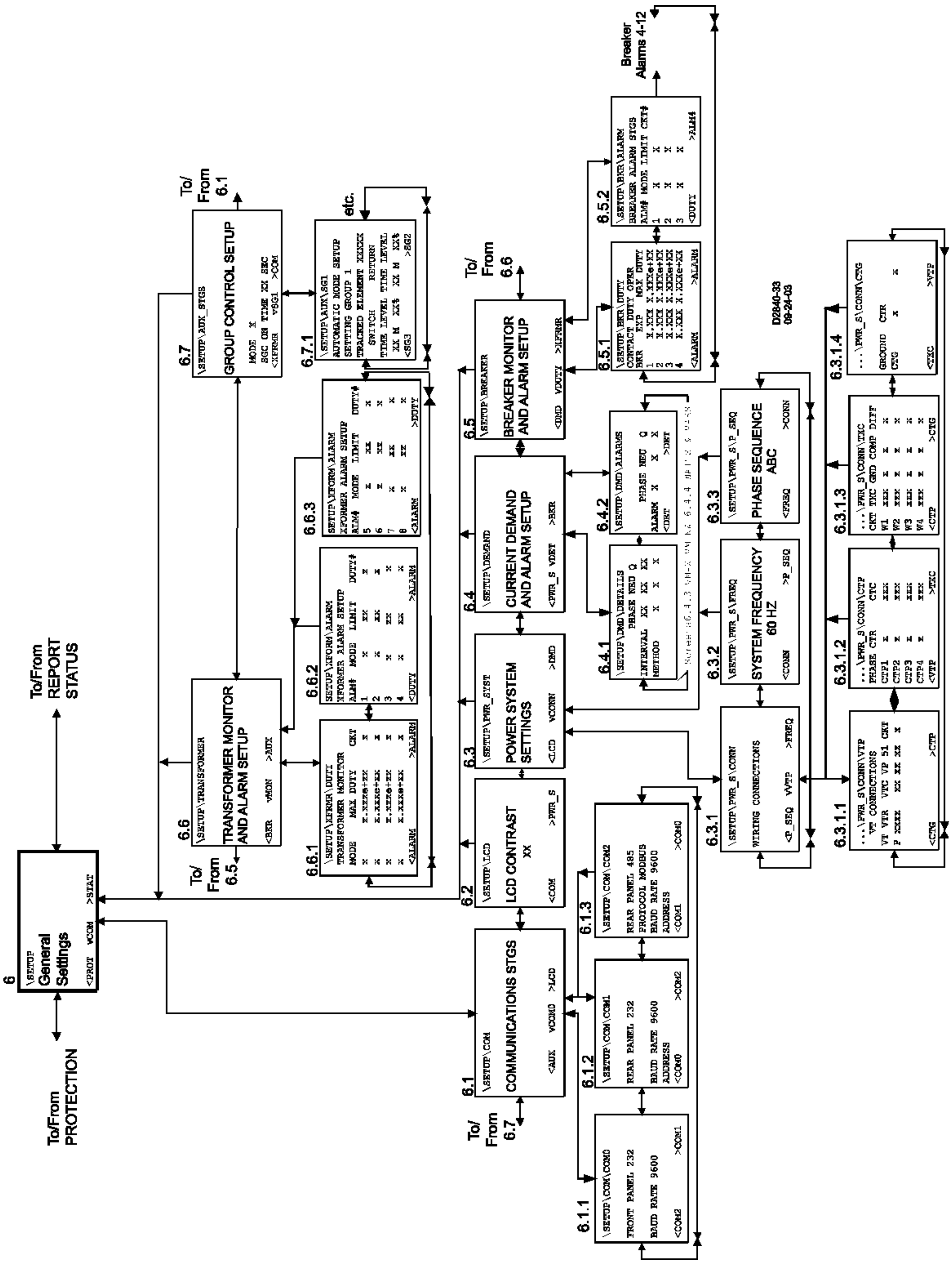

Figure 10-9. BE1-CDS240 Menu Tree (General Settings Branch)

Automatic Display Priority

If no front panel-scrolling key has been pressed for approximately five minutes, the relay automatically switches to and displays the highest priority REPORT STATUS menu screen. In a typical application, the user would return to the relay and prefer to see the data that is of the most interest already on the screen. The automatic screen display follows the priority logic described in Table 10-2. For example, if a trip has occurred, the *Targets* screen is the highest priority and will be displayed automatically.

Table 10-2. Automatic Screen Display Priority Status

Priority	Priority Logic State	Screen	Displayed Data
1	Targets active	\STAT\TARGETS	Scrolling display of Target Elements and Fault Currents.
2	Alarms active	\STAT\ALARMS	Scrolling display of Active Alarms.
3	Scrolling Screens active	\STAT\SCRNS\SCRN	Scrolling display of User Screens programmed with the SG-SCREEN command.
4	Scrolling Screens disabled	\STAT\TARGETS	Default target screen showing 'TARGETS NONE'.

If there are no targets or alarms, then the relay will automatically scroll through the user programmable scroll list (there is a scrolling display of up to 16 screens).

When the display is scrolling through the programmed scroll list, you can freeze the display and manually scroll through the scroll list. Pressing the *RIGHT* or *LEFT* scroll pushbutton will freeze the display. Repeatedly pressing the *RIGHT* scroll pushbutton will progress through the scroll list in ascending order. Repeatedly pressing the *LEFT* scroll pushbutton will progress through the scroll list in descending order. Pressing the *UP* scroll pushbutton will leave the automatic scroll list and place you in the menu tree at Screen 1.3, STAT\SCREENS.

Once the user has taken manual control of the display by pressing any of the scrolling pushbuttons, automatic priority has been disabled until the display times out. Thus, if a trip or alarm occurs during this time, the trip or Alarm LED will light up but the display will not jump to the appropriate screen. It will be necessary to manually scroll to the *Targets* or *Alarms* screen to see this data and to reset it.

The HMI can be returned to automatic priority immediately without waiting for the timer to time out by scrolling to Screen 1.3, STAT\SCREENS and pressing the *DOWN* scroll pushbutton to return to the automatic scroll list.

Setting the Screen Scroll list

The default screen number is the screen number displayed in the upper-left-hand corner of display screen shown in Figures 10-2 through 10-9. Consult these Figures for assistance when making or interpreting scrolling screens settings.

The default scrolling screens are:

SG-SCREEN1 = 1.4.6
SG-SCREEN2 = 3.1.2
SG-SCREEN3 = 3.4.1
SG-SCREEN4 = 3.5.1
SG-SCREEN5 = 3.2.1
SG-SCREEN6 = 3.2.1.1
SG-SCREEN7 = 3.2.1.2
SG-SCREEN8 = 3.2.2
SG-SCREEN9 = 3.2.2.1
SG-SCREEN10 = 3.2.2.2
SG-SCREEN11 = 0
SG-SCREEN12 = 0
SG-SCREEN13 = 0
SG-SCREEN14 = 0
SG-SCREEN15 = 0
SG-SCREEN16 = 0

To edit the automatic scrolling list using BESTCOMS™, select *General Operation* from the *Screens* pull-down menu. Then select the *HMI Display* tab. Refer to Figure 10-10. The screen numbers listed exhibit the default scrolling list. The list of numbers on the right represents the screen numbers and the order in which they will be displayed when automatic scrolling begins. The number closest to the top will be displayed first. The four buttons on the screen can be used to add or remove screens from the list. They can also be used to change a selected screens position in the list.

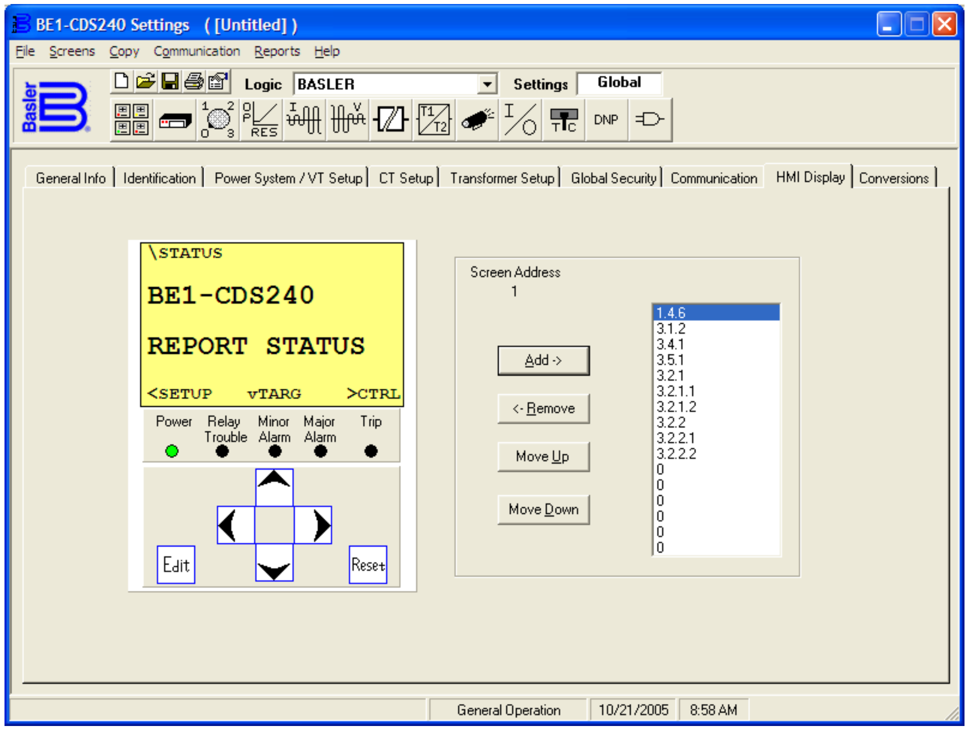

Figure 10-10. General Operation Screen, HMI Display Tab

To add a screen to the list, select the screen on the HMI simulation by clicking the mouse pointer on the arrows. Select the *Add->* button to add the screen to the list.

Alternately, these settings may be made using the SG-SCREEN ASCII command.

HMI Operations

The following paragraphs describe how the HMI is used to set and control relay functions.

Entering Settings

Settings for protection functions can be edited from menu branch 5, *PROTECTION* of the LCD HMI. Control functions can be edited from menu branch 2, *CONTROL.* Settings for general and reporting functions can be edited from menu branch 6, *GENERAL SETTINGS.* To edit a setting using the manual scrolling pushbuttons, perform the following procedures:

1. Scroll to the screen that displays the function to be edited.
2. Press the *Edit* pushbutton to gain access. If password security has been initiated for settings, you will be prompted to enter the appropriate password. See the paragraphs, *Entering Passwords,* for details on entering passwords from the HMI. Once access has been gained, the Edit LED will be lighted and a cursor will appear in the first settings field on the screen.
3. Press the *UP* or *DOWN* scrolling key to select the desired setting. Some settings require entering a number one character at a time. For example, to enter a 51 pickup as 7.3 amps, you would press the *UP* pushbutton until the 7 is showing. Then, press the *RIGHT* pushbutton to move the cursor over and press the *UP* pushbutton until the "." is showing. Then, press the *RIGHT* pushbutton to move the cursor over and press the *UP* pushbutton until the 3 is showing. Other settings require scrolling through a list of selections. For example, you would move the cursor over to the CRV field and then scroll through a list of available TCC curves.

4. Once all of the settings on the screen have been entered, press the *Edit* pushbutton a second time and the settings will be validated. If the settings are in range, the screen will flash **CHANGES SAVED**, and the Edit LED will go out. If you want to abort the edit session without changing any settings, press the *Reset* pushbutton before you press the *Edit* pushbutton the second time. The screen will flash **CHANGES LOST** and the Edit LED will go out.

Performing Control Operations

Control operations can be executed from the LCD HMI from menu branch 2, *CONTROL.* These functions allow you to control the state of virtual switches, override logic and control the active setting group, and override the logic and control the state of output contacts. All of these functions work similarly to the process of entering settings in that you press the *Edit* pushbutton, use the *UP* and *DOWN* scroll pushbuttons to select the desired state and press the *Edit* pushbutton for the action to be executed.

Figure 10-11 shows virtual switch 243 as an example of a virtual switch screen. See Section 4, *Protection and Control,* for more details on the x43 and 101 functions. Table 10-3 describes each of the callouts shown on Figure 10-11. The user programmable label for this switch has been set to DIFF_CUTOFF. The TRUE (closed) state label has been set to NORMAL and the FALSE (open) state label has been set to 87_OFF. The logical mode for this application would be set to Mode 2 (On/Off switch).

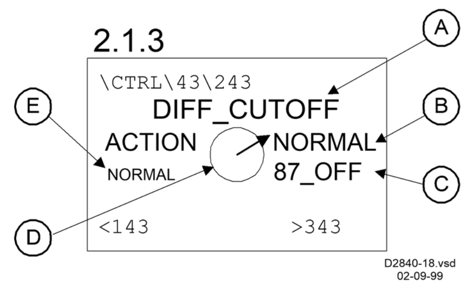

Figure 10-11. Virtual Control Switch 243

Table 10-3. Virtual Control Switches Controls and Indicators

Locator	Description
A	User selectable label (meaningful name) for specific virtual switches. Switch 243 identification label set to DIFF_CUTOFF.
B	User selectable label for the closed (1) state for Virtual Switch 243. Switch 243 closed state label set to NORMAL.
C	User selectable label for the open (0) state for Virtual Switch 243. Switch 243 open state label set to 87_OFF.
D	Icon to show the current switch position (status). In Figure 10-11, the current status is the closed state, which is labeled NORMAL.
E	Current switch status. This indicator should correspond to the current user labeled switch status. The switch is closed (1) and the user label for closed is NORMAL.

To operate the switch, you would use the following procedure:

1. Using the manual scrolling pushbuttons, scroll to Screen 2.1.x, \CTRL\43\. Alternatively, if the screen has been placed in the automatic scroll list, simply wait for it to appear and press the *RIGHT* or *LEFT* scroll pushbutton to freeze the display.
2. Press the *Edit* pushbutton to gain access. If password security has been initiated for control functions, you will be prompted to enter the appropriate password. See the following paragraphs, *Entering Passwords,* for details on entering passwords from the HMI. Once access has been gained to the control function, the Edit LED will be lighted and a cursor will appear in the action field.
3. Press the *UP* or *DOWN* scrolling key to select the desired action. The selections available are dependent upon the logic mode setting for that switch. If it is set to Mode 1, the action choices are pulse or one of the two positions as defined by the user programmable state labels. If the mode is set to Mode 2 (ON/OFF Switch), the choices for action are limited to one of the two positions. If the mode is set to Mode 3 (OFF/Momentary ON Switch), the choice for action is limited to pulse.
4. Press the *Edit* pushbutton a second time and the switch will change to the selected position, the screen will flash **CHANGES SAVED** and the Edit LED will go out. If you want to abort the edit session without changing any controls, press the *Reset* pushbutton before you press the *Edit* pushbutton the second time. The screen will flash **CHANGES LOST** and the Edit LED will go out.

Resetting Functions

The *Reset* pushbutton is context sensitive. Its purpose is dependent upon the screen that is presently being displayed. For example, pressing the *Reset* key when the demand screen is displayed will reset the demands but it will not reset the alarms, etc. It is necessary to scroll through the menu tree to the *Alarms* screen to reset an alarm. You are not prompted for a password when using the *Reset* key.

There are two BESTlogic variables associated with the HMI *Reset* pushbutton. Logic variable TRSTKEY becomes TRUE when the *Reset* pushbutton is pressed while the *Targets* screen is displayed. Logic variable ARSTKEY becomes TRUE when the *Reset* pushbutton is pressed while the *Alarms* screen is displayed. See Section 8, *Application, Application Tips,* for examples on the use of these variables.

Entering Passwords

If password security has been initiated for a function, the HMI will prompt you to enter a password when the *Edit* pushbutton is pressed. To gain access, you must enter the appropriate password. A field of 8 asterisks appears with the cursor located under the leftmost character position. You can enter passwords by performing the following procedures:

1. Press the *UP* or *DOWN* scrolling pushbuttons until the proper first character of the password appears. Pressing *UP* scrolls through the alphabet and then the numbers in ascending order. Pressing *DOWN* scrolls through the numbers and then the alphabet in descending order.
2. Press the *RIGHT* scrolling pushbutton to move the cursor to the next character of the password and select the appropriate character.
3. Continue the process until the entire password has been spelled out. If the password is less than 8 characters, leave the remaining asterisks in place instead of entering blanks.
4. Press the *Edit* pushbutton to enter the password. If the proper password has been entered, the screen will flash **ACCESS GRANTED**. If an incorrect password has been entered, the screen will flash **ACCESS DENIED** and the Edit LED will go out.
5. Once you gain access, it remains in effect for five minutes after the last pushbutton has been pressed. As long as you continue to press the *Edit* key for a function for which you have gained access, the five-minute timer will be refreshed and you will not be prompted for a password.

SECTION 11 • ASCII COMMAND INTERFACE

TABLE OF CONTENTS

SECTION 11 • ASCII COMMAND INTERFACE

Introduction

Relay and power system information can be retrieved from a remote location using the ASCII command interface. The ASCII command interface is also used to enter settings, retrieve reports and metering information, and perform control operations. A communication port on the relay front panel provides a temporary, local interface for communication. Communication ports on the rear panel provide a permanent communication interface.

Front and rear panel communication ports can be connected to computers, terminals, serial printers, modems, and intermediate communication/control interfaces such as RS-232 serial multiplexors. BE1-CDS240 communication protocols support ASCII and binary data transmissions. ASCII data is used to send and receive human readable data and commands. Binary data is used for computer communication and transmission of raw oscillographic fault data if available.

DNP, Modbus®, and other common protocols are also available. Available communication protocol instruction manuals include 9365200991 for DNP3. and 9365200992 for Modbus. For information about other protocols, consult your Basler Electric representative.

Serial Port

Communication connections consist of two Data Communication Equipment (DCE) RS-232 ports, one RS-485 port, and an IRIG port. The BE1-CDS240 communication protocol is compatible with readily available modem/terminal software. If required, password protection provides security against unauthorized operation. Detailed information about making communication connections is provided in Section 12, *Installation*. Communications port setup is covered in this section. Security settings are covered in Section 9, *Security*.

RS-232 Ports

Two female RS-232 (DB-9) connectors are provided. One port is located on the front panel and is designated COM 0. Another port is located on the rear panel and is designated COM 1. Both ports support full-duplex operation. Polled operation is possible at the rear port using a simple RS-232 splitter if a polling address is programmed for COM 1.

RS-485 Port

RS-485 terminal block connections are located on the rear panel and designated COM 2. This port supports half-duplex, multi-drop operation. Multi-drop operation is possible if a polling address is programmed for the port.

IRIG-B Input

Connections at the rear panel accept a demodulated (TTL) IRIG-B signal and provide the capability to time synchronize the BE1-CDS240 internal clock to within one millisecond of the IRIG-B source.

ASCII Command Interface

A computer terminal or PC running terminal emulation software can be used at any of the three serial ports to send commands to the relay. Simple ASCII command language is used to communicate with the relay. When the relay receives a command, it responds with the appropriate action. ASCII commands can be used in human to machine interactions and in batch download type operations.

Command Structure

An ASCII command consists of a string made up of one or two letters followed by a hyphen and an object name:

xy-object name	
x	Specifies the general command function.
y	Specifies the command subgroup.
Object Name	Defines the specific object to which the command refers.

Examples of object names include 51N (neutral inverse time overcurrent function) and RD3-PIA (phase A peak current demand register in current circuit 3). A command string entered alone is a read command. A command string followed by an equal sign (=) and one or more parameters is a write command.

General command functions are organized into five major groups plus one group of miscellaneous commands.

CONTROL (C): Control commands perform select-before-operate control actions such as circuit breaker tripping and closing and active setting group changes. Subgroups include Select (S) and Operate (O).

GLOBAL (G): One Global command performs operations that don't fall into the other general groups. The command for reading and changing passwords (GS-PW) is the only global command available.

METERING (M): Commands in this group report all real-time metering values. No subgroup is used with metering commands.

REPORTS (R): Reports commands read and reset reporting functions such as time and date, demand registers and breaker duty statistics. Subgroups include Alarms (A), Breaker Monitoring (B), Demand Recording (D), Fault Summary Reporting (F), General Information (G), Sequence of Events Recorder (S), and Oscillography (O).

SETTINGS (S): This group contains all of the setting parameters that govern relay function. Subgroups include Setting Groups 0, 1, 2 and 3 (0, 1, 2, 3), Protection Settings (P) not in setting groups, Alarm Settings (A), Breaker Monitor Settings (B), General Settings (G), Logic Settings (L), and DNP Settings (DNP).

MISCELLANEOUS: Miscellaneous commands include Access, Exit, and Help. Note that only the first letter of these commands must be entered; entering the full command name is optional.

Using the ASCII Command Interface

Human to Machine ASCII Command Operations

Using ASCII commands, settings can be read and changed on a function-by-function basis. The mnemonic format of the commands helps you interact with the relay. It isn't necessary to remember all of the object names. Most commands don't require that you specify a complete object name. If the first two letters of a command are entered, the relay will respond with all applicable object names.

ASCII Command Examples:

Example 1. Obtain a breaker operations count by entering RB (Report Breaker). The BE1-CDS240 responds with the operations counter value along with all other breaker report objects. If you know that the object name for the breaker operations counter is OPCNTR, you can enter RB-OPCNTR and read only the number of breaker operations.

Partial object names are also supported. This allows multiple objects to be read or reset at the same time.

Example 2. Read all peak-since-reset demand current registers. Entering RD2-PI (Report Demand - Peak Current (I)) will return demand values and time stamps for phase A, B, C, neutral, and negative sequence current for current input circuit 2. To read only the neutral demand value, the full object name (RD2-PIN) is entered. Entering RD2-PI=0 resets all five of the peak-since-reset current demand registers.

Command Text File Operations

In command text file operations, an ASCII text file of commands is created and sent to the relay. For example, the S command is used to retrieve a complete list of settings from the relay in ASCII command format. This list of commands is captured, saved to a file, edited with any ASCII text editor, and then uploaded to the relay. Because the number of relay settings is so large, loading settings with a text file is the preferred method of setting the BE1-CDS240.

Embedding Comments into ASCII Text Files

Adding comments to ASCII settings files is an easy way to organize and label your settings. A comment line is started with two forward slashes (//) followed by the comment text. When the relay encounters // in a text file, it ignores all following characters until the next carriage return or linefeed character.

Example of embedding comments in a settings file:

```
//Group0 is used during normal operation
>S0-50TP=7.50,0m;S0-50TN=2.5,0m . . .
//Group1 is used during cold load pickup
>S1-50TP=0,0m; S1-50TN=0,0m; S1-50TQ=0,0m
```

Miscellaneous Command Descriptions

HELP Command

The HELP (H) command provides general information on command syntax and functionality when the manual is not available. Entering HELP or H provides information about using the HELP command. HELP1 or H1 returns a complete list of relay commands. Entering HELP <cmd> where <cmd> is a specific command, returns information about the use and format of the command along with an example of how the command is used.

HELP Command

Purpose:	Obtain help on command operation
Syntax:	HELP {cmd} or H {cmd} for help on {cmd}, H1 for command list
Example:	HELP, H1, H SG-COM

ACCESS Command

Before making settings changes through a communication port, the ACCESS command must be used to obtain programming access. Enter ACCESS=<password> to obtain access to change settings associated with the password. Different passwords give the ability or access to perform different operations. The relay will deny access if an invalid password is entered or if another user has already been granted programming access through another serial port or at the front panel. Only one user can have access at any one time.

Even if password protection is not used, it is still necessary to obtain access so that accidental changes are prevented. If password protection is disabled, then ACCESS= will be accepted in place of a password. The relay will respond with `ACCESS GRANTED: GLOBAL` if the command entered was received and executed. The relay will respond with an error message and a '?' if the command could not be executed.

The ACCESS (A) command and the EXIT (E) command are used to change relay settings, reset report registers, and enable control commands through a serial port. These commands prevent changes from being made concurrently from two areas. For example, a user cannot make changes through COM 0 at the same time a remote user is making changes through COM 2.

ACCESS Command

Purpose:	Read/Set Access level in order to change settings
Syntax:	ACCESS[={password}]
Example:	ACCESS=CDS
Comments:	The ACCESS command must be used before any changes to settings can be made. Available ACCESS privileges are summarized in the following paragraphs.

READ-ONLY: This is the default access privilege when no passwords are active. Read-only access allows you to read settings and reports but not make settings changes.

PRIVILEGE G: GLOBAL ACCESS. Global access is obtained by password G (PWG). Global access permits entry of any command with no restrictions.

PRIVILEGE S: SETTING ACCESS. Setting access is obtained by password S (PWS). Setting access allows changes to any settings.

PRIVILEGE C: CONTROL ACCESS. Control access is obtained by password C (PWC). Control access enables relay control operations.

PRIVILEGE R: REPORT ACCESS. Report access is obtained by password R (PWR). Report access enables report operations to be performed.

An access privilege is obtained only when the appropriate password is entered. When a valid password is entered, the relay responds with the access privilege provided by the password entered. If an invalid password is entered, an error message is returned. If password protection is disabled in one or more privileges, then entering any string will provide access to the unprotected privileges.

Note: In examples throughout this manual, relay responses are printed in `Courier New` typeface.

ACCESS Command Examples:

Example 1. A valid password is entered.
>ACCESS=OPENUP
`ACCESS GRANTED:    GLOBAL`

Example 2. An invalid password is entered.
>ACCESS=POENUP
`ACCESS DENIED`

Example 3. The current access privilege is read.
>ACCESS
`ACCESS:    GLOBAL`

EXIT Command

After changes are made, the new data is saved or discarded using the EXIT command. Prior to saving or discarding any changes, you must confirm that you wish to exit the programming mode. There is three exit options: Y (yes), N (no), or C (continue).

EXIT Command

Purpose: Exit programming mode
Syntax: EXIT (Note: Relay will prompt for verification.)
Example: EXIT
Comments: It's important to make all programming changes before executing the EXIT command. This prevents a partial or incomplete protection scheme from being implemented.

When access privileges are obtained, all programming changes are made to a temporary, scratchpad copy of relay settings. These changes aren't saved to nonvolatile memory and initiated until the EXIT command is invoked and confirmed. After the EXIT command is entered, the relay prompts to confirm that the new data should be saved. Three options, Y, N, or C are available. Entering Y will save the data. If N is entered, the relay will clear the changes and resume operating with the old settings. Entering C will abort the EXIT command and allow programming to continue.

EXIT Command Example: Release programming privileges and save settings changes.

>EXIT<CR>

`SAVE CHANGES (Y/N/C)?`	Prompt to save Yes, No, or Continue
>Y<CR>	Confirmation to save changes
`CHANGES SAVED`	Confirmation that changes were saved

Settings (S) Command Descriptions

Reading All Settings

All user programmable settings can be listed using the S command. This read-only command is useful for documenting relay status during installation. The settings retrieved by the S command can be saved to a standard text file and sent to another relay to be configured with the same settings. This type of settings transfer takes less than one minute.

S Command

Purpose: Read all relay setting parameters
Syntax: S
Example: S

The S command returns the values of relay setting parameters in the same form that they are programmed. It can be used at the end of a programming session to make a record of the relay settings. If saved in a file, the report can be sent to another BE1-CDS240 that will use the same settings. Because the report that is created is a set of commands, sending the report to a different relay re-programs that relay with the settings contained in the S report.

Reading Specific Groups of Settings

While the S command is useful for reading all relay settings, several commands are available to read specific groups of settings.

SA Command

Purpose: Read all alarm settings for Major, Minor and Logic alarms
Syntax: SA
Example: SA

SA Command Example:

Example 1. Read all alarm settings.

>SA

```
SA-DIFF=67
SA-BKR1=0,0,1;      SA-BKR2=0,0,1;      SA-BKR3=0,0,1;      SA-BKR4=0,0,2
SA-BKR5=0,0,2;      SA-BKR6=0,0,2;      SA-BKR7=0,0,3;      SA-BKR8=0,0,3
SA-BKR9=0,0,3;      SA-BKR10=0,0,4;     SA-BKR11=0,0,4;     SA-BKR12=0,0,4
SA-DIP=0.00,0.00,0.00,0.00;             SA-DIN=0.00,0.00,0.00,0.00
SA-DIQ=0.00,0.00,0.00,0.00
SA-DIG=0.00
SA-DVP=0.00,0.00;   SA-DVN=0.00,0.00
SA-DVAR=0.0,0.0
SA-DWATT=0.0,0.0
SA-24=0.00,  0m
SA-27=0.00
SA-59=0.00
SA-LGC=0
SA-MAJ=9/45
SA-MIN=10
SA-RESET=0
SA-TX1=0,0,1;       SA-TX2=0,0,1;       SA-TX3=0,0,1;       SA-TX4=0,0,1
SA-TX5=0,0,1;       SA-TX6=0,0,1;       SA-TX7=0,0,1;       SA-TX8=0,0,1
```

SB Command

Purpose: Read all breaker settings
Syntax: SB
Example: SB

SB Command Example:

Example 1. Read all breaker settings.

>SB

```
SB-DUTY1=0.0000,0.000e+00,0
SB-DUTY2=0.0000,0.000e+00,0
SB-DUTY3=0.0000,0.000e+00,0
SB-DUTY4=0.0000,0.000e+00,0
SB-LOGIC1=0,BREAKER_LABEL1,0
SB-LOGIC2=0,BREAKER_LABEL2,0
SB-LOGIC3=0,BREAKER_LABEL3,0
SB-LOGIC4=0,BREAKER_LABEL4,0
```

SG Command

Purpose: Read all general settings

Syntax: SG

Example: SG

SG Command Example:

Example 1. Obtain a report of all general settings.

>SG

```
SG-FREQ=60
SG-PHROT=ABC
SG-VCKT=  0,  0
SG-CKT1=WYE,0,A,P,N
SG-CKT2=WYE,0,A,P,N
SG-CKT3=WYE,0,A,P,N
SG-CKT4=WYE,0,A,P,N
SG-CTP1=1,WYE
SG-CTP2=1,WYE
SG-CTP3=1,WYE
SG-CTP4=1,WYE
SG-CTG=1
SG-VTP=1.00,4W,PP,PP,1,0
SG-NOM=69.3,5.00
SG-IN1=  4, 16;     SG-IN2=  4, 16;     SG-IN3=  4, 16;     SG-IN4=  4, 16
SG-IN5=  4, 16;     SG-IN6=  4, 16;     SG-IN7=  4, 16;     SG-IN8=  4, 16
SG-IN9=  4, 16;     SG-IN10=  4, 16;    SG-IN11=  4, 16;    SG-IN12=  4, 16
SG-HTIME= 20s
SG-SGCON= 5
SG-DC=1,2,3,4
SG-DIP= 15,T;       SG-DIN=  1,T;       SG-DIQ=  1,T
SG-LOG=15
SG-TARG=87U/87R/87ND/187ND/24/27P/127P/47/50BF/150BF/250BF/350BF/60FL/59P/
159P/62/162/262/362/59X/50TP/150TP/250TP/350TP/450TP/550TP/650TP/750TP/81/181
/281/381/481/581/50TN/150TN/250TN/350TN/450TN/50TQ/150TQ/250TQ/350TQ/51P/151P
/251P/351P/51N/151N/251N/351N/451N/51Q/151Q/251Q/351Q,0
SG-TRIGGER=BFT1+BFT2+BFT3+BFT4+VO11,BFRT1+BFRT2+BFRT3+BFRT4+VO12,0
SG-ID=BE1-CDS240   ,SUBSTATION_1,USER1_ID    ,USER2_ID
SG-CLK=M,24,0,0
SG-SCREEN1=1.4.6;   SG-SCREEN2=3.1.2;   SG-SCREEN3=3.4.1;   SG-SCREEN4=3.5.1
SG-SCREEN5=3.2.1;   SG-SCREEN6=3.2.1.1; SG-SCREEN7=3.2.1.2; SG-SCREEN8=3.2.2
SG-SCREEN9=3.2.2.1; SG-SCREEN10=3.2.2.2;SG-SCREEN11=0;      SG-SCREEN12=0
SG-SCREEN13=0;      SG-SCREEN14=0;      SG-SCREEN15=0;      SG-SCREEN16=0
SG-COM0=9600,A0,P0,R1,X1;               SG-COM1=9600,A0,P0,R1,X1
SG-COM2=9600,A0,P0,R1,X0,MF1,MPN,MR10,MS1,PW0
```

```
SG-OSC=16
SG-HOLDA=0;          SG-HOLD1=1;          SG-HOLD2=1;          SG-HOLD3=1
SG-HOLD4=1;          SG-HOLD5=1;          SG-HOLD6=1;          SG-HOLD7=1
SG-HOLD8=1;          SG-HOLD9=1;          SG-HOLD10=1;         SG-HOLD11=1
SG-HOLD12=1;         SG-HOLD13=1;         SG-HOLD14=1
SG-NSAP=39840F80123456200000006F6F007001000000000000000000
SG-RID1=REMOTE_1_NAME,000000000000
SG-RID2=REMOTE_2_NAME,000000000000
SG-RID3=REMOTE_3_NAME,000000000000
SG-RID4=REMOTE_4_NAME,000000000000
SG-RID5=REMOTE_5_NAME,000000000000
SG-RID6=REMOTE_6_NAME,000000000000
SG-RID7=REMOTE_7_NAME,000000000000
SG-RID8=REMOTE_8_NAME,000000000000
SG-RID9=REMOTE_9_NAME,000000000000
SG-RID10=REMOTE_10_NAME,000000000000
SG-RID11=REMOTE_11_NAME,000000000000
SG-RID12=REMOTE_12_NAME,000000000000
SG-RID13=REMOTE_13_NAME,000000000000
SG-RID14=REMOTE_14_NAME,000000000000
SG-RID15=REMOTE_15_NAME,000000000000
SG-RID16=REMOTE_16_NAME,000000000000
SG-USERST1=0,2,0,33
SG-USERST2=0,2,0,34
SG-USERST3=0,2,0,35
SG-USERST4=0,2,0,36
SG-USERST5=0,2,0,37
SG-USERST6=0,2,0,38
SG-USERST7=0,2,0,39
SG-USERST8=0,2,0,40
SG-USERST9=0,2,0,41
SG-USERST10=0,2,0,42
SG-USERST11=0,2,0,43
SG-USERST12=0,2,0,44
SG-USERST13=0,2,0,45
SG-USERST14=0,2,0,46
SG-USERST15=0,2,0,47
SG-USERST16=0,2,0,48
SG-USERST17=0,2,0,49
SG-USERST18=0,2,0,50
SG-USERST19=0,2,0,51
SG-USERST20=0,2,0,52
SG-USERST21=0,2,0,53
SG-USERST22=0,2,0,54
SG-USERST23=0,2,0,55
SG-USERST24=0,2,0,56
SG-USERST25=0,2,0,57
SG-USERST26=0,2,0,58
SG-USERST27=0,2,0,59
SG-USERST28=0,2,0,60
SG-USERST29=0,2,0,61
SG-USERST30=0,2,0,62
SG-USERST31=0,2,0,63
SG-USERST32=0,2,0,64
SG-VIN1= 1, 0,0,2
SG-VIN2= 2, 0,0,2
SG-VIN3= 3, 0,0,2
```

```
SG-VIN4= 4, 0,0,2
SG-VIN5= 5, 0,0,2
SG-VIN6= 6, 0,0,2
SG-VIN7= 7, 0,0,2
SG-VIN8= 8, 0,0,2
SG-VIN9= 9, 0,0,2
SG-VIN10=10, 0,0,2
SG-VIN11=11, 0,0,2
SG-VIN12=12, 0,0,2
SG-VIN13=13, 0,0,2
SG-VIN14=14, 0,0,2
SG-VIN15=15, 0,0,2
SG-VIN16=16, 0,0,2
```

SN Command

Purpose: Read/Set User Programmable Names
Syntax: SN[-{var}[={name},{TRUE label},{FALSE label}]
Example: SN or SN-VO1=TRIP,CLOSED,OPEN or SN-IN1=BREAKER,OPEN,CLOSED

SN Command Example:

Example 1. Read the programmed labels for the alarm output (OUTA).
>SN-VOA
```
VOA_LABEL,TRUE,FALSE
```

S<g> Command

Purpose: Read all Protection settings
Syntax: S{g} where g=setting group 0-3 or # for all groups
Example: S# or S0 or S1

S <g> Command Example:

Example 1. Obtain a list of settings for Setting Group 1.
>S1
```
S1-TAP87=MANUAL,2.00,2.00,2.00,2.00
S1-TAP87ND=2.00,2.00
S1-TAP187ND=2.00,2.00
S1-87=0.00,45,18.0,35.0, 0,1
S1-87ND=0.00,20,500m
S1-187ND=0.00,20,500m
S1-50BF=  0m,0.00,0.00,  0m
S1-150BF=  0m,0.00,0.00,  0m
S1-250BF=  0m,0.00,0.00,  0m
S1-350BF=  0m,0.00,0.00,  0m
S1-50TP=0.00,  0m
S1-50TN=0.00,  0m
S1-50TQ=0.00,  0m
S1-150TP=0.00,  0m
S1-150TN=0.00,  0m
S1-150TQ=0.00,  0m
S1-250TP=0.00,  0m
S1-250TN=0.00,  0m
S1-250TQ=0.00,  0m
S1-350TP=0.00,  0m
S1-350TN=0.00,  0m
S1-350TQ=0.00,  0m
```

```
S1-450TP=0.00,  0m
S1-450TN=0.00,  0m
S1-550TP=0.00,  0m
S1-650TP=0.00,  0m
S1-750TP=0.00,  0m
S1-51P=0.00,0.0,V2
S1-51N=0.00,0.0,V2
S1-51Q=0.00,0.0,V2
S1-151P=0.00,0.0,V2
S1-151N=0.00,0.0,V2
S1-151Q=0.00,0.0,V2
S1-251P=0.00,0.0,V2
S1-251N=0.00,0.0,V2
S1-251Q=0.00,0.0,V2
S1-351P=0.00,0.0,V2
S1-351N=0.00,0.0,V2
S1-351Q=0.00,0.0,V2
S1-451N=0.00,0.0,V2
S1-27R=0.00,R
S1-24=0.00,0.0,0.0,2
S1-24D=0.00, 50m,0.00, 50m
S1-27P=0.00, 50m,0.00
S1-127P=0.00, 50m,0.00
S1-47=0.00, 50m
S1-59P=0.00, 50m
S1-59X=0.00, 50m
S1-159P=0.00, 50m
S1-81=00.00,  0m,O
S1-181=00.00,  0m,O
S1-281=00.00,  0m,O
S1-381=00.00,  0m,O
S1-481=00.00,  0m,O
S1-581=00.00,  0m,O
S1-81INH=40.0
S1-62=  0m,  0m
S1-162=  0m,  0m
S1-262=  0m,  0m
S1-362=  0m,  0m
SP-60FL=ENA,PNQ
SP-CURVE=  0.2663,  0.0339,  1.0000,  1.2969,  0.5000
SP-GROUP1= 0,  0, 0,  0,51P;            SP-GROUP2= 0,  0, 0,  0,51P
SP-GROUP3= 0,  0, 0,  0,51P
```

Reading Logic Settings

The SL command is used to view the names of available logic schemes in memory. It also will return all of the logic equations for a specific logic scheme.

SL Command

Purpose: Obtain Setting Logic Information
Syntax: SL:[{name}]
Example: SL, SL: or SL:BASIC-87
Comments: No password access is required to read settings.

Entering SL by itself returns all of the logic equations associated with the active logic scheme including custom logic. Entering SL: returns the names of all available logic schemes. Entering SL:<name> returns all logic equations and settings for the named logic scheme.

SL Command Examples:

Example 1. Read the logic schemes available in memory.

>SL:

```
CDS240-BATX-A-BE, CDS240-BATX-B-BE, NONE
```

Example 2. Read all logic settings associated with the CDS240-BATX-A-BE logic scheme.

>SL: CDS240-BATX-A-BE

```
SL-N=CDS240-BATX-A-BE,BASLER
SL-87=1,0
SL-87ND=0,0
SL-187ND=0,0
SL-50BF=0,0,0,0,0
SL-150BF=0,0,0,0,0
SL-250BF=0,0,0,0,0
SL-350BF=0,0,0,0,0
SL-50TP=0,0
SL-50TN=0,0
SL-50TQ=0,0
SL-150TP=0,0
SL-150TN=0,0
SL-150TQ=0,0
SL-250TP=0,0
SL-250TN=0,0
SL-250TQ=0,0
SL-350TP=0,0
SL-350TN=0,0
SL-350TQ=0,0
SL-450TP=0,0
SL-450TN=0,0
SL-550TP=0,0
SL-650TP=0,0
SL-750TP=0,0
SL-51P=0,0
SL-51N=G,0
SL-51Q=0,0
SL-151P=1,0
SL-151N=1,0
SL-151Q=1,0
SL-251P=2,0
SL-251N=2,0
SL-251Q=2,0
SL-351P=0,0
SL-351N=0,0
SL-351Q=0,0
SL-451N=0,0
SL-24=0,0
SL-27P=0,0
SL-127P=0,0
SL-47=0,0
SL-59P=0,0
SL-59X=0,0
SL-159P=0,0
SL-81=0,0
SL-181=0,0
SL-281=0,0
SL-381=0,0
SL-481=0,0
```

```
SL-581=0,0
SL-62=0,0,0
SL-162=0,0,0
SL-262=0,0,0
SL-362=0,0,0
SL-GROUP=1,0,0,0,0,/0
SL-43=0
SL-143=0
SL-243=0
SL-343=0
SL-443=0
SL-543=0
SL-643=0
SL-743=0
SL-101=0
SL-1101=0
SL-2101=0
SL-3101=0
SL-VOA=0
SL-VO1=87RT+87UT
SL-VO2=0
SL-VO3=0
SL-VO4=151PT+51NT+151NT+151QT
SL-VO5=251PT+251NT+251QT
SL-VO6=ALMMAJ
SL-VO7=0
SL-VO8=0
SL-VO9=0
SL-VO10=0
SL-VO11=87RT+87UT+151PT+251PT+51NT+151NT+251NT+151QT+251QT
SL-VO12=87RPU+87UT+151PPU+251PPU+51NPU+151NPU+251NPU+151QPU+251QPU
SL-VO13=IN6
SL-VO14=IN7
SL-VO15=IN8
SL-OUTA=VOA
SL-OUT1=VO1
SL-OUT2=VO1
SL-OUT3=VO1
SL-OUT4=VO4
SL-OUT5=VO5
SL-OUT6=VO6
SL-OUT7=0
SL-OUT8=0
SL-OUT9=0
SL-OUT10=0
SL-OUT11=0
SL-OUT12=0
SL-OUT13=0
SL-OUT14=0
```

Configuring the Serial Port Communication Protocol

The serial communication protocol is defined with the SG-COM command shown below.

SG-COM Command

Purpose: Read/Set serial communications protocol

Syntax: SG-COM[#[={baud},A{addr},P{pglen},R{reply ack},X{XON ena}]]

Example: SG-COM0=9600 or SG-COM1=9600,A0,P24,R1,X1

Comments: Password Access Privilege G or Privilege S required to change settings

= port number. (0 = Front, 1 = Rear 232, 2= Rear 485)

baud = baud rate (300/600/1200/2400/4800/9600/19K)

Ax = Address for polled operation where x = 0 (No polling) to 65534

Px = Page length (lines/pg) setting where x = 0 (No page mode) to 40

Rx = Reply acknowledgment level where x = 0 (disabled). 1 (enabled)

Xx = Xon/Xoff setting where X0 = handshake disabled, X1 = handshake enabled.

The following parameters pertain to relays using Modbus communication protocol at COM2:

MFx = Modbus extended precision format where x = 0 for floating point or 1 for triple precision

MPx = Modbus parity where x = N (None), O (Odd) and E (Even).

MRx = Modbus remote delay time where x = 10(msec.) to 200(msec.).

MSx = Modbus stop bit where x = 1 for one stop bit or 2 for two stop bits.

If a non-zero address is programmed in the 'A' parameter, then the relay will ignore all commands that are not preceded by its specific address. If an address of 0 is programmed, then the relay will respond with an error message for any command preceded by an address.

If polling software sends a command preceded by an address of 0, then that command will be treated as a global command. All relays will execute the command but no relay will respond to avoid bus contention.

NOTE: Polling is disabled on COM0 (Front RS-232), so an attempt to program an address other than A0 will cause an error message. The factory default settings are 9600, A0, P24, R1, X1 for COM 0 and COM 1 and 9600, A0, P0, R1, X0 for COM 2.

SG-COM Command Example:

Example 1. Program front port for 1200 baud

>SG-COM0=1200

Example 2. Read the protocol setting for the rear RS-485 port.

>SG-COM2

```
19K, A156,P0,R1,X0
```

Example 3. Read settings for all ports.

>SG-COM

```
SG-COM0=1200,P24,R1,X1
SG-COM1=9600,A0,P24,R1,X1
SG-COM2=19K,A156,P0,R1,X0
```

Command Summary

Miscellaneous Commands

ACCESS Command

Purpose: Read/Set Access level in order to change settings

Syntax: ACCESS[={password}]

Example: ACCESS=CDS

Reference: Section 11, *ASCII Command Interface, Miscellaneous Command Descriptions*

EXIT Command

Purpose: Exit programming mode

Syntax: EXIT - Note: Relay will prompt for verification

Example: EXIT

Reference: Section 11, *ASCII Command Interface, Miscellaneous Command Descriptions*

HELP Command

Purpose: Obtain help on command operation
Syntax: HELP {cmd} or H {cmd} for help on {cmd}, H1 for command list
Example: HELP, H1, H SG-COM
Reference: Section 11, *ASCII Command Interface, Miscellaneous Command Descriptions*

Metering Commands

M Command

Purpose: Read all metered values in primary or secondary units
Syntax: M[,P/,S] where P=primary, S=secondary
Example: M or M,S
Reference: Section 5, *Metering*

M-V3V0 Command

Purpose: Read calculated neutral voltage (3V0) in primary units
Syntax: M-V3V0
Example: M-V3V0
Reference: Section 5, *Metering*

M-FAST Command

Purpose: Read fast metered values in primary units
Syntax: M-FAST[{xy}] where x=V,I,F,P,Q,S and y=P,L,S,1,2,3,4,5,6,G
Example: M-FAST,V or M-FAST,VP or M-FAST,I or M-FAST,I3
Reference: Section 5, *Metering*

M-FREQ Command

Purpose: Read measured frequency
Syntax: M-FREQ
Example: M-FREQ
Reference: Section 5, *Metering*

M-I Command

Purpose: Read metered currents (I) in primary or secondary units
Syntax: M-I[G],[y] where y = P for primary, S for secondary
Example: M-I or M-IG or M-I,S
Reference: Section 5, *Metering*

M-PF Command

Purpose: Read metered 3 Phase Power Factor
Syntax: M-PF
Example: M-PF
Reference: Section 5, *Metering*

M-S Command

Purpose: Read metered 3 Phase VA in primary units
Syntax: M-S
Example: M-S
Reference: Section 5, *Metering*

M-V Command

Purpose: Read metered voltage (V) in primary units
Syntax: M-V[{phase}] where phase = A/B/C/AB/BC/CA/1/2/3
Example: M-V or M-VA or M-VAB or M-V2
Reference: Section 5, *Metering*

M-VAR Command

Purpose: Read metered 3 Phase Vars in primary units
Syntax: M-VAR[{phase}] where phase = 3/A/B/C
Example: M-VAR or M-VAR3, M-VARA, M-VARB, or M-VARC
Reference: Section 5, *Metering*

M-WATT Command

Purpose: Read metered 3 Phase Watts (W) in primary units
Syntax: M-WATT[{phase}] where phase = 3/A/B/C
Example: M-WATT or M-WATT3, M-WATTA, M-WATTB, or M-WATTC
Reference: Section 5, *Metering*

M-I Command

Purpose: Read CT circuit #1-6 current primary or secondary units
Syntax: M[{n}-I[p],[y]] where n=1-6, p=A/B/C/N/Q, y=P for primary, S for secondary
Example: M1 or M2-I or M3-IA
Reference: Section 5, *Metering*

MD Command

Purpose: Read differential currents (compensated currents, Iop & Harmonics)
Syntax: MD[,P/,S] where P=primary, S=secondary
Example: MD or MD,S
Reference: Section 5, *Metering*

MD-2ND Command

Purpose: Read 2nd harmonics as a percentage of Iop
Syntax: MD-[Ip]2ND where p = A/B/C
Example: MD-2ND or MD-IA2ND
Reference: Section 5, *Metering*

MD-5TH Command

Purpose: Read 5th harmonics as a percentage of Iop
Syntax: MD-[Ip]5TH where p = A/B/C
Example: MD-5TH or MD-IA5TH
Reference: Section 5, *Metering*

MD-I Command

Purpose: Read differential currents (compensated currents & Iop)
Syntax: MD-I[p[,P/,S]] where p = A/B/C/N
Example: MD-I or MD-IA or MD-IN or MD-I,S
Reference: Section 5, *Metering*

MD-ICOMP Command

Purpose: Read differential currents (compensated currents)
Syntax: MD-Ip[#][COMP[,P/,S]] where p = A/B/C/G/N, # = 1,2,3, or 4
Example: MD-IA1COMP or MD-IB2 or MD-IACOMP or MD-IA1,S
Reference: Section 5, *Metering*

MD-IOP Command

Purpose: Read differential currents (Iop)
Syntax: MD-IpOPx where p = A/B/C/N, and x = 1/2 for N only
Example: MD-IAOP or MD-IBOP or MD-INOP1 or MD-INOP2
Reference: Section 5, *Metering*

Control Commands

CO Command

Purpose: Control Operation

Syntax: CO-{control}[={mode}] where control=GROUP/OUT/x43/x101
mode=0-3/L for GROUP, 0/1/P/L/ENA/DIS for OUT,
0/1/P for x43 and T/C for x101

Example: CO-GROUP=2 or CO-OUT1=1 or CO-43=P

Reference: Section 3, *Input And Output Functions, Outputs (CO-OUT)*
Section 4, *Protection and Control, Setting Groups (CO-GROUP)*
Section 4, *Protection and Control, Virtual Switches (CO-43)*
Section 4, *Protection and Control, Virtual Switches (CO-101)*

CS Command

Purpose: Control Selection

Syntax: CS-control[={mode}] where control=GROUP/OUT/x43/x101
mode=0-3/L for GROUP, 0/1/P/L/ENA/DIS for OUT,
0/1/P for x43 and T/C for x101

Example: CS-GROUP=2 or CS-OUT1=1 or CS-43=P

Reference: Section 3, *Input And Output Functions, Outputs (CS-OUT)*
Section 4, *Protection and Control, Setting Groups (CS-GROUP)*
Section 4, *Protection and Control, Virtual Switches (CS-43)*
Section 4, *Protection and Control, Virtual Switches (CS-101)*

Report Commands

RA Command

Purpose: Report/Reset Alarm information

Syntax: RA[=0]

Example: RA

Reference: Section 6*, Reporting and Alarms, Alarms Function*

RA-DIFF Command

Purpose: Read/Trigger Differential Report Data

Syntax: RA-DIFF[=TRIG] where TRIG triggers a Differential Report

Example: RA-DIFF (displays the differential report)

Reference: Section 6, *Reporting and Alarms, Differential Current Monitoring Function*

RA-LGC Command

Purpose: Report/Reset Logic Alarm information

Syntax: RA-LGC[=0]

Example: RA-LGC

Reference: Section 6, *Reporting and Alarms, Alarms Function*

RA-MAJ Command

Purpose: Report/Reset Major Alarm information

Syntax: RA-MAJ[=0]

Example: RA-MAJ

Reference: Section 6, *Reporting and Alarms, Alarms Function*

RA-MIN Command

Purpose: Report/Reset Minor Alarm information

Syntax: RA-MIN[=0]

Example: RA-MIN

Reference: Section 6, *Reporting and Alarms, Alarms Function*

RA-REL Command

Purpose: Report/Reset Relay Alarm information
Syntax: RA-REL[=0]
Example: RA-REL
Reference: Section 6, *Reporting and Alarms, Alarms Function*

RA-SER Command

Purpose: Report Relay Alarm Sequence of Events information
Syntax: RA-SER
Example: RA-SER
Reference: Section 6, *Reporting and Alarms, Sequence of Events Recorder Function*

RB Command

Purpose: Read Breaker Status
Syntax: RB
Example: RB
Reference: Section 6, *Reporting and Alarms, Breaker Monitoring*

RB-DUTY Command

Purpose: Read/Set Breaker Contact Duty Log where n = 1,2,3,4 for Ckt1,Ckt2,Ckt3,Ckt4
Syntax: RB-DUTY[n][{phase}[={%duty}]] where %duty is % of dmax set with SB-DUTY
Example: RB-DUTY1A or RB-DUTY2B=50
Reference: Section 6, *Reporting and Alarms, Breaker Monitoring*

RB-OPCNTR Command

Purpose: Read/Set Breaker Operation Counter where n = 1,2,3,4 for Ckt1,Ckt2,Ckt3,Ckt4
Syntax: RB-OPCNTR[n][={#operations}]
Example: RB-OPCNTR1=32 or RB-OPCNTR2=652
Reference: Section 6, *Reporting and Alarms, Breaker Monitoring*

RD Command

Purpose: Report all demand data
Syntax: RD
Example: RD
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD{n} Command

Purpose: Report all demand data for CKT1-4
Syntax: RD[n], where n=1,2,3,4
Example: RD1, RD2, RD3, RD4
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-PI Command

Purpose: Read/Reset peak demand current (I)
Syntax: RD{n}-PI[{p}[=0]] where n=1,2,3,4, p=A/B/C/N/Q
Example: RD1-PI or RD2-PIA or RD3-PIN or RD1-PI=0
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-TI Command

Purpose: Report today's demand current (I)
Syntax: RD{n}-TI[{p}] where n=1,2,3,4, p=A/B/C/N/Q
Example: RD1-TI or RD2-TIA or RD3-TIN
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-YI Command

Purpose: Report yesterday's demand current (I)
Syntax: RD{n}-YI[{p}] where n=1,2,3,4, p=A/B/C/N/Q
Example: RD1-YI or RD2-YIA or RD3-YIN
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-LOG Command

Purpose: Report load profile data
Syntax: RD-LOG,<n>
Example: RD-LOG,23 (view load profile record for last 23 records)
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-P Command

Purpose: Read/Reset peak demands since reset
Syntax: *RD-P[=0]*
Example: *RD-P or RD-P=0*
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-PIG Command

Purpose: Read/Reset peak IG demand current
Syntax: RD-PIG[=0]
Example: RD-PIG or RD-PIG=0
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-PV Command

Purpose: Read/Reset peak Max and Min demand voltage (V)
Syntax: RD-PV[{p}[=0,0]]] where p=A/B/C/N - Max, Min demand voltage
Example: RD-PV or RD-PVA or RD-PVN or RD-PV=0
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-PVAR Command

Purpose: Read/Reset peak Forward and Reverse demand vars
Syntax: RD-PVAR[=0,0] - Fwd,Rev Var Flow
Example: RD-PVAR or RD-PVAR=0,0
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-PWATT Command

Purpose: Read/Reset peak Forward and Reverse demand watts
Syntax: RD-PWATT[=0,0] - Fwd,Rev Power Flow
Example: RD-PWATT or RD-PWATT=0,0
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-T Command

Purpose: Report today's demands
Syntax: RD-T
Example: RD-T
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-TIG Command

Purpose: Report today's IG demand current
Syntax: RD-TIG
Example: RD-TIG
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-TV Command

Purpose: Report today's Max and Min demand voltage (V)
Syntax: RD-TV[{p}] where p=A/B/C/N
Example: RD-TV or RD-TVA or RD-TVN
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-TVAR Command

Purpose: Report today's Forward and Reverse demand vars
Syntax: RD-TVAR
Example: RD-TVAR
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-TWATT Command

Purpose: Report today's Forward and Reverse demand watts
Syntax: RD-TWATT
Example: RD-TWATT
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-Y Command

Purpose: Report yesterday's demands
Syntax: RD-Y
Example: RD-Y
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-YIG Command

Purpose: Report yesterday's IG demand current
Syntax: RD-YIG
Example: RD-YIG
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-YV Command

Purpose: Report yesterday's Max and Min demand voltage (V)
Syntax: RD-YV[{p}] where p=A/B/C/N
Example: RD-YV or RD-YVA or RD-YVN
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-YVAR Command

Purpose: Report yesterday's Forward and Reverse demand vars
Syntax: RD-YVAR
Example: RD-YVAR
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RD-YWATT Command

Purpose: Report yesterday's Forward and Reverse demand watts
Syntax: RD-YWATT
Example: RD-YWATT
Reference: Section 6, *Reporting and Alarms, Demand Functions*

RE Command

Purpose: Report all energy data
Syntax: RE
Example: RE
Reference: Section 6, *Reporting and Alarms, Energy Data*

RE-KVARH Command

Purpose: Read/Reset/Preset 3 Phase KiloVarHours in primary units
Syntax: RE-KVARH[={pos kvarh},{neg kvarh}]
Example: RE-KVARH or RE-KVARH=100,10 or RE-KVARH=0,0
Reference: Section 6, *Reporting and Alarms, Energy Data*

RE-KWH Command

Purpose: Read/Reset/Preset 3 Phase KiloWattHours in primary units
Syntax: RE-KWH[={pos kwh},{neg kwh}]
Example: RE-KWH or RE-KWH=100,10 or RE-KWH=0,0
Reference: Section 6, *Reporting and Alarms, Energy Data*

RF Command

Purpose: Read/Reset Fault Report Data
Syntax: RF[-n/NEW][=0/TRIG] where n=record # or NEW = new records
Example: RF (displays a directory of all fault reports in memory)
RF-23 (view summary report for fault record 23)
RF-NEW (view summary report for newest fault record since RF=0 reset)
RF=0 (reset NEW fault counter)
RF=TRIG (Manually Trigger a fault record)
Reference: Section 6, *Reporting and Alarms, Fault Reporting*

RG Command

Purpose: Report General information
Syntax: RG
Example: RG
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-101STAT Command

Purpose: Report 101 status
Syntax: RG-101STAT
Example: RG-101STAT
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-43STAT Command

Purpose: Report 43 status
Syntax: RG-43STAT
Example: RG-43STAT
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-ADDR Command

Purpose: Report/Set COM1/COM2 Address for Polled Communications
Syntax: RG-ADDR[n][={com addr}] where n = 1 for COM1 or 2 for COM2
Example: RG-ADDR or RG-ADDR1=0 or RG-ADDR2=27
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-BREAKER Command

Purpose: Report breaker status
Syntax: RG-BREAKER
Example: RG-BREAKER
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-DATE Command

Purpose: Report/Set Date
Syntax: RG-DATE[={M/D/Y}] or RG-DATE[={D-M-Y}]
Example: RG-DATE=12/31/96 or RG-DATE=31-12-96 (Format set by SG-CLK Command)
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-GRPACTIVE Command

Purpose: Report active group
Syntax: RG-GRPACTIVE
Example: RG-GRPACTIVE
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-GRPCNTRL Command

Purpose: Report group logic override control status
Syntax: RG-GRPCNTRL
Example: RG-GRPCNTRL
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-INPUT Command

Purpose: Report INPUT status
Syntax: RG-INPUT
Example: RG-INPUT
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-LOGIC Command

Purpose: Report active logic
Syntax: RG-LOGIC
Example: RG-LOGIC
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-OUTCNTRL Command

Purpose: Report OUTPUT CONTROL status
Syntax: RG-OUTCNTRL
Example: RG-OUTCNTRL
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-OUTSTAT Command

Purpose: Report OUTPUT status
Syntax: RG-OUTSTAT
Example: RG-OUTSTAT
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-TARG Command

Purpose: Report/Reset Target status
Syntax: RG-TARG
Example: RG-TARG or RG-TARG=0
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-TIME Command

Purpose: Report/Set Time
Syntax: RG-TIME[=hr:mn:sc] or RG-TIME[=hr:mn{f}sc]
Example: RG-TIME=13:25:00 or RG-TIME=1:25P00 (Format(f) set by SG-CLK Command)
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RG-VER Command

Purpose: Read Model #, Style #, Program Version, Serial #
Syntax: RG-VER
Example: RG-VER
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RL Command

Purpose: Read Logic Variables (each Logic Variable is 32 bits long)
Syntax: RL-[n] where n = 1, 2, 3, 4, 5, or 6
Example: RL or RL-1
Reference: Section 6, *Reporting and Alarms, General Status Reporting*

RO Command

Purpose: Read Oscillographic COMTRADE .DAT/.CFG/.HDR Fault Report
Syntax: RO-nA/B[#][A].CFG/DAT/HDR, n=report num,A/B=ASCII/BINARY,#=OSC 1/2, A=1999 format
Example: RO-3A1.CFG, RO-3A1.DAT, RO-5B2.CFG, RO-5B2.DAT, RO-5A.HDR, RO-3A1A.CFG
Reference: Section 6, *Reporting and Alarms, Fault Reporting*

RS Command

Purpose: Read/Reset Sequence of Events Record Data
Syntax: RS[-n/Fn/ALM/IO/LGC/NEW][=0] where n=# of events and Fn=fault record #
Example: RS (displays a directory of all event records in memory)
RS-23 (view SER report for last 23 events)
RS-F12 (view SER report associated with fault record 12)
RS-ALM (view all SER report ALARM events since RS=0 reset)
RS-IO (view all SER report INPUT OUTPUT events since RS=0 reset)
RS-LGC (view all SER report LOGIC events since RS=0 reset)
RS-NEW (view all SER report events since RS=0 reset)
RS=0 (reset NEW records counter)
Reference: Section 6, *Reporting and Alarms, Sequence of Events Recorder Function*

RT Command

Purpose: Read Transformer Duty Status
Syntax: RT
Example: RT
Reference: Section 6, *Reporting and Alarms, Transformer Monitoring*

RT-DUTY Command

Purpose: Read/Set Transformer Through Fault Duty Log
Syntax: RT-DUTY[{n}{phase}[={%duty}]] where n=1,2,3,4 and %duty is % of dmax set with ST-DUTY
Example: RT-DUTY1A or RT-DUTY1B=50
Reference: Section 6, *Reporting and Alarms, Transformer Monitoring*

RT-TFCNTR Command

Purpose: Read/Set Transformer Through Fault Counter
Syntax: RT-TFCNTR[={#operations}]
Example: RT-TFCNTR=32 or RT-TFCNTR=652
Reference: Section 6, *Reporting and Alarms, Transformer Monitoring*

Setting Command

S Command

Purpose: Read all relay setting parameters
Syntax: S
Example: S
Reference: Section 11, *ASCII Command Interface, Settings (S) Command Descriptions*

Alarm Setting Commands

SA Command

Purpose: Read all alarm settings for Major, Minor and Logic alarms
Syntax: SA
Example: SA
Reference: Section 6, *Reporting and Alarms, Alarms Function*

SA-24 Command

Purpose: Read/Set Volts Per Hertz alarm settings
Syntax: SA-24[={alarm level},{td(m)}] alarm level=volts per hertz
Example: SA-24 or SA-24=1.1,2000 or SA-24=1.08,500
Reference: Section 4, *Protection and Control, Voltage Protection*

SA-27 Command

Purpose: Read/Set Under Voltage alarm settings
Syntax: SA-27[={alarm level}] where alarm level = volts
Example: SA-27 or SA-27=110 or SA-27=5
Reference: Section 4, *Protection and Control, Voltage Protection*

SA-59 Command

Purpose: Read/Set Over Voltage alarm settings
Syntax: SA-59[={alarm level}] where alarm level = volts
Example: SA-59 or SA-59=125 or SA-59=5
Reference: Section 4, *Protection and Control, Voltage Protection*

SA-BKR Command

Purpose: Read/Set breaker alarm settings where n = 1 to 12 alarms
Syntax: SA-BKR[n][={mode},{alarm limit},{Ckt#}] where mode=0-3(dis/%duty/#op/BkrOpTim)
Example: SA-BKR or SA-BKR1=1,80 or SA-BKR2=2,250,2 or SA-BKR3=3,6c,3
Reference: Section 6, *Reporting and Alarms, Breaker Monitoring*

SA-DI Command

Purpose: Read/Set demand alarm settings for Dmd1, Dmd2, Dmd3 and Dmd4
Syntax: SA-DI[p][={Dmd1 level},{Dmd2 level},{Dmd3 level},{Dmd4 level}] where p=P/N/Q
Example: SA-DI or SA-DIP=8.0,4.0,3.2,3.0 or SA-DIN=2.4
Reference: Section 6, *Reporting and Alarms, Demand Functions*

SA-DIFF Command

Purpose: Read/Set differential alarm setting
Syntax: SA-DIFF[={alarm level}] where alarm level=Percentage (between 50 and 100)
Example: SA-DIFF or SA-DIFF=75
Reference: Section 6, *Reporting and Alarms, Differential Current Monitoring Function*

SA-DIG Command

Purpose: Read/Set IG demand alarm setting
Syntax: SA-DIG[={alm level}
Example: SA-DIG or SA-DIG=2.4
Reference: Section 6, *Reporting and Alarms, Demand Functions*

SA-DV Command

Purpose: Read/Set Voltage Max and Min demand alarm setting
Syntax: SA-DV[p][={max alm lvl},{min alm lvl}] where p=P/N, alm lvl= Sec Volts
Example: SA-DV or SA-DVP=0,0 or SA-DVN=100,10
Reference: Section 6, *Reporting and Alarms, Demand Functions*

SA-DVAR Command

Purpose: Read/Set Var demand alarm setting
Syntax: SA-DVAR[={pos alm lvl},{neg alm lvl}] where alm lvl= POS,NEG Sec Vars
Example: SA-DVAR or SA-DVAR=0,0 or SA-DVAR=5000,1000
Reference: Section 6, *Reporting and Alarms, Demand Functions*

SA-DWATT Command

Purpose: Read/Set Watt demand alarm setting
Syntax: SA-DWATT[={pos alm lvl},{neg alm lvl}] where alm lvl= POS,NEG Sec Watts
Example: SA-DWATT or SA-DWATT=0,0 or SA-DW=5000,1000
Reference: Section 6, *Reporting and Alarms, Demand Functions*

SA-LGC Command

Purpose: Read/Set logic alarm setting mask
Syntax: SA-LGC[={alarm num 1}[/{alarm num 2}]...[/{alarm num n}]]
Example: SA-LGC or SA-LGC=2/6/7/10/11
Reference: Section 6, *Reporting and Alarms, Alarms Function*

SA-MAJ Command

Purpose: Read/Set major alarm setting mask
Syntax: SA-MAJ[={alarm num 1}[/{alarm num 2}]...[/{alarm num n}]]
Example: SA-MAJ or SA-MAJ=1/3/5/12
Reference: Section 6, *Reporting and Alarms, Alarms Function*

SA-MIN Command

Purpose: Read/Set minor alarm setting mask
Syntax: SA-MIN[={alarm num 1}[/{alarm num 2}]...[/{alarm num n}]]
Example: SA-MIN or SA-MIN=2/6/7/10/11
Reference: Section 6, *Reporting and Alarms, Alarms Function*

SA-RESET Command

Purpose: Read/Set Programmable Alarms Reset logic
Syntax: SA-RESET[={rst alm logic}]
Example: SA-RESET or SA-RESET=VO1
Reference: Section 6, *Reporting and Alarms, Alarms Function*

SA-TX Command

Purpose: Read/Set transformer alarm settings where n = 1 to 8 alarms
Syntax: SA-TX[n][={mode},{alarm limit},{Duty#}] where mode=0-2(disabled/%duty/#thflts)
Example: SA-TX or SA-TX1=1,80,1 or SA-TX=2,250,3
Reference: Section 6, *Reporting and Alarms, Transformer Monitoring*

Breaker Monitor Setting Commands

SB Command

Purpose: Read all breaker settings
Syntax: SB
Example: SB
Reference: Section 6, Reporting and Alarms, Breaker Monitoring

SB-DUTY Command

Purpose: Read/Set Breaker Contact Duty where n = 1,2,3,4 for Ckt1,Ckt2,Ckt3,Ckt4
Syntax: SB-DUTY[n][={Exponent},{DMax},{BLKBKR logic}]
Example: SB-DUTY1=1.5,60E3,IN5
Reference: Section 6, *Reporting and Alarms, Breaker Monitoring*

SB-LOGIC Command

Purpose: Read/Set Breaker Contact Logic where n = 1,2,3,4 for Ckt1,Ckt2,Ckt3,Ckt4
Syntax: SB-LOGIC[n]={breaker close logic},{breaker name},{trip coil enable}]
Example: SB-LOGIC1=IN1,NAME,1 or SB-LOGIC2=/IN2,BREAKER10,0
Reference: Section 6, *Reporting and Alarms, Breaker Monitoring*

DNP Setting Commands

SDNP Command

Purpose: Read all Distributed Network Protocol (DNP) settings
Syntax: SDNP
Example: SDNP
Reference: *Distributed Network Protocol (DNP) manual for BE1-CDS240*

SDNP-AIMAP Command

Purpose: Read/Set selection of DNP Analog Input Map
Syntax: SDNP-AIMAP[=USER(or U)/DEFAULT(or DFT or D)]
Example: SDNP-AIMAP=U or SG-AIMAP =DFLT
Reference: *Distributed Network Protocol (DNP) manual for BE1-CDS240*

SDNP-BIMAP Command

Purpose: Read/Set selection of DNP Binary Input Map
Syntax: SDNP-BIMAP[=USER(or U)/DEFAULT(or DFT or D)]
Example: SDNP-BIMAP=U or SDNP-AIMAP =DFLT
Reference: *Distributed Network Protocol (DNP) manual for BE1-CDS240*

SDNP-DFLT Command

Purpose: Reads DNP parameters for all DNP default analog and binary points as obtained with SDNP-DFLTAI; SDNP-DFLTBI; commands
Syntax: SDNP-DFLT
Example: SDNP-DFLT
Reference: *Distributed Network Protocol (DNP) manual for BE1-CDS240*

SDNP-SYNCH Command

Purpose: Read/Set DNP synchronization period with Master
Syntax: SDNP-SYNCH[=valueX] where X is D/H/M/S for days/hours/min/sec and value is from 0 to max 31(if D)/24(if H)/60(if M or S)
Example: SDNP-SYNCH or SDNP-SYNCH=0S or SDNP-SYNCH=12H or SDNP-SYNCH=15D
Reference: *Distributed Network Protocol (DNP) manual for BE1-CDS240*

SDNP-TXDL Command

Purpose: Read/Set DNP pre transfer delay in ms
Syntax: SDNP-TXDL[= delay] where delay is from 0 to 50000 ms
Example: SDNP-TXDL or SDNP-TXDL = 40
Reference: *Distributed Network Protocol (DNP) manual for BE1-CDS240*

SDNP-USERAI Command

Purpose: Read/Set user configuration of DNP Analog Input points
Syntax: SDNP-USERAI[=T,startndx,endndx,startpDftID,..,endpDftID]
where T is total number of points in user map,
startndx is a reporting index of data with default index startDftID,
endndx is a reporting index of data with default index endDftID,
Max. number of points specified in one command is 50.
Example: SDNP-USERAI or
SDNP-USERAI =20,0,9,0,1,31,32,62,63,64,74,76,78
SDNP-USERAI =20,10,19,2,33,34,45,50,78,79,94,105,135
To map for example 420 AI points, min 9 SDNP-USERAI commands must be sent.
Reference: *Distributed Network Protocol (DNP) manual for BE1-CDS240*

SDNP-USERBI Command

Purpose: Read/Set user configuration of DNP Binary Input points.
Syntax: SDNP-USERBI[=T,startndx,endndx,startpDftID,..,endpDftID]
where T is total number of points in user map,
startndx is a reporting index of data with default index startDftID,
endndx is a reporting index of data with default index endDftID,
Max. number of points specified in one command is 50.
Example: SDNP-USERBI or
To report 23 BI points:
SDNP-USERBI=23,0,22,127,128,129,165,166,167,168,177,178,44,45,46,47,0,1,2,4,5,7,10,23,24,78
Reference: *Distributed Network Protocol (DNP) manual for BE1-CDS240*

General Setting Commands

SG Command

Purpose: Read all general settings
Syntax: SG
Example: SG
Reference: Section 11, *ASCII Command Interface, Settings (S) Command Descriptions*

SG-CKT Command

Purpose: Read/Set Transformer configuration for each winding
Syntax: SG-CKT[t][={tx con},{gnd src},{tx comp},{diff ckt},{180 comp}]
Example: SG-CKT1=WYE,0,A,P,N or SG-CKT2=DAB,1,B,S,N
Reference: Section 3, *Input and Output Functions, Power System Inputs*

SG-CLK Command

Purpose: Read/Program format of date and time display. Enable/disable time/date logging to SER.
Syntax: SG-CLK[={date format(M/D)},{time format(12/24)},{dst enable(0/1)},{SER enable(0/1)}]
Example: SG-CLK=D,12,1,0 or SG-CLK=M,24,0,1
Reference: Section 6, *Reporting and Alarms, Clock*

SG-COM Command

Purpose: Read/Set serial communications protocol

Syntax: SG-COM[#[={baud},A{addr},P{pglen},R{reply ack},X{XON ena}]]

Example: SG-COM0=9600 or SG-COM1=9600,A0,P24,R1,X1

Reference: Section 11, *ASCII Command Interface, Settings (S) Command Descriptions, Configuring the Serial Port Communication Protocol*

SG-CTG Command

Purpose: Read/Set Ground CT ratio

Syntax: SG-CTG[={ct ratio}]

Example: SG-CTG=80 or SG-CTG=400:5

Reference: Section 3, *Input and Output Functions, Power System Inputs*

SG-CTP Command

Purpose: Read/Set Phase CT ratios and connections

Syntax: SG-CTP[t][={ct ratio},{ct con}]

Example: SG-CTP1=80,WYE or SG-CTP2=400:5,DAB or SG-CTP1=400/5,DAC

Reference: Section 3, *Input and Output Functions, Power System Inputs*

SG-DC Command

Purpose: Read/Set Demand Circuit

Syntax: SG-DC[={Demand1 Ckt#},{Demand2 Ckt#},{Demand3 Ckt#},{Demand4 Ckt#}]

Example: SG-DC or SG-DC=1,2,5,6

Reference: Section 6, *Reporting and Alarms, Demand Functions*

SG-DI Command

Purpose: Read/Set demand current interval

Syntax: SG-DI[p][={interval},{method}] where p=P/N/Q, method=T,B,S

Example: SG-DI or SG-DIP=15,T or SG-DIN=1,T

Reference: Section 6, *Reporting and Alarms, Demand Functions*

SG-FREQ Command

Purpose: Read/Enter power system Frequency

Syntax: SG-FREQ[={freq(HZ)}]

Example: SG-FREQ=60 or SG-FREQ=50

Reference: Section 3, *Input and Output Functions, Power System Inputs*

SG-HOLD Command

Purpose: Read/Program Output Hold operation

Syntax: SG-HOLD[n][={1/0 hold ena}] where 1=TRUE, 0=FALSE

Example: SG-HOLD or SG-HOLD1=1 or SG-HOLD2=0

Reference: Section 3, *Input and Output Functions, Outputs*

SG-ID Command

Purpose: Read/Set relay ID, station ID, UserID1 and UserID2 used in reports

Syntax: SG-ID[={relayID},{StationID},{UserID1},{UserID2}]

Example: SG-ID=448,SUBSTATION3 or SG-ID=GEN3,POWERPOINT_SUB,POWER,PLANT3

Reference: Section 6, *Reporting and Alarms, Relay Identifier Information*

SG-IN Command

Purpose: Read/Set Input recognition/debounce

Syntax: SG-IN[#[={r(ms)},{db(ms)}]] where ms=4-255msec

Example: SG-IN or SG-IN3 or SG-IN3=4,16

Reference: Section 3, *Input And Output Functions, Contact Sensing Inputs*

SG-LOG Command

Purpose: Read/Set load profile interval
Syntax: SG-LOG[={interval}] where interval is between 1 and 60 minutes
Example: SG-LOG or SG-LOG=15
Reference: Section 6, *Reporting and Alarms, Demand Functions*

SG-NOM Command

Purpose: Read/Enter power system nominal Voltage & Current
Syntax: SG-NOM[={Nom Volts},{Nom Amps}]
Example: SG-NOM or SG-NOM=120,5 or SG-NOM=120,1
Reference: Section 3, *Input and Output Functions, Power System Inputs.*

SG-OSC Command

Purpose: Read/Set the number of oscillograph fault records saved
Syntax: SG-OSC[=6/8/10/12/15/16/20/24/32]
Example: SG-OSC or SG-OSC=16
Reference: Section 6, *Reporting and Alarms, Fault Reporting, Oscillographic Records*

SG-PHROT Command

Purpose: Read/Set Phase Rotation setting
Syntax: SG-PHROT[={phase rotation}] ABC/ACB
Example: SG-PHROT or SG-PHROT=ABC or SG-PHROT=ACB
Reference: Section 3, *Input and Output Functions, Power System Inputs*

SG-SCREEN Command

Purpose: Read/Set default screen(s)
Syntax: SG-SCREEN[n][={default screen number}]
Example: SG-SCREEN or SG-SCREEN1=2.2.1 or SG-SCREEN2=2.2.2
Reference: Section 4, *Human-Machine Interface, Front Panel Display*

SG-SGCON Command

Purpose: Read/Set SGC output on time
Syntax: SG-SGCON[={time}] where time is in (s)ec
Example: SG-SGCON or SG-SGCON=1S or SG-SGCON = 5S
Reference: Section 4, *Protection and Control, Setting Groups*

SG-TARG Command

Purpose: Report/Enable Target List and reset target logic
Syntax: SG-TARG[={x/x/..x},{rst TARG logic}] where x = 50T,51,87U,87R,BF etc.
Example: SG-TARG or SG-TARG=51/50TP/50TN/50TQ/151TP/87R
Reference: Section 6, *Reporting and Alarms, Fault Reporting*

SG-TRIGGER Command

Purpose: Read/Set Trigger logic
Syntax: SG-TRIGGER[={TRIP trig},{PU trig},{LOGIC trig}]
Example: SG-TRIGGER or SG-TRIGGER=VO1,VO12,IN4
Reference: Section 6, *Reporting and Alarms, Fault Reporting*

SG-VCKT Command

Purpose: Read/Set Virtual Circuits I5 & I6 Configuration
Syntax: SG-VCKT[={ckt},{rest}] where ckt = 0-13, rest=0-3
Example: SG-VCKT=0 for (disable) or SG-VCKT=1,1 or SG-VCKT=9,2
Reference: Section 3, *Input and Output Functions, Power System Inputs*

SG-VTP Command

Purpose: Read/Set VT ratio, connection, 27/59 sensing mode, 51/27R sensing mode
Syntax: SG-VTP[={VT_ratio},{connection},{27/59mode},{51/27Rmode},{winding},{polarity}]
Example: SG-VTP or VTP=10,4W,PN,PN,1,0 or VTP=1200:120,3W,PP,PP,2,0
or VTP=1200/120,AB
Reference: Section 3, *Input and Output Functions, Power System Inputs*

Programmable Logic Setting Commands

SL Command

Purpose: Obtain Setting Logic Information
Syntax: SL:[{name}]
Example: SL, SL: or SL:BASIC-87
Reference: Section 11, *ASCII Command Interface, Settings (S) Command Descriptions*

SL-GROUP Command

Purpose: Read/Set Logic for Setting Group Module
Syntax: SL-GROUP[={mode},{D0logic},{D1logic},{D2logic},{D3logic},{AUTOlogic}]
Example: SL-GROUP or SL-GROUP=1,IN3,IN4,0,0,0
Reference: Section 4, *Protection and Control, Setting Groups*

SL-N Command

Purpose: Read/Set Name of the active logic
Syntax: SL-N[={name}]
Example: SL-N=CDSTEST
Reference: Section 7, *BESTlogic Programmable Logic, Logic Schemes*

SL-OUT Command

Purpose: Read/Set Hardware Output Logic
Syntax: SL-OUT[x[={y+y+..y}]] where x is 1 - 14 or A and y = VOA,VO1,...V015
Example: SL-OUT or SL-OUT1=VO1 or SL-OUT2=VO1+VO2+VO9
Reference: Section 7, *BESTlogic Programmable Logic, Working With Programmable Logic, Output Logic Settings*

SL-VO Command

Purpose: Read/Set Output Logic
Syntax: SL-VO[x[={Boolean equation}]] where x is 1 - 15 or A
Example: SL-VO or SL-VO1=50TPT+50TNT+51PT+51NT+101T or SL-VO2=101C+*/VO2
Reference: Section 7, *BESTlogic Programmable Logic, Working With Programmable Logic*

SL-101 Command

Purpose: Read/Set Logic for Virtual Breaker switch x101 where x=blank,1,2,3
Syntax: SL-x101[=mode] where mode=0/1 (disabled/enabled)
Example: SL-101 or SL-2101=0 or SL-3101=1
Reference: Section 4, *Protection and Control, Virtual Switches*

SL-24 Command

Purpose: Read/Set Logic for 24 Function Modules
Syntax: SL-24[={mode},{BLK logic}]
Example: SL-24 or SL-24=1,0 or SL-24=1,IN3
Reference: Section 4, *Protection and Control, Voltage Protection*

SL-27 Command

Purpose: Read/Set Logic for 27 Function Modules
Syntax: SL-x27P[={mode},{BLK logic}]] where x= blank or 1
Example: SL-27 or SL-27P=1,0 or SL-127P=3,0 or SL-27P=1,IN3
Reference: Section 4, *Protection and Control, Voltage Protection*

SL-43 Command

Purpose: Read/Set Logic for Virtual switch (x43)
Syntax: SL-{x}43[=mode] where x = blank,1,2,3,4,5,6,7 and mode=0,1,2,3
Example: SL-43 or SL-743=0 or SL-143=1
Reference: Section 4, *Protection and Control, Virtual Switches*

SL-47 Command

Purpose: Read/Set Logic for 47 Function Modules
Syntax: SL-47[={mode},{BLK logic}]
Example: SL-47 or SL-47=1,0 or SL-47=1,IN3
Reference: Section 4, *Protection and Control, Voltage Protection*

SL-50BF Command

Purpose: Read/Set Logic for x50BF Breaker Failure Functions where x=blank,1,2,3
Syntax: SL-50BF[={mode},{50INIlogic},{52INIlogic},{52Statuslogic},{BLKlogic}]
Example: SL-50BF or SL-50BF=1,VO1,VO2,VO3,0 or SL-50BF=1,VO1,IN1
Reference: Section 4, *Protection and Control, BF Breaker Failure Protection*

SL-50T Command

Purpose: Read/Set Logic for x50 Function Modules where x = blank,1,2,4,5,6,7
Syntax: SL-x50T[{p}[={mode},{BLK logic}]] where p = P/N/Q and mode = Ckt
Example: SL-50TP or SL-50TP=1,0 or SL-150TN=1,IN3 or SL-250TQ=2,IN2
Reference: Section 4, *Protection and Control, Overcurrent Protection*

SL-51 Command

Purpose: Read/Set Logic for x51 Function Modules where x = blank,1,2,3,4
Syntax: SL-x51[{p}[={mode},{BLK logic}]] where p = P/N/Q and mode = Ckt
Example: SL-51P or SL-51P=1,0 or SL-151N=1,IN3 or SL-251Q=2,IN2
Reference: Section 4, *Protection and Control, Overcurrent Protection*

SL-59 Command

Purpose: *Read/Set Logic for 59 Function Modules*
Syntax: SL-x59[{p}][={mode},{BLK logic}] where x = blank or 1 and p=P/X
Example: SL-59P or SL-59P=1,0 or SL-59X=2,0 or SL-159P=1,IN3
Reference: Section 4, *Protection and Control, Voltage Protection*

SL-62 Command

Purpose: Read/Set Logic for x62 Function Modules where x = blank,1,2,3
Syntax: SL-x62[={mode},{INI logic},{BLK logic}] where mode 1 - 6
Example: SL-62 or SL-62=1,VO10,0 or SL-162=2,VO9,VO8
Reference: Section 4, *Protection and Control, General Purpose Logic Timers*

SL-81 Command

Purpose: Read/Set Logic for 81 Function Modules
Syntax: SL-x81[={mode},{BLK logic}] where mode=0/1, x = blank,1,2,3,4,5
Example: SL-81 or SL-81=1,0 or SL-181=1,IN3
Reference: Section 4, *Protection and Control, Frequency Protection*

SL-87 Command

Purpose: Read/Set Logic for the 87 Function
Syntax: SL-87[={mode},{BLK logic}]
Example: SL-87 or SL-87=1,0 or SL-87=1,IN3
Reference: Section 4, *Protection and Control, Differential Protection*

SL-87ND Command

Purpose: Read/Set Logic for the x87ND Function where x=blank or 1
Syntax: SL-x87ND[={mode},{BLK logic}]
Example: SL-x87ND or SL-87ND=1,0 or SL-187ND=2,IN3
Reference: Section 4, *Protection and Control, Differential Protection*

User Programmable Name Setting Command

SN Command

Purpose: Read/Set Name of the active logic
Syntax: SL-N[={name}]
Example: SL-N=CDSTEST
Reference: Section 7, *BESTlogic Programmable Logic, User Input and Output Logic Variable Names*

Protection Setting Commands

S<g> Command

Purpose: Read all Protection settings
Syntax: S{g} where g=setting group 0-3 or # for all groups
Example: S# or S0 or S1
Reference: Section 11, *ASCII Command Interface, Settings (S) Command Descriptions*

S<g>-24 Command

Purpose: Read/Set 24 pickup level, time delay, reset delay and curve
Syntax: S{g}-24[={pu(V/Hz)},{td},{rst},{crv}] where g=0,1,2,3
Example: S0-24 or S0-24=2.5,6.5,9.9,2 or S1-24=3,2.0,5.0,1
Reference: Section 4, *Protection and Control, Voltage Protection*

S<g>-24D Command

Purpose: Read/Set 24 definite time pickup levels and time delays
Syntax: S{g}-24D[={pu1(V/Hz)},{td1},{pu2(V/Hz)},{td2}] where g=0,1,2,3
Example: S0-24D or S0-24D=1.1,6000,1.18,45000 or S1-24D=1.12,8000,1.20,60000
Reference: Section 4, *Protection and Control, Voltage Protection*

S<g>-27 Command

Purpose: Read/Set 27 pickup level, time delay and inhibit level
Syntax: S{g}-x27P[={pu(V)},{td(m)},{inh(V)}] where x= blank/1 and g=0,1,2,3
Example: S0-27P or S1-27P=100,10s,20 or S2-27P=80,50,20
Reference: Section 4, *Protection and Control, Voltage Protection*

S<g>-27R Command

Purpose: Read/Set (51)/27R control level and operating mode
Syntax: S{g}-27R[={pu(V)},{mode(m)}] where g=0,1,2,3, m=C-Control/R-Restraint
Example: S0-27R or S1-27R=100,C or S2-27=80,R
Reference: Section 4, *Protection and Control, Overcurrent Protection*

S<g>-47 Command

Purpose: Read/Set 47 pickup level and time delay

Syntax: S{g}-47[={pu(V)},{td(m)}] where g=0,1,2,3

Example: S0-47 or S1-47=100,0

Reference: Section 4, *Protection and Control, Voltage Protection*

S<g>-50BF Command

Purpose: Read/Set the x50BF Breaker Failure settings where x=blank,1,2,3

Syntax: S0-x50BF[={TimeDelay},{PhPu},{NeuPu},{CtrlTimeDelay}]

Example: S0-50BF or S0-50BF=50m or S0-150BF=3c

Reference: Section 4, *Protection And Control, BF Breaker Failure Protection*

S<g>-50TP Command

Purpose: Read/Set x50T pickup level and time delay where x = blank,1,2,3,4,5,6,7

Syntax: S{g}-x50T[{p}][={pu(A)}[,{td(m)}]] where g = 0-3, p = P/N/Q

Example: S0-50TP or S1-50TP=25,0 or S1-150TN=3,20 or S2-250TN=3,20

Reference: Section 4, *Protection and Control, Overcurrent Protection*

S<g>-51 Command

Purpose: Read/Set x51 pickup level, time dial and curve where x = blank,1,2,3,4

Syntax: S{g}-x51[{p}][={pu(A)},{td},{crv}] where g = 0-3, p = P/N/Q

Example: S0-51P or S0-51P=7.5,6.5,S1 or S1-151Q=3,2.0,S1 or S2-251Q=3,2.0,S1

Reference: Section 4, *Protection and Control, Overcurrent Protection*

S<g>-59 Command

Purpose: Read/Set 59 pickup level and time delay

Syntax: S{g}-x59[{p}][={pu(V)},{td(m)}] where x = blank or 1, g=0,1,2,3 and p=P/X

Example: S0-59P or S1-59P=100,0 or S1-59X=80,20 S1-159P=80,20

Reference: Section 4, *Protection and Control, Voltage Protection*

S<g>-62 Command

Purpose: Read/Set x62 Time Delay where x = blank, 1, 2 or 3

Syntax: S{g}-x62[={td1},{td2}] where td suffix m=msec, s=sec, c=cy

Example: S0-62=500m,200m or S0-62=0.5s,0.2s or S2-162=30c,12c

Reference: Section 4, *Protection and Control, General Purpose Logic Timers*

S<g>-81 Command

Purpose: Read/Set 81 pickup level, time delay, and mode

Syntax: S{g}-x81[={pu(Hz)},{td(m)},{mode}] where x = blank,1,2,3,4,5 and g=0,1,2,3

Example: S0-81 or S0-81=59.00,6.5,U or S1-81=60.50,2.0,O

Reference: Section 4, *Protection And Control, Frequency Protection*

S<g>-81INH Command

Purpose: Read/Set 81 Under Voltage Inhibit level

Syntax: S{g}-81INH[={pu(V)}] where g=0,1,2,3

Example: S0-81INH or S0-81INH=80 or S1-81INH=0

Reference: Section 4, *Protection and Control, Frequency Protection*

S<g>-87 Command

Purpose: Read/Set the 87 parameters

Syntax: S{g}-87[={minpu},{slope},{2nd},{5th},{URO},{2nd harmonic sharing}]

Example: S#-87 or S0-87=0.35,45,18,35,10,1

Reference: Section 4, *Protection and Control, Differential Protection*

S<g>-87ND Command

Purpose: Read/Set the x87ND parameters where x = blank or 1
Syntax: S{g}-x87ND[={minpu},{slope},{td}]
Example: S#-87ND, S#-187ND or S0-87ND=0.35,45,500m
Reference: Section 4, *Protection And Control, Differential Protection*

S<g>-TAP87 Command

Purpose: Read/Set the 87 Tap parameters
Syntax: S{g}-TAP87[={mva},{kv1/tap1},{kv2/tap2},{kv3/tap3},{kv4/tap4}]
Example: S#-TAP87 or S0-TAP87=5,13.8,4.16,4.16,4.16
Reference: Section 4, *Protection and Control, Differential Protection*

SP-60FL Command

Purpose: Read/Set 60 Fuse Loss Blocking
Syntax: SP-60FL[={I_Blk},{V_Blk}] I_Blk=ENA/DIS, V_Blk=DIS/PNQ/PN/PQ/NQ/P/N/Q
Example: SP-60FL or SP-60FL=ENA,PNQ or SP-60FL=DIS,DIS
Reference: Section 4, *Protection and Control, Voltage Transformer Fuse Loss Detection*

SP-CURVE Command

Purpose: Read/Set the user programmable 51 curve parameters
Syntax: SP-CURVE[={A},{B},{C},{N},{R}]
Example: SP-CURVE or SP-CURVE=1.0,0,0,2.5,0
Reference: Section 4, *Protection and Control, Overcurrent Protection*

SP-GROUP Command

Purpose: Read/Program auxiliary setting group 1-3 operation
Syntax: SP-GROUP[{g}]=[{sw_time},{sw_level},{ret_time},{ret_level},{prot_ele}]
Example: SP-GROUP or SP-GROUP1=10,75,10,45,51P
Reference: Section 4, *Protection And Control, Setting Groups*

ST-DUTY Command

Purpose: Read/Set Transformer Duty
Syntax: ST-DUTY[n][={mode},{dmax},{ct ckt#},{BLKTXFMR logic}] where n=1,2,3,4, mode = 0/1/2
Example: ST-DUTY1=1,60E3,1,IN5
Reference: Section 6, *Reporting and Alarms, Transformer Duty Monitoring*

Global Commands

GS-PW Command

Purpose: Read/Set Password and password access port(s)
Syntax: GS-PW[{t}[={password},{com ports(0/1/2)}]] where t=G/S/C/R
Example: GS-PWG=TEST,0 or GS-PWS=XYZ,1/2
Reference: Section 9, *Security*

SECTION 12 • INSTALLATION

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SECTION 12 • INSTALLATION

General

BE1-CDS240 Current Differential Systems are delivered with an instruction manual and BESTCOMS™ software in a sturdy carton to prevent shipping damage. Upon receipt of the relay, check the model and style number against the requisition and packaging list for agreement. If there is evidence of shipping damage, file a claim with the carrier, and notify the Basler Electric Regional Sales Office, your sales representative, or a sales representative at Basler Electric, Highland, Illinois.

If the BE1-CDS240 is not installed immediately, store it in the original shipping package in a moisture and dust free environment.

Contact-Sensing Input Jumpers

NOTE

The BE1-CDS240 relays with mid- or high-range power supplies are delivered with the jumpers in the H (HIGH) position. Read the following paragraphs before placing the relay in service.

BE1-CDS240 relays have eight or twelve contact-sensing inputs, depending on style number, to initiate relay actions. An external wetting voltage is required for the contact-sensing inputs. The nominal voltage level of the external dc source must comply with the dc power supply input voltage ranges listed in Section 1, *General Information, Specifications.* To enhance user flexibility, the BE1-CDS240 uses wide range ac/dc power supplies that cover several common control voltages. The contact sensing input circuits are designed to respond to voltages at the lower end of the control voltage range while not overheating at the high end of the range.

Energizing levels for the contact-sensing inputs are jumper selectable for a minimum of approximately 5 Vdc for 24 Vdc nominal sensing voltage, 26 Vdc for 48 Vdc nominal sensing voltages, or 69 Vdc for 125 Vdc nominal sensing voltages. See Table 12-1 for the contact-sensing turn-on voltages.

Table 12-1. Contact-Sensing Turn-On Voltages

Style Option	Nominal Input Voltage	Contact-Sensing Turn-On Voltage *		
		Jumper (L) (Low Position)	Jumper (H) (High Position)	Jumper Not Installed
xxxx1xxxxxx	48 Vdc or 125 Vac/dc	26 to 38 Vdc	69 to 100 Vdc 56 to 97 Vac	n/a
xxxx2xxxxxx	125/250 Vac/dc	69 to 100 Vdc 56 to 97 Vac	138 to 200 Vdc 112 to 194 Vac	n/a
xxxx3xxxxxx	24 Vdc	n/a	n/a	Approx. 5 Vdc

* AC voltage ranges are calculated using the default recognition time (4 ms) and debounce time (16 ms).

Each BE1-CDS240 with a mid- or high-range power supply is delivered with the contact-sensing jumpers installed (H position) for operation in the higher end of the control voltage range. If the contact-sensing inputs are to be operated at the lower end of the control voltage range, the jumpers must be changed to L position.

The following paragraphs describe how to locate and remove/change the contact sensing input jumpers.

1. Remove the drawout assembly by pulling the two latches outward and sliding the assembly out of the case. Observe all electrostatic discharge (ESD) precautions when handling the drawout assembly.

2. Locate the eight jumper terminal blocks (or 12, Option A) that are mounted on the Input/Output Circuit Board. The Input/Output Circuit Board is the middle board in the assembly and the jumper terminal blocks are located on the back edge on the component side of the circuit board. Each terminal block has three pins. With the jumper as installed at the factory, one pin should be visible when viewed from the rear of the unit. Figure 12-1 illustrates the location of the jumpers placed in the high voltage position.
3. To select operation at the lower end of the control voltage range, position the blue jumper on the two terminals closest to the rear of the circuit board (L). Use care when removing each jumper so that no components are damaged.
4. When all jumpers are positioned for operation in the desired control voltage range, prepare to place the drawout assembly back into the case.
5. Align the drawout assembly with the case guides and slide the assembly into the case.
6. Push the latches down until they are parallel with the front panel.

Trip Coil Monitor (TCM) Jumpers

BE1-CDS240 relays have four trip coil monitor circuits for monitoring up to four breaker trip coils. Each TCM includes a High/Low Input jumper and a TCM On/Off jumper. The High/Low jumper establishes the operate voltage level of the Input as explained above and the On/Off jumper enables or disables the TCM logic. The TCMs are associated with Outputs 7, 8, 9, and 10. Relays are shipped with the jumpers in the TCM ON (active) position. To move the jumper to the off position, follow the procedure outlined under *Contact Sensing Input Jumpers* and look for the terminals labeled TCM as shown on Figure 12-1.

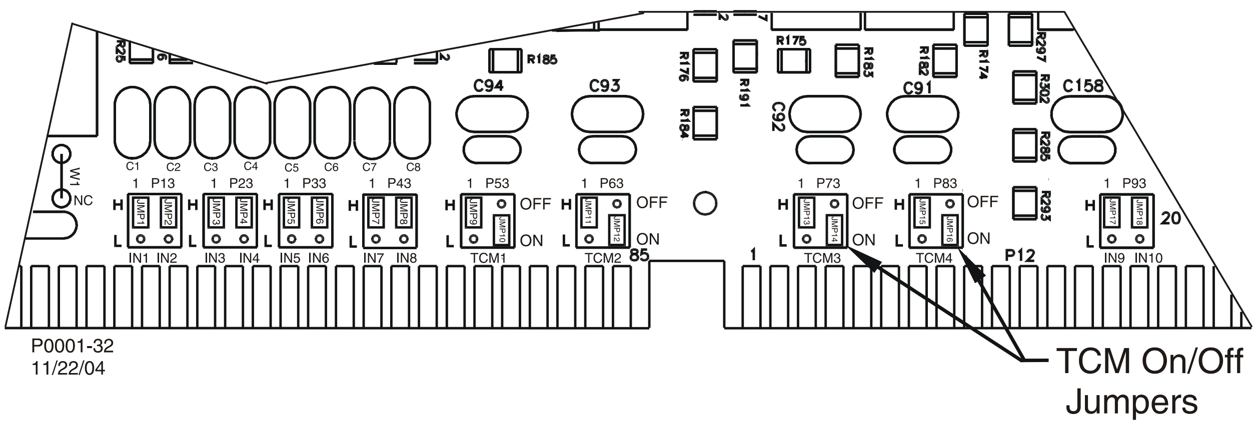


Figure 12-1. Contact-Sensing and TCM Jumper Locations

Mounting

Because the unit is of solid-state design, it does not have to be mounted vertically. Any convenient mounting angle may be chosen. BE1-CDS240 Overcurrent Protection Systems are available in Basler Electric's MX case design. MX cases are fully drawout with current circuit shorting provisions. MX cases are available in four configurations: a standard 19-inch rack horizontal mount, a horizontal panel mount, and two vertical panel mounts (I/O Option "A" and I/O Option "E"). The short vertical panel mount configuration fits cutout and panel drilling dimensions of Basler Electric M1, GE M1 and M2, and Westinghouse FT31 and FT32 size cases. The long vertical mounting pane fits cutout and drilling dimensions of the GE L2 and Westinghouse FT42 cases.

- Figures 12-2 through 12-4 show the overall dimensions of the case with vertical panel mounting or horizontal panel mounting, M-size.
- Figure 12-5 is the panel-drilling diagram for the vertical panel mount or horizontal mount, MX case.
- Figures 12-6 through 12-8 show the overall dimensions of the case with the horizontal rack mounting.
- Figures 12-9 through 12-11 show the overall dimensions of the case with the vertical panel mounting, L-size.
- Figure 12-12 shows the front dimensions for the horizontal panel mount case.

- Vertical and horizontal configurations are functionally the same with some controls and indicators relocated. All drawing dimensions are listed in inches and millimeters.

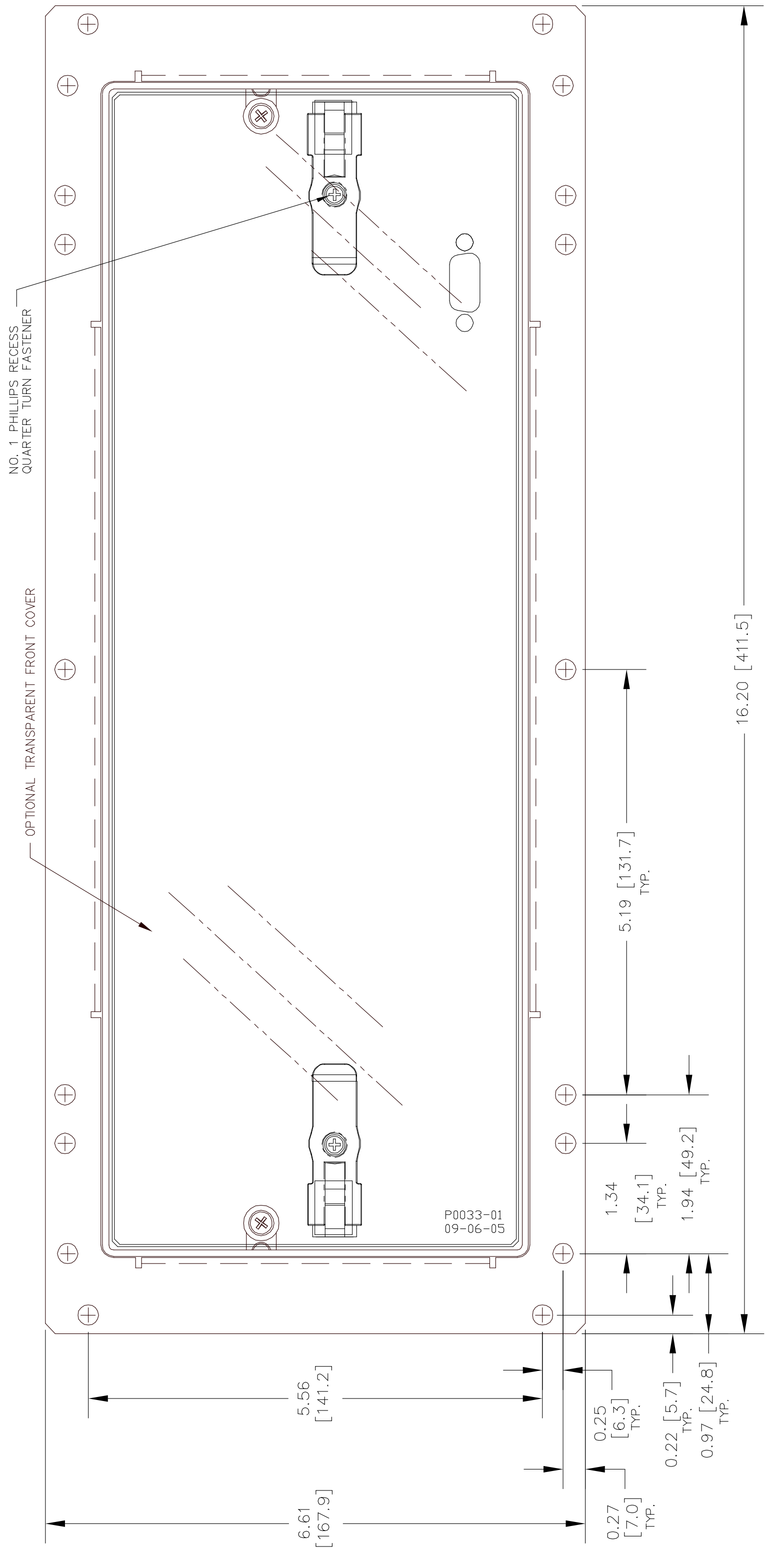


Figure 12-2. Vertical Panel Mount, M-size, Front View

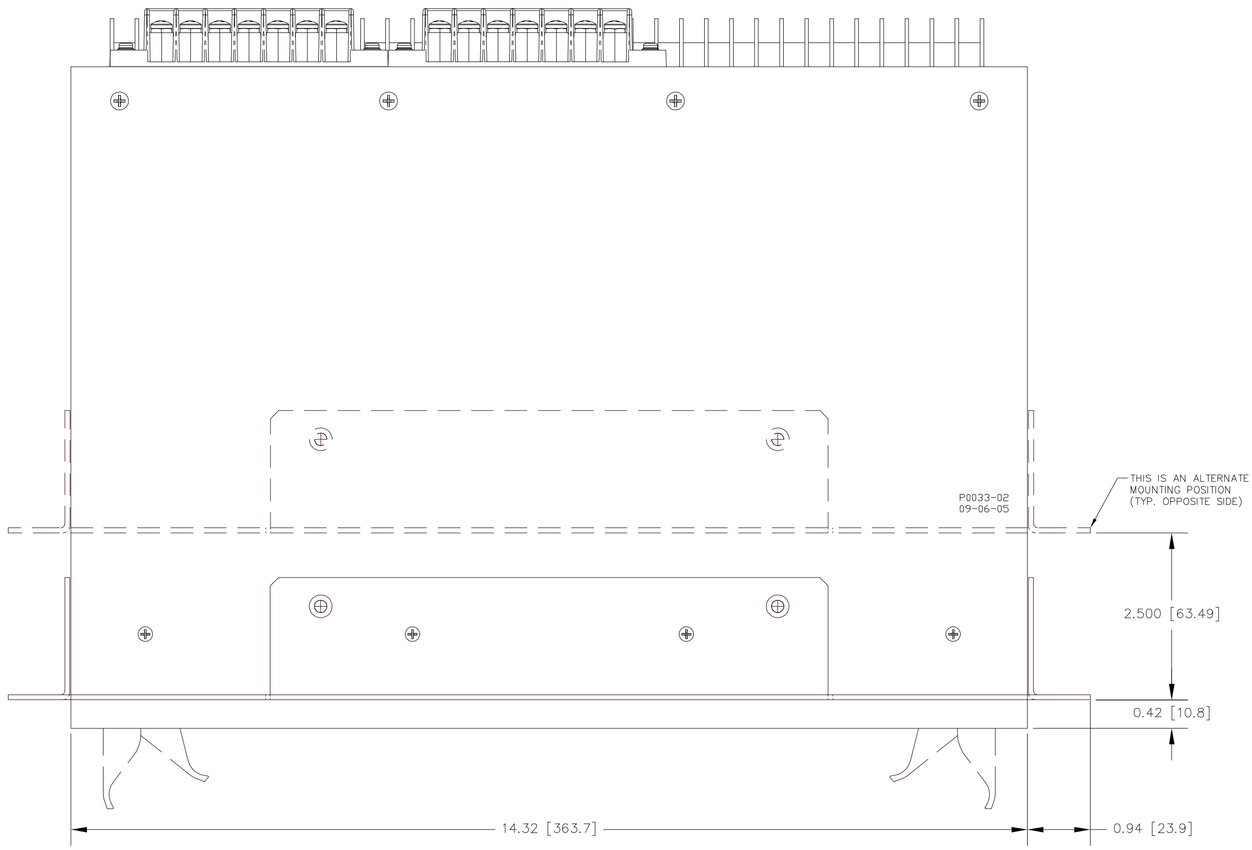


Figure 12-3. Vertical Panel Mount, M-size, Side View or Horizontal Panel Mount, Top View

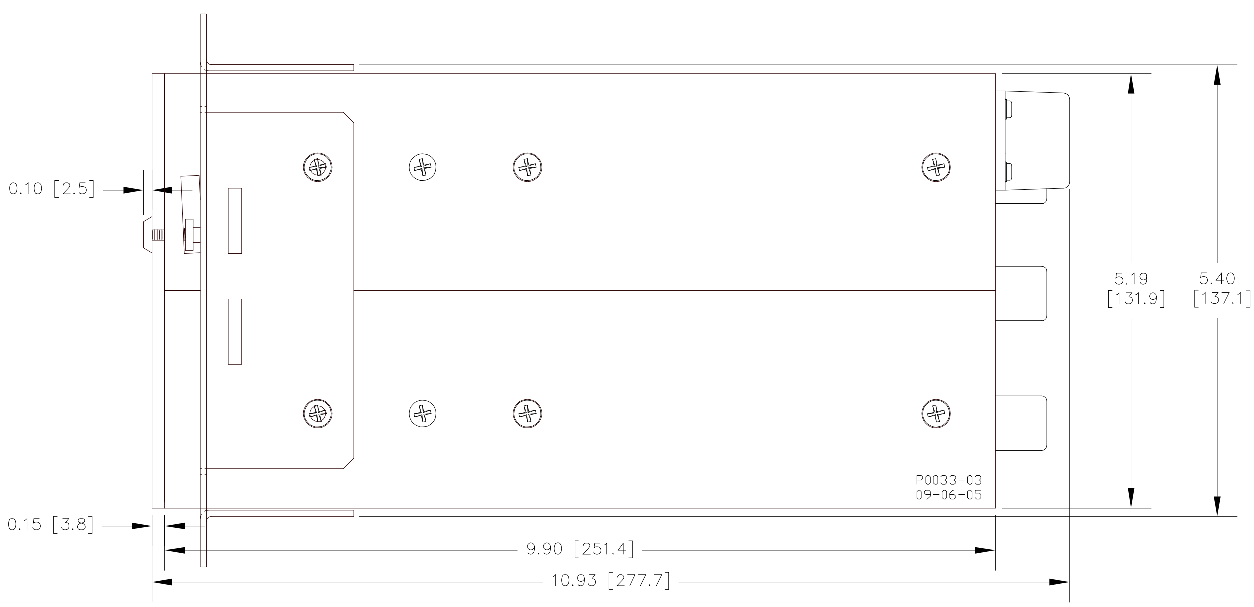


Figure 12-4. Vertical Panel Mount, M-size, Top View, or Horizontal Panel Mount Side View

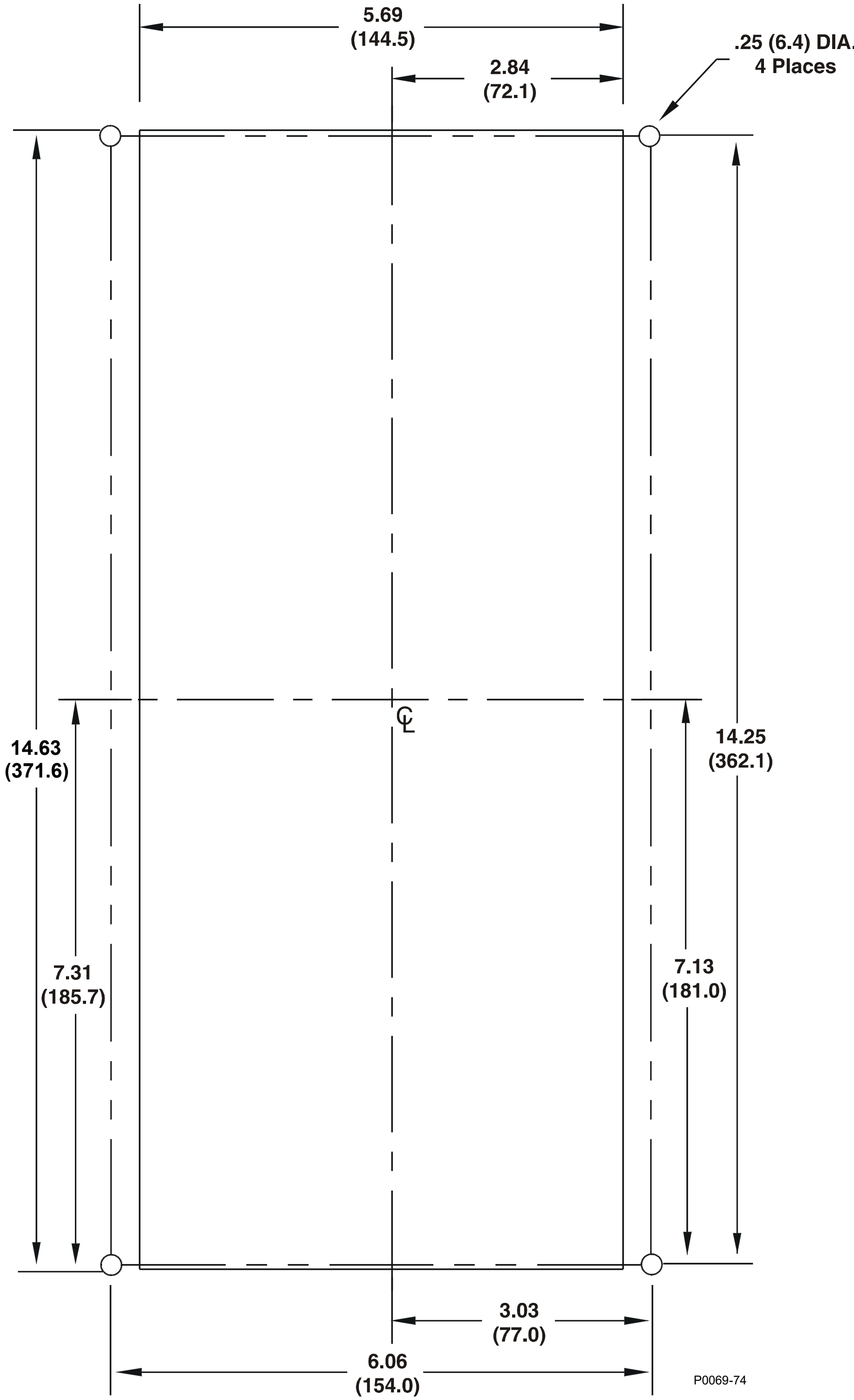


Figure 12-5. Vertical Panel or Horizontal Panel Mount MX Case, Panel Drilling Diagram

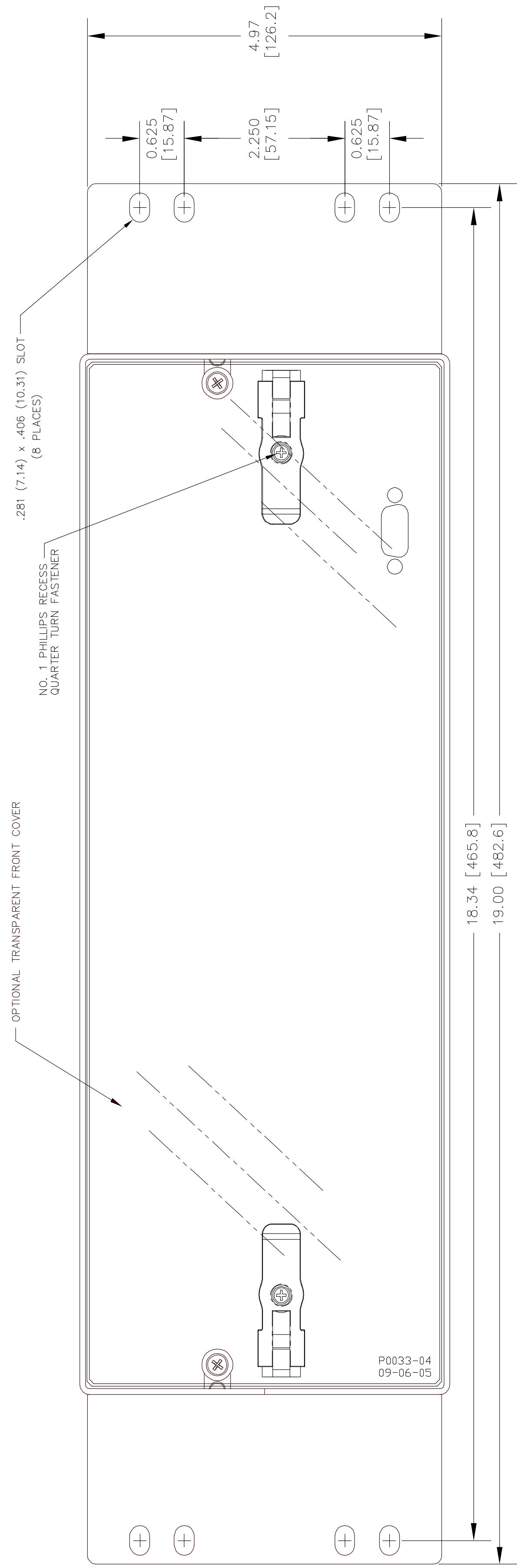


Figure 12-6. Horizontal Rack Mount, Front View

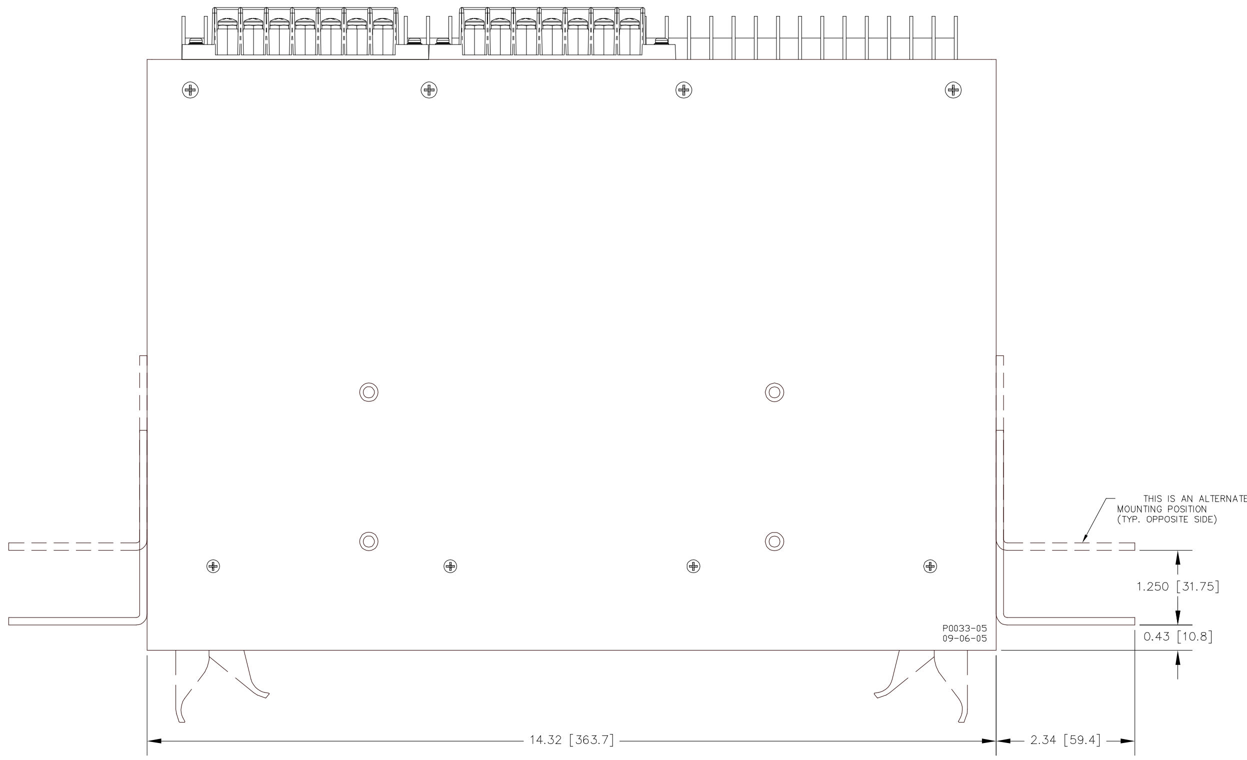


Figure 12-7. Horizontal Rack Mount, Top View

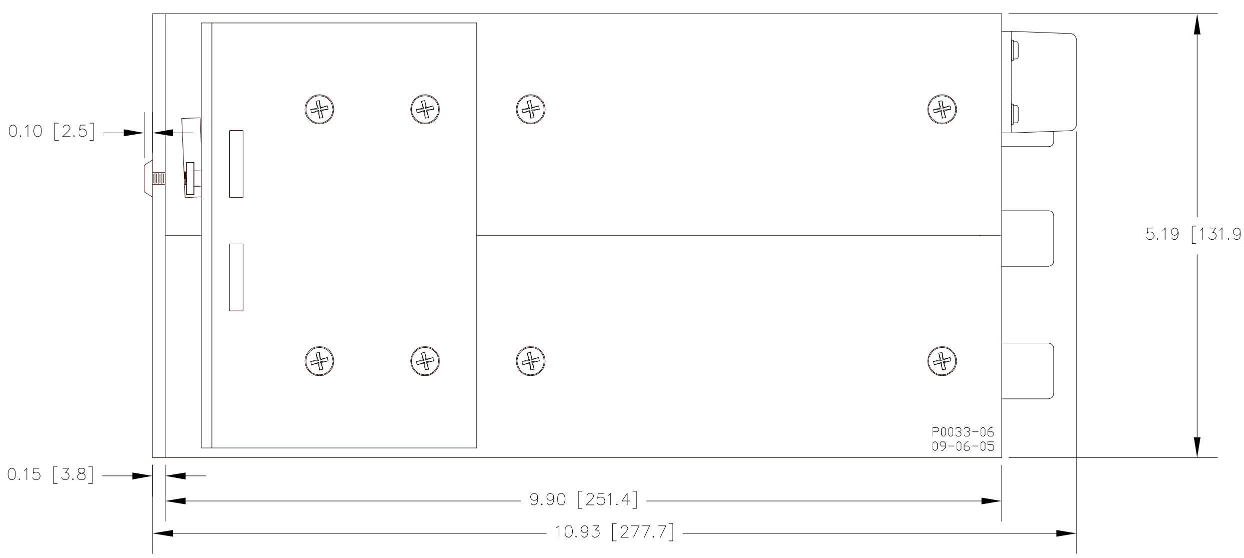


Figure 12-8. Horizontal Rack Mount, Side View

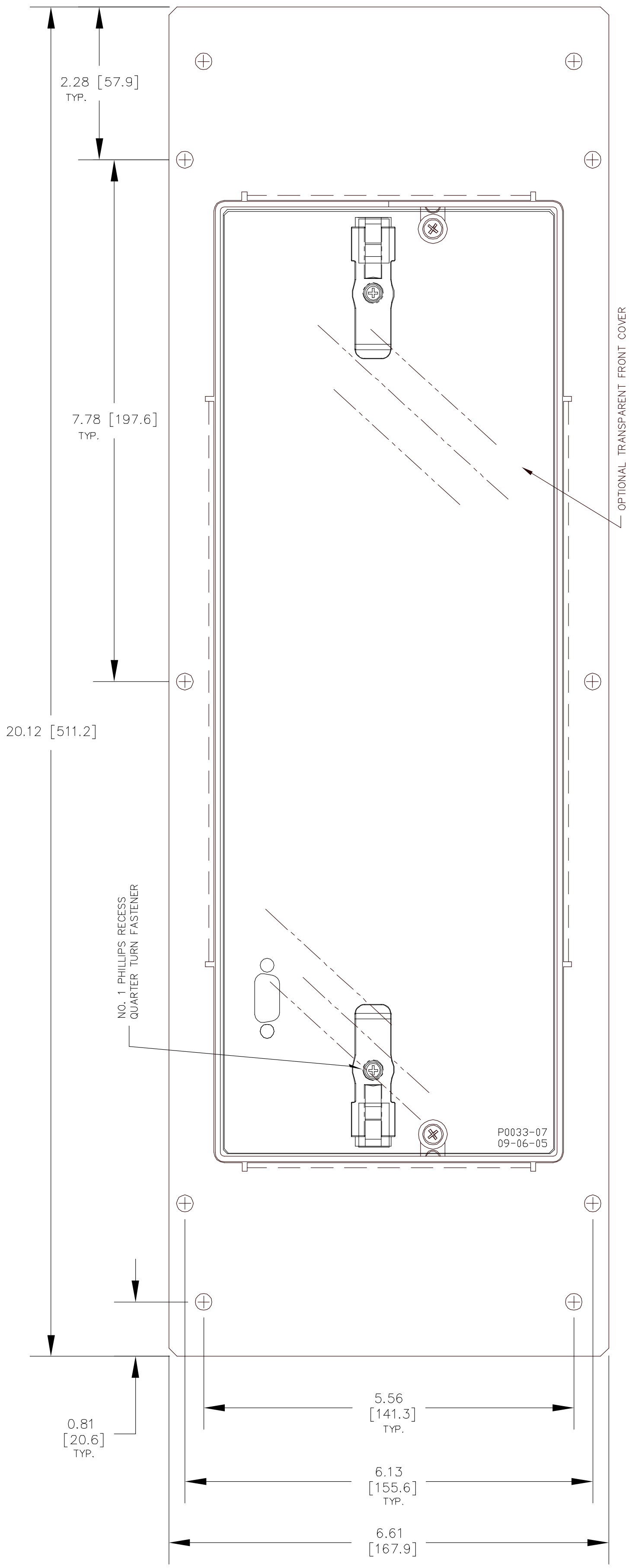


Figure 12-9. Vertical Panel Mount, L-size, Front View

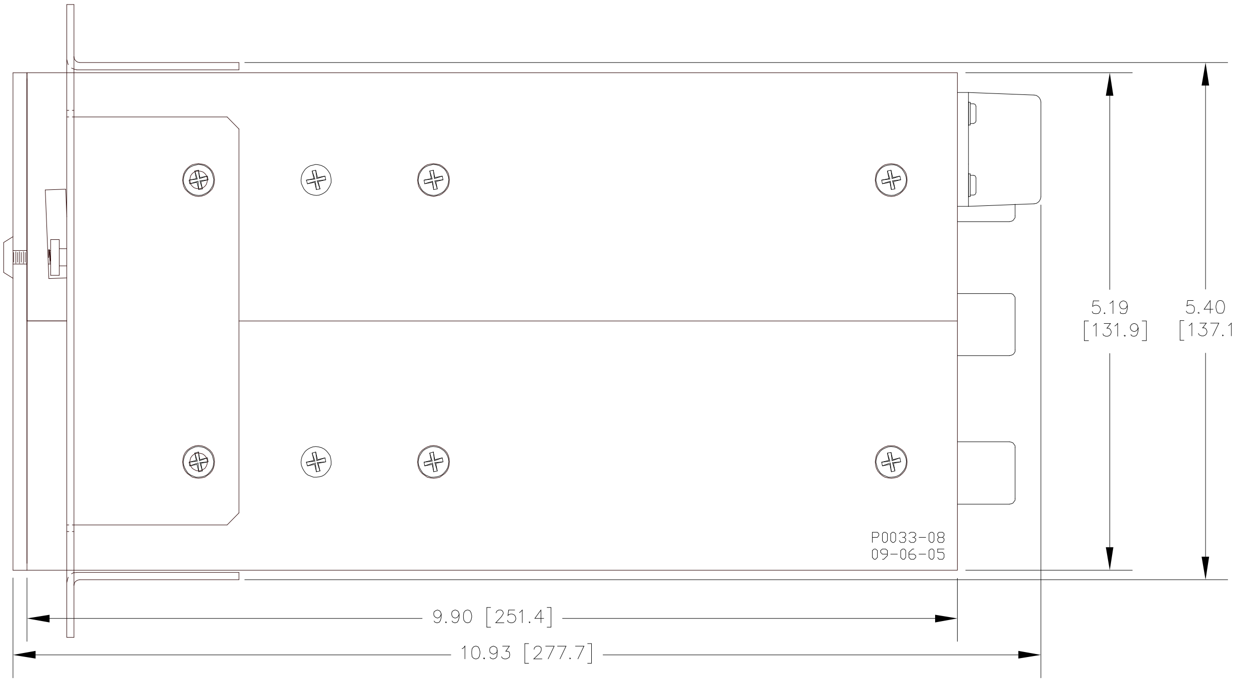


Figure 12-10. Vertical Panel Mount, L-size, Top View

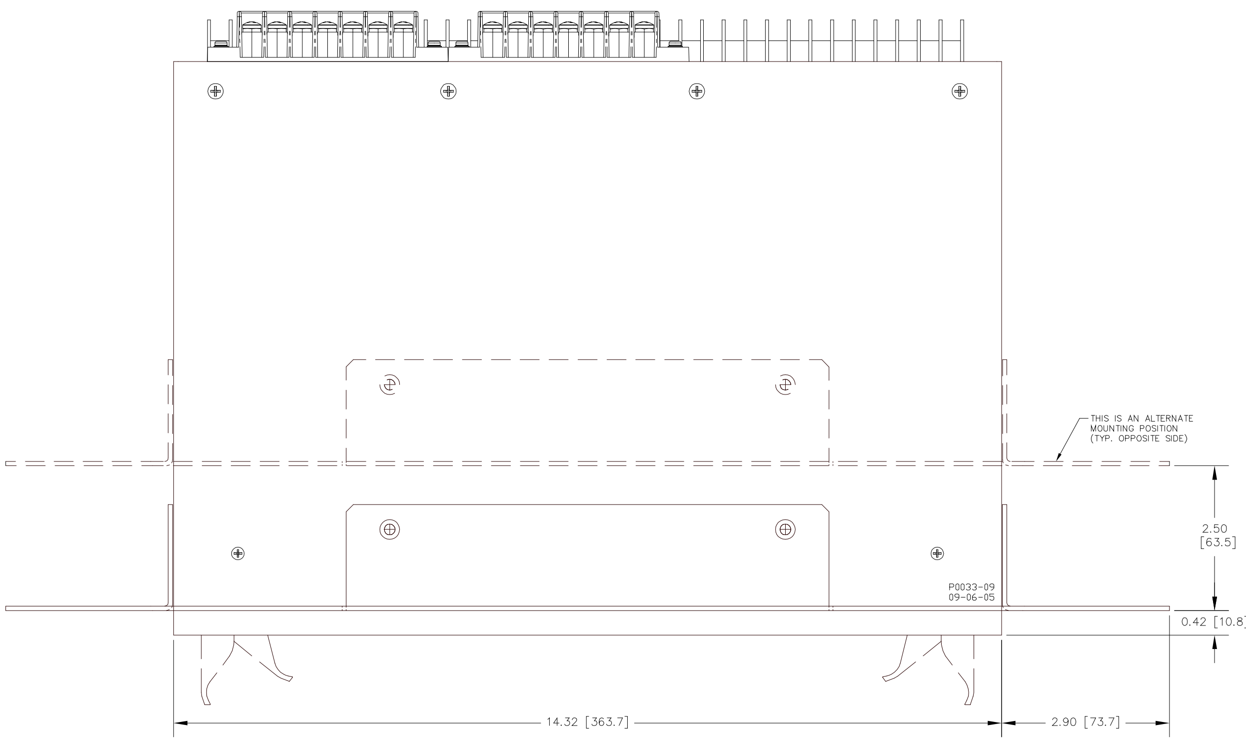


Figure 12-11. Vertical Panel Mount, L-size, Side View

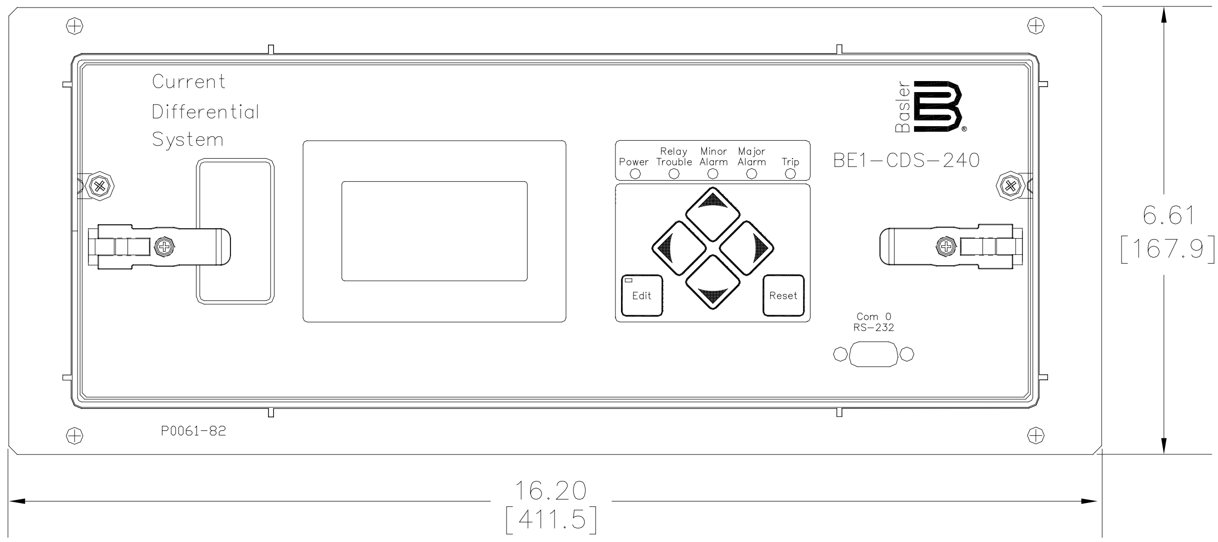


Figure 12-12. Horizontal Panel Mount, Front View

Relay Connections

Relay connections are dependent on the application and logic scheme used. Not all inputs or outputs may be used in a given installation. Incorrect wiring may result in damage to the relay. Be sure to check the model and style number against the options listed in Figure 1-8, *Style Number Identification Chart,* in Section 1, *General Information,* before connecting and energizing a particular relay.

Terminal Blocks

There are two sizes of terminal blocks used on the BE1-CDS240. Terminals A1 through A28 are for current inputs and use 8-32 pan head (Phillips) screws with a lock washer. The remaining terminals use 6-32 pan head (Phillips) screws with no washer.

The lock washers on Terminals B, C, and D are integral parts of the current input circuit wiring and should not be removed. Without the lock washer, the 8-32 screw may bottom out and prevent a good mechanical connection with the terminal block.

Maximum wire lug width accommodated by Terminals A1 through A28 is 0.344 inches (8.6 mm). Maximum wire lug width accommodated by the other terminals is 0.320 inches (8.1 mm). Figure 12-13 (Option "A") and Figure 12-14 (Option "E") are rear views of the BE1-CDS240 case showing the terminal connections.

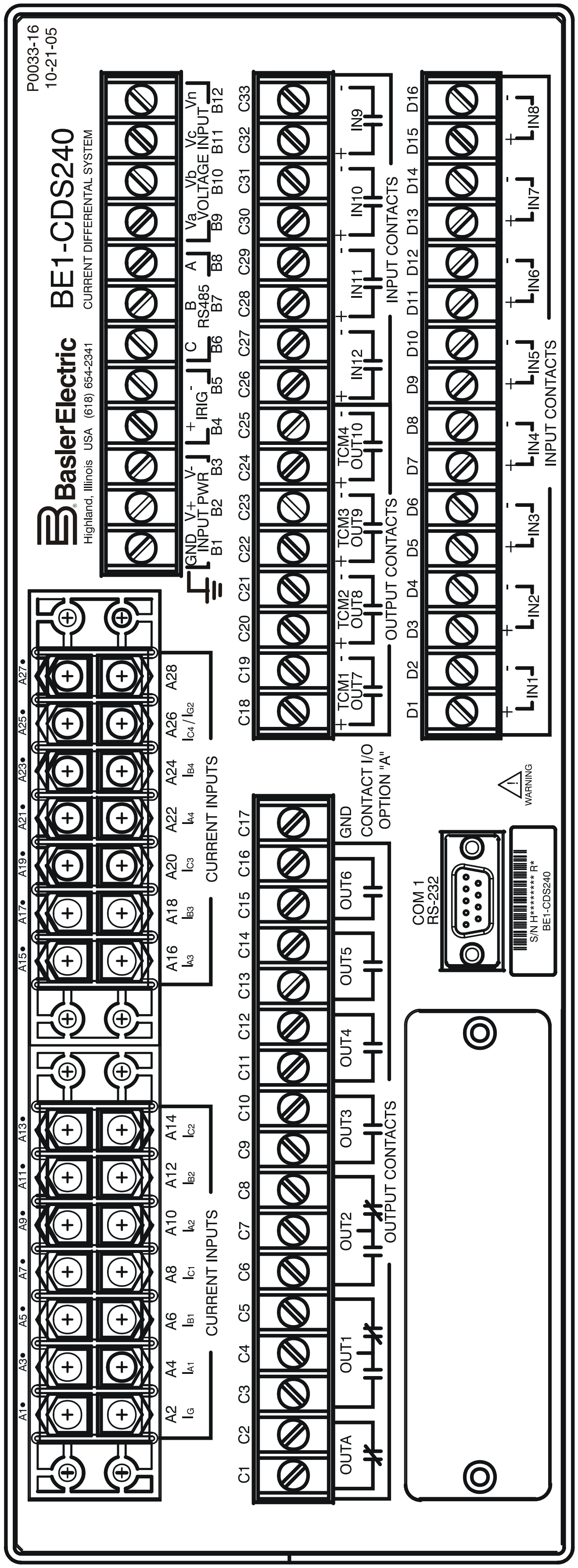


Figure 12-13. Horizontal or Vertical Rear View Terminal Connections (I/O Option "A" Shown)

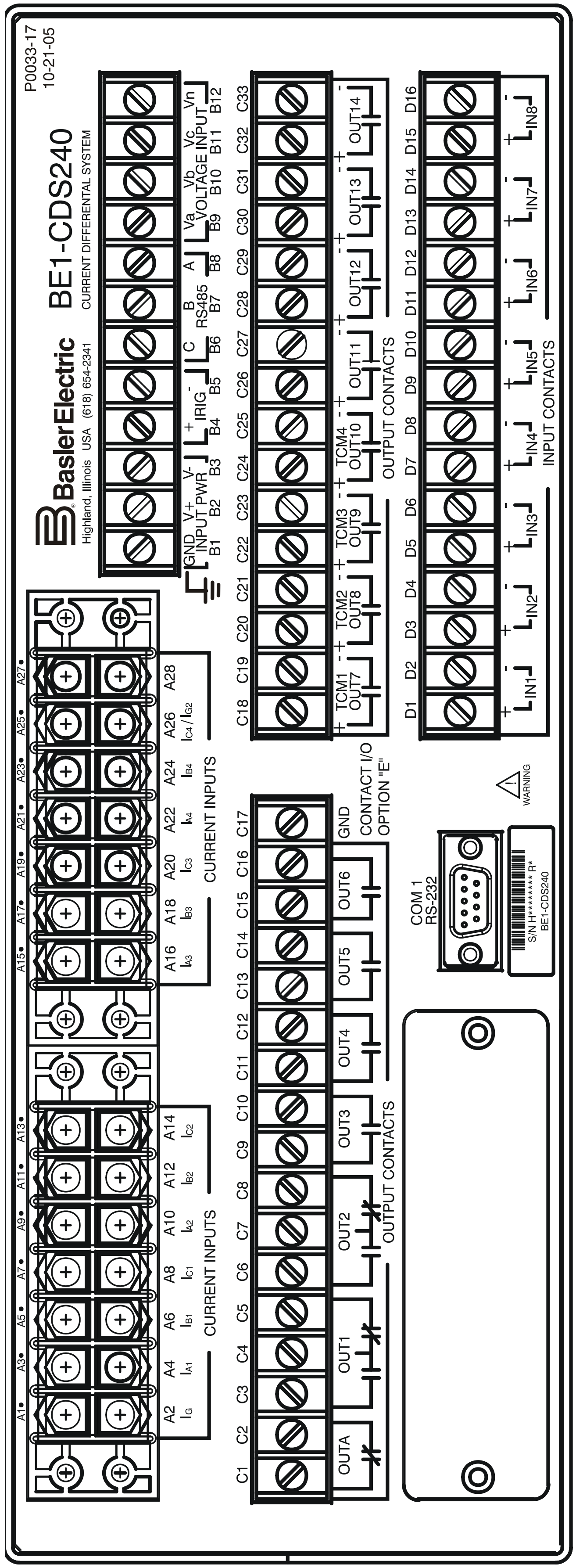


Figure 12-14. Horizontal or Vertical Rear View Terminal Connections (I/O Option "E" Shown)

Typical AC and DC Connections

Typical external ac and dc connections for the BE1-CDS240 are shown in Figures 12-15 through 12-16.

> **NOTE**
>
> The relay should be hard-wired to earth ground with no smaller than 12 AWG copper wire attached to the rear ground terminal of the relay case. When the relay is configured in a system with other protective devices, a separate ground bus lead is recommended for each relay.

Except as noted above, connections should be made with minimum wire size of 14 AWG. Be sure to use the correct input power for the power supply specified.

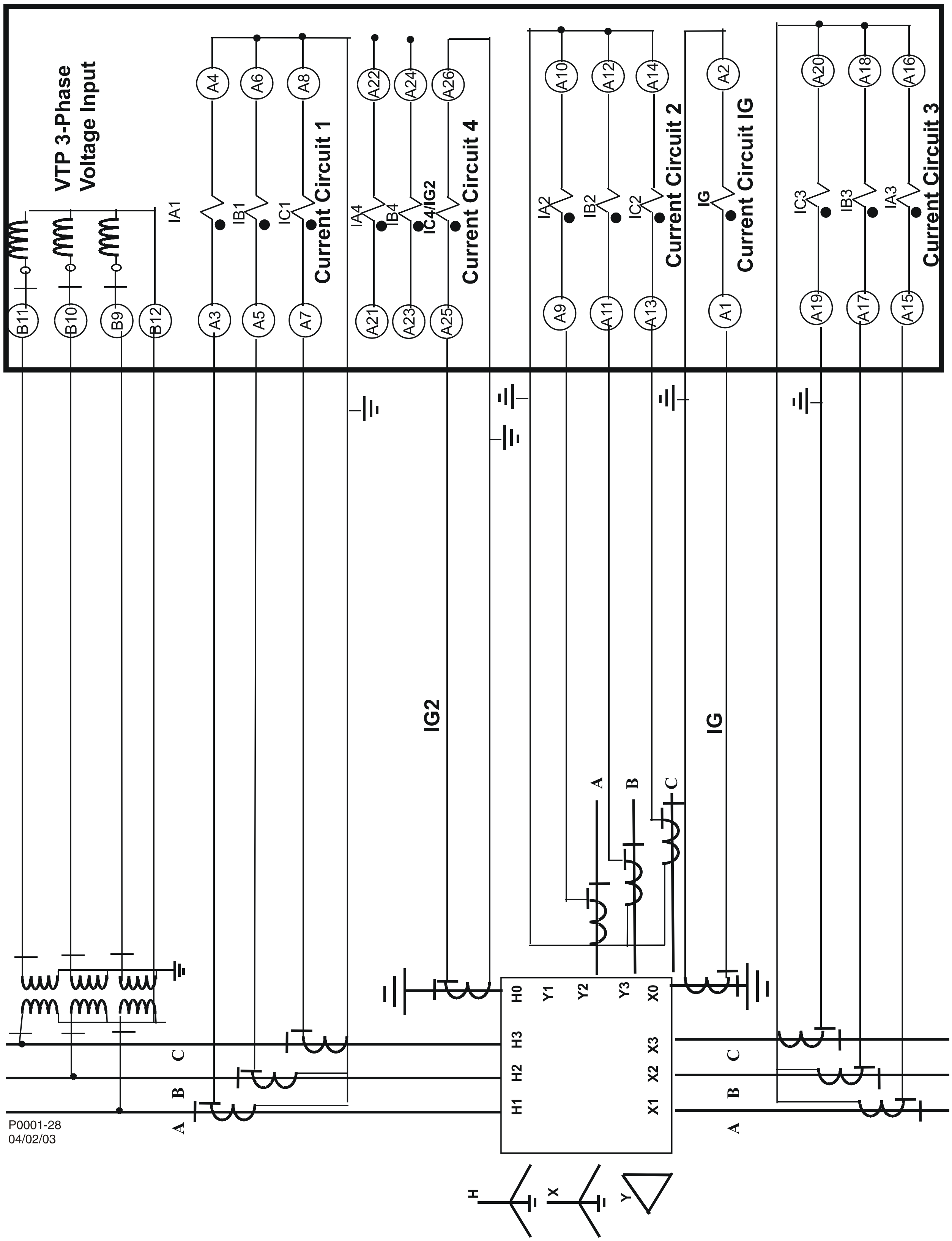


Figure 12-15. Typical AC Connection, 3-Restraint Windings, 2-IG Inputs with Voltage Protection

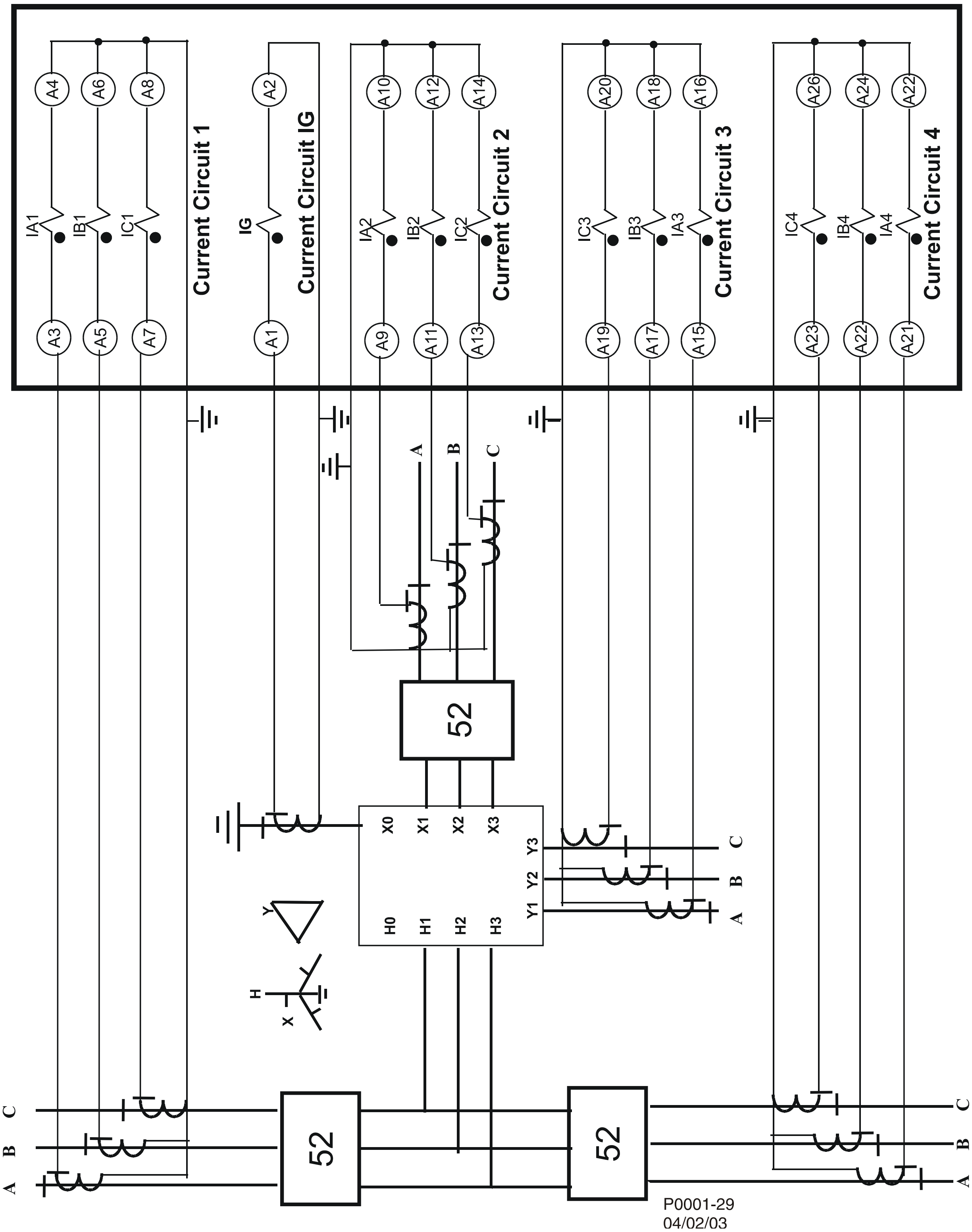


Figure 12-16. Typical AC Connection, 4-Restraint Windings, 1-IG without Voltage Protection

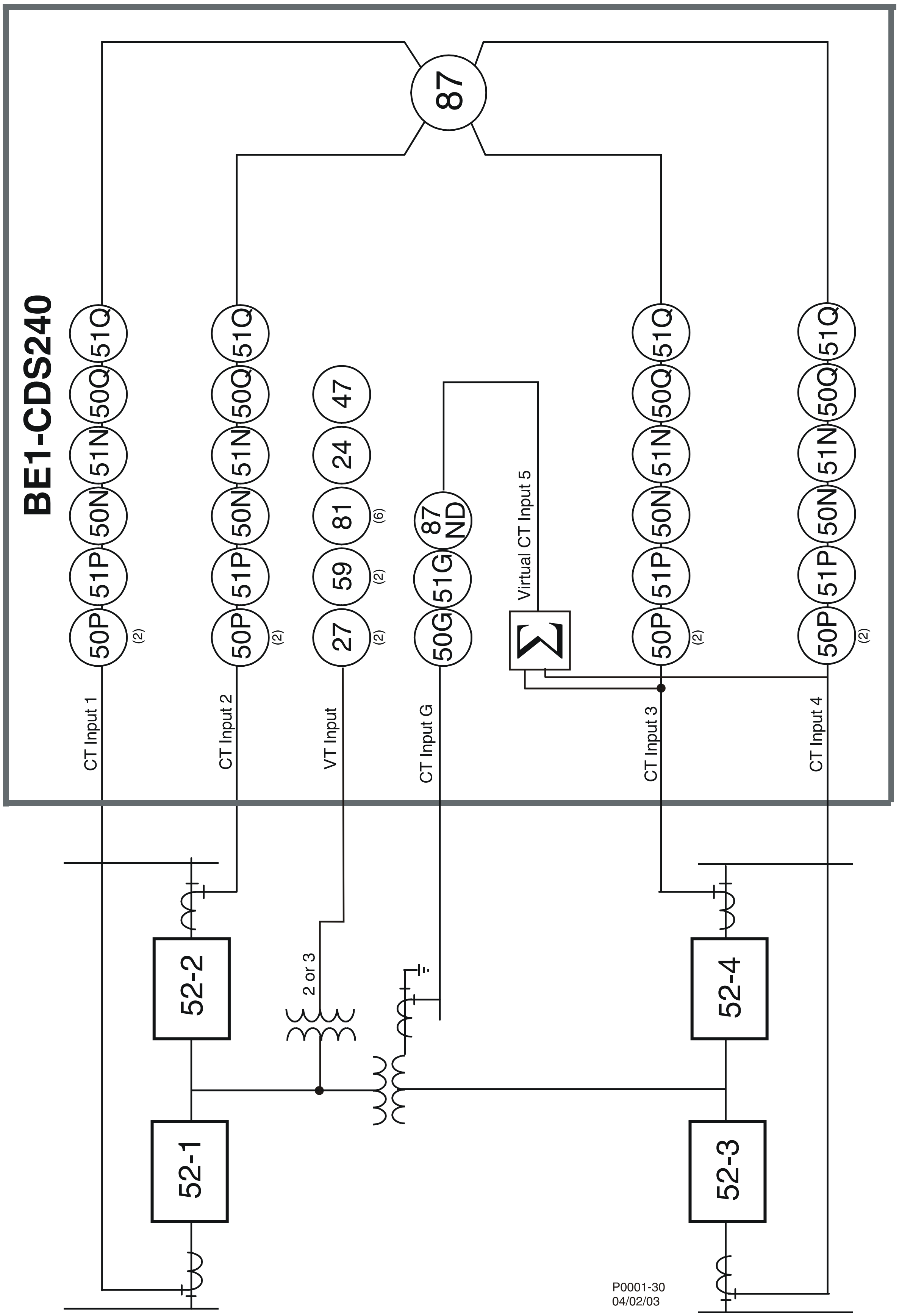


Figure 12-17. Typical Application, Two-winding, Transformer with 4-Restraint Connections

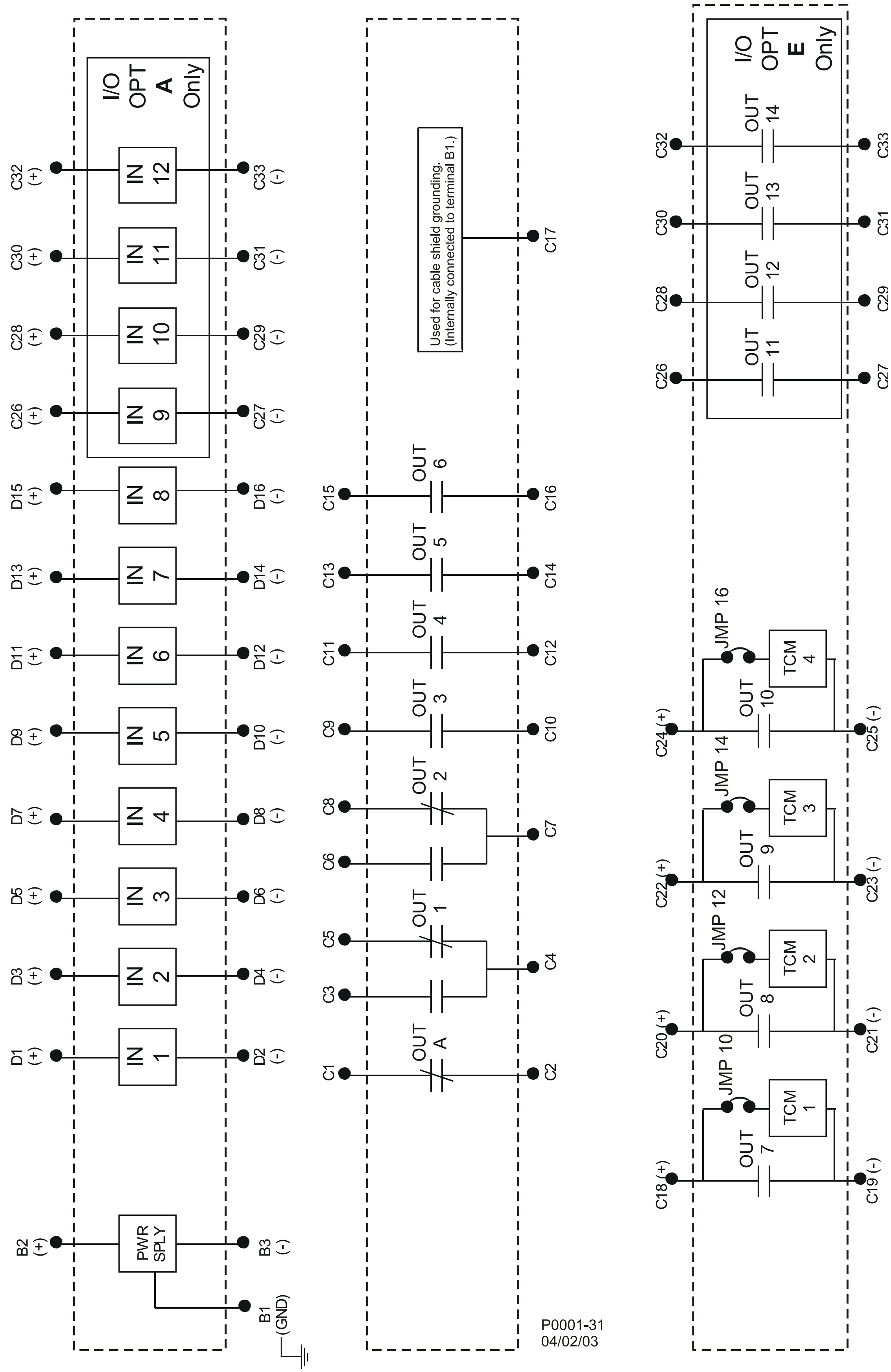


Figure 12-18. Typical DC Connection Diagrams

CT Polarity

CT polarity is critical to the proper operation of the BE1-CDS240. The sidebar below provides fundamental information on CT polarity and protective relays.

Sidebar: Current Circuit Polarity

By ANSI convention, Current Transformer Polarity will face away from the protected winding of a transformer, motor, generator, or reactor and away from the contacts in a circuit breaker. Therefore, primary current flow towards the winding or contacts (direction of protected zone) will result in a secondary current out X1, in phase with the primary. (See Figures 12-19 and 12-20.)

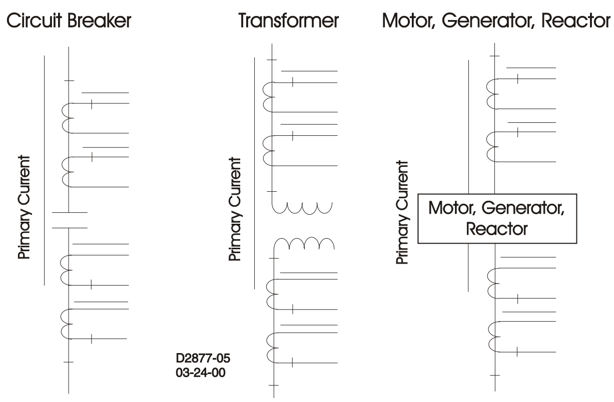


Figure 12-19. Standard CT Polarity

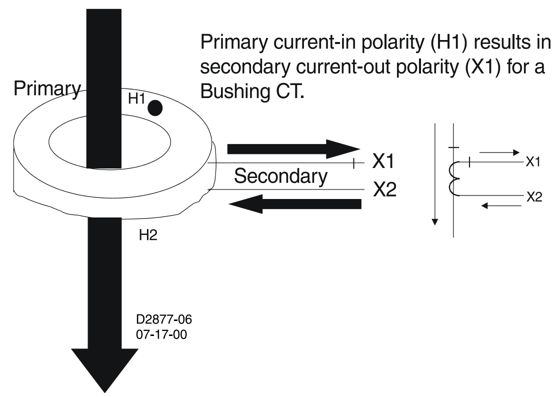


Figure 12-20. Current Transformer Action

On occasion, however, protection engineers will encounter situations where CT polarity is reversed for a specific application. That is, non-polarity of the CT secondary will be in phase with the primary current flow (Figure 12-21). For example, a transformer differential CT from a breaker with a different polarity convention, such as low voltage switchgear or a bus differential CT taken from the low side of a transformer.

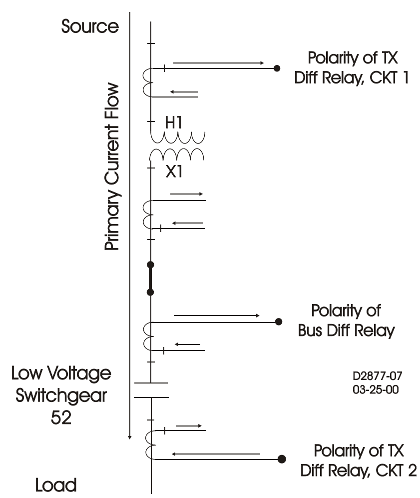


Figure 12-21. Example of Reversed CT Polarity

Orientation of CT polarity relative to primary current flow establishes the secondary CT terminal that should be connected to polarity of the protective relay.

Power System Applications

Figures 12-22 through 12-26 are examples of the applications that can be served by the Basler Electric BE1-CDS240 Current Differential System. Many of these applications can be used in concert with other Basler numeric systems such as the BE1-851and BE1-951 Overcurrent Protection System, the BE1-CDS220 Current Differential System or the BE1-GPS100 Generator Protection System.

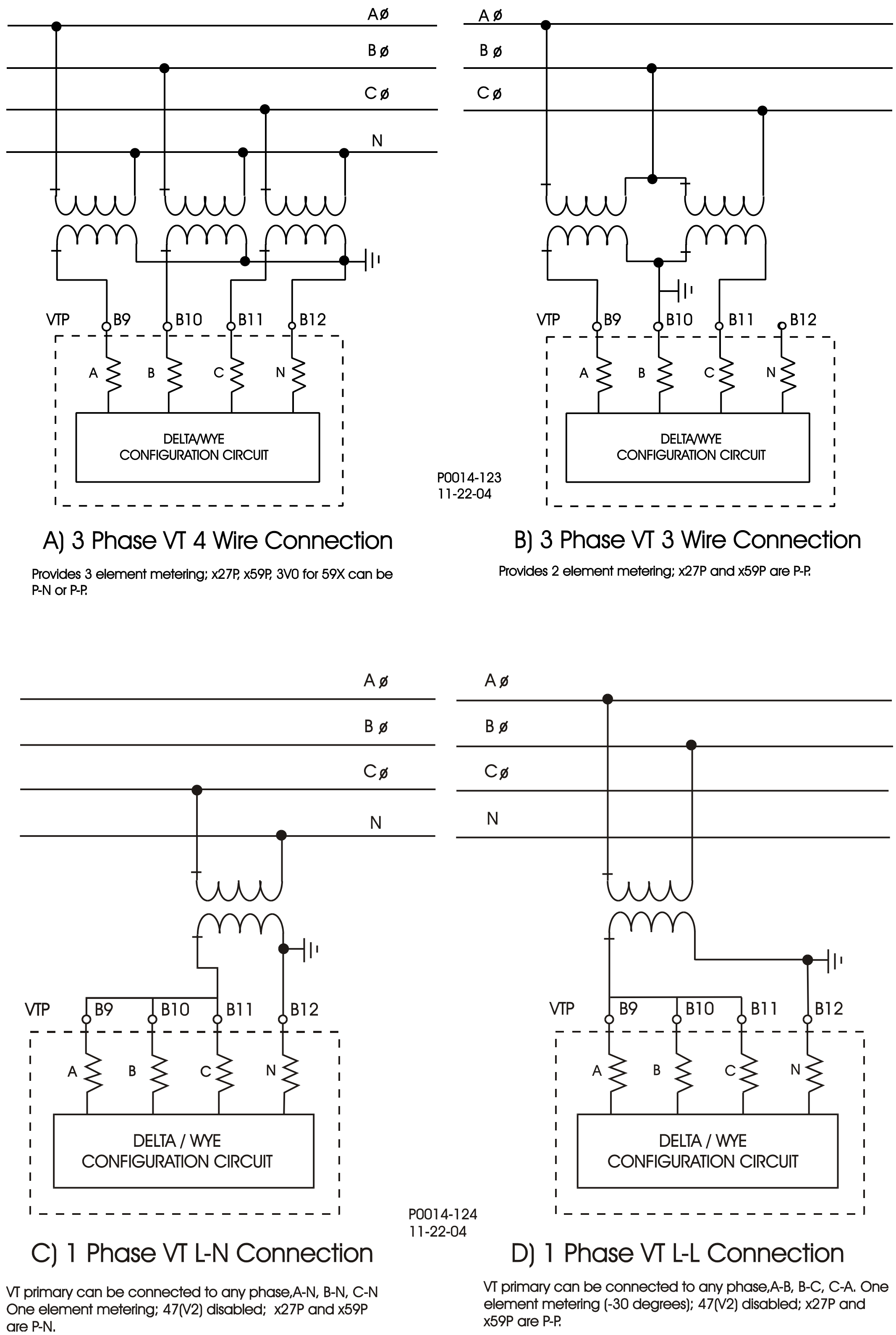
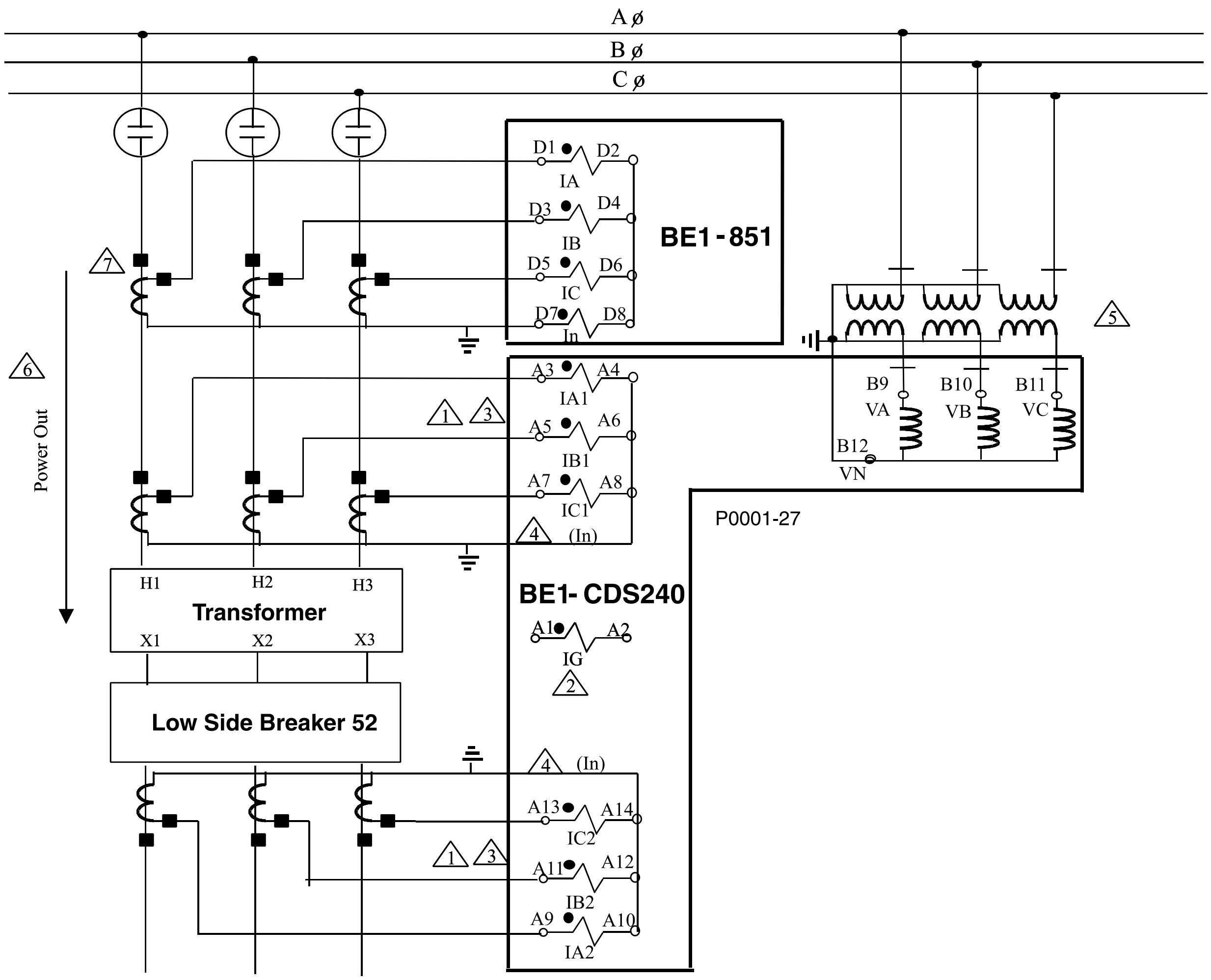


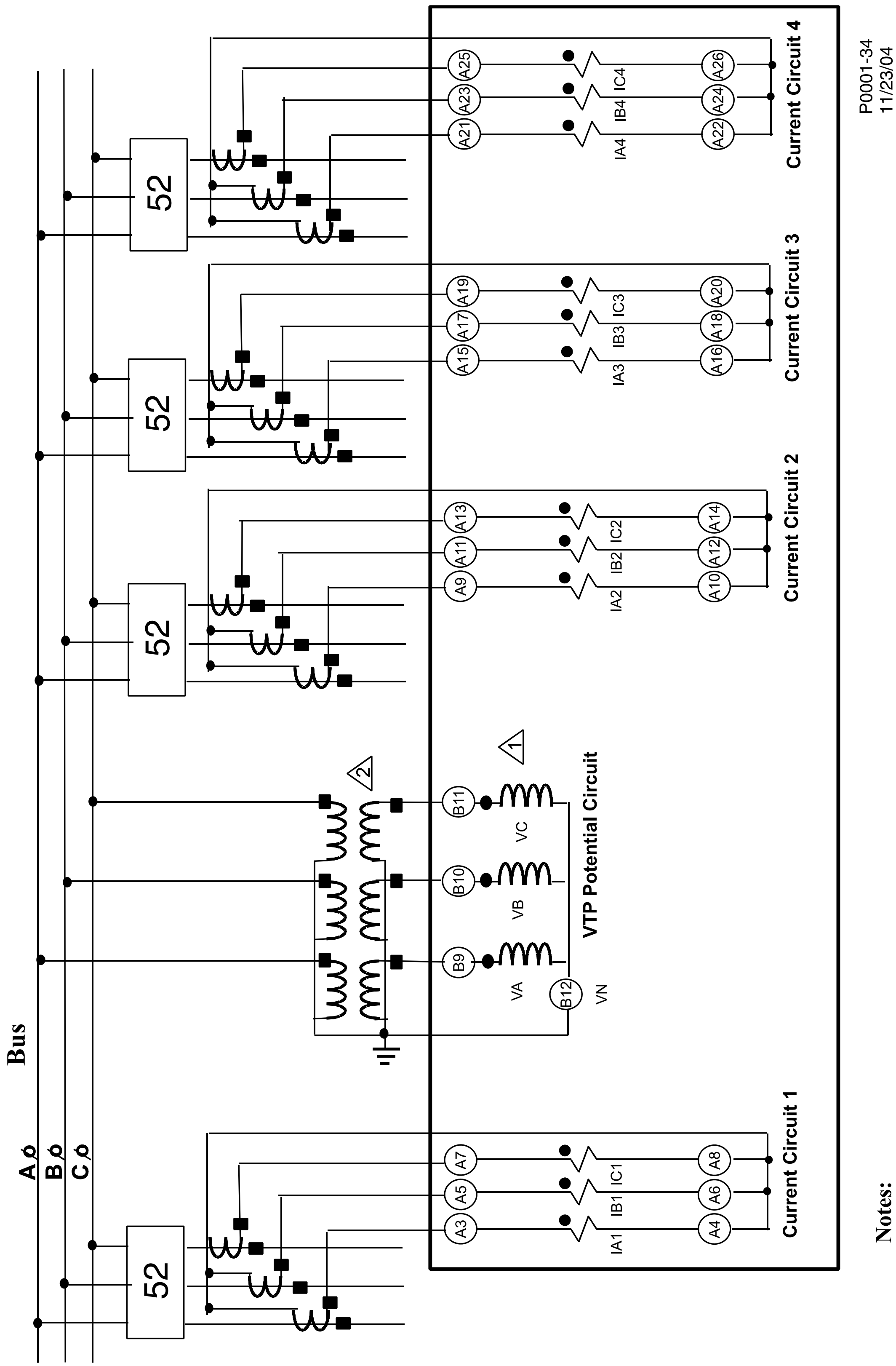
Figure 12-22. Voltage Sensing, Alternate VTP Input



Notes:

1. With the appropriate transformer and CT connection information, the relay can automatically determine the required compensation. The relay can accommodate any combination of transformer and CT connection (wye, delta AB or Delta AC). For more information, refer to Section 3, *Input and Output Functions, Power System Inputs.*
2. Independent ground input (I_G) can be connected for overcurrent or neutral differential protection. See Figures 12-15 and 12-16, for details.
3. Phase, residual and I_2 overcurrent elements can be connected to any CT circuit (4 inputs) for backup protection. For more information on applying overcurrent backup, refer to Section 8, *Application.*
4. Overcurrent neutral ground (I_N) operates on internally calculated residual (3I0) current.
5. A four-wire connection is shown as typical. For more information on VTP connections, see Figure 12-22.
6. With CT polarity connected to relay polarity, power flow from the high side to the low side is defined as power out and equals positive watts.
7. Shown with separate, overlapping CT for independent backup protection.

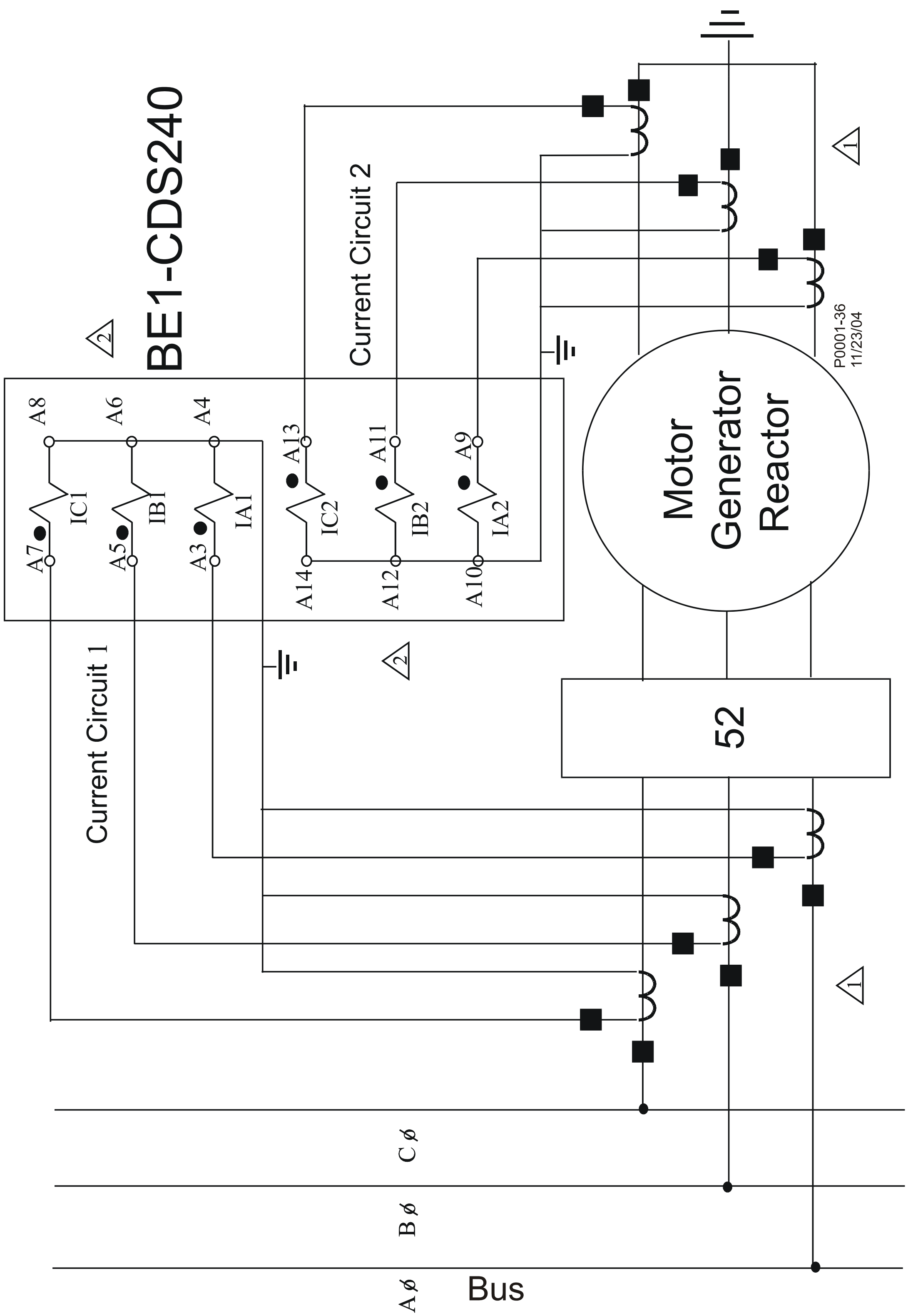
Figure 12-23. BE1-CDS240 Connected for Primary Protection, BE1-851 Connected for Independent Backup



Notes:

1. For complete metering and voltage protection, connect the VTP potential circuit.
2. Four-wire connection shown as typical. For more information on VTP connections, see Figure 12-22.

Figure 12-24. BE1-CDS240 Percentage Differential Bus Protection

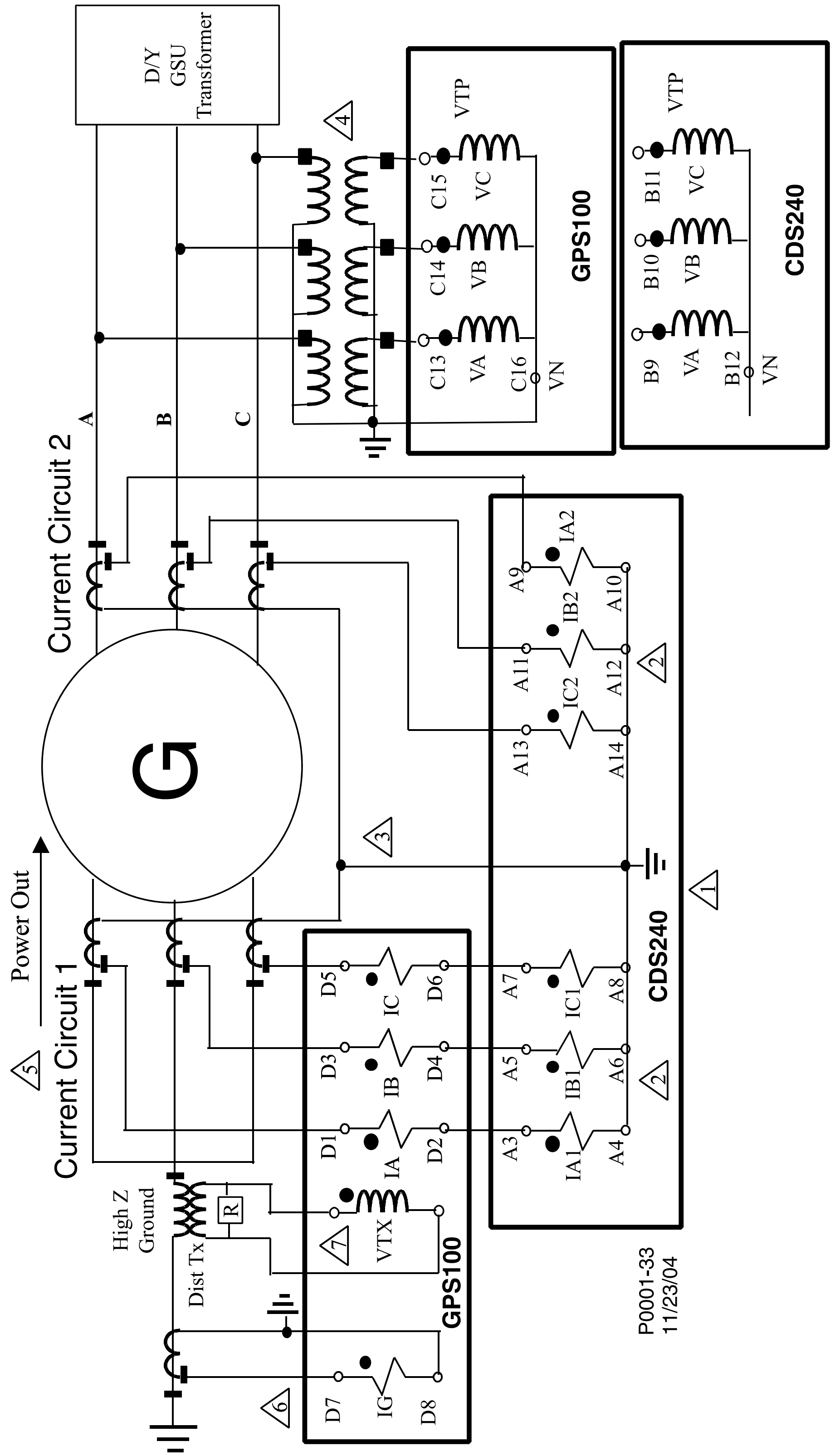


Notes:

1 Phase, Residual, and I_2 overcurrent elements can be connected to either CT circuit for backup protection. For more information on applying overcurrent backup, refer to Section 8, *Application*.

2 Overcurrent neutral ground (I_N) operates on internally calculated residual (3I0) current.

Figure 12-25. Typical Connection for Motor, Generator, or Reactor Differential Protection



Notes:
1. Connected for high speed generator differential protection.
2. Phase, Residual and I2 overcurrent elements can be connected to either CT circuit for backup protection. For more information on applying overcurrent backup, refer to Section 8, *Application*.
3. Overcurrent neutral ground (**I N**) operates on internally calculated residual (3I0) current.
4. Four-wire connection is shown as typical. For more information on VTP connections for the CDS240, see Figure 12-22. For more information on case connections for the GPS-100, see Section 12, *Installation*, in the BE1-GPS100 Instruction Manual.
5. With CT polarity connected to relay polarity, power flow is out the generator and equals positive watts.
6. Optional independent ground input (**I G**) connected for backup ground fault protection.
7. VTX connected for third harmonic detection.

Figure 12-26. CDS 240 Large Generator Protection - BE1-CDS240 Connected for Primary Current Differential, Voltage and Frequency Protection and Metering; BE1-GPS100 Connected for Independent Backup Fault Protection, Detection of Abnormal Situations and Backup Monitoring

Settings

Settings for your application should be entered and confirmed before placing the relay in service. Register settings such as breaker operations and breaker duty can be entered to match the current state of your system.

Preparing the Relay for Service

Basler microprocessor-based protection systems are similar in nature to a panel of electromechanical or solid-state component relays. Both must be wired together with inputs, outputs, and have operating settings applied. Logic settings determine which protection elements are electronically wired to the inputs and outputs of the device. Operating settings determine the pickup thresholds and time delays. The logic and operating settings should be tested by applying actual inputs and operating quantities and verifying proper output response. For more details, refer to Section 13, *Testing and Maintenance.* All of the following connections and functions should be verified during commissioning tests:

- Proper connection and sensing of current and voltage signals
- Input and output contact connections
- I/O sensing versus virtual sensing
- Settings validation
- Proper operation of equipment (main or auxiliary)
- Proper alarming (to SCADA) and/or targeting

Refer to Section 7, *BESTlogic Programmable Logic,* for information about customizing preprogrammed logic and creating user-defined logic and Section 8, *Application,* for information about the application of preprogrammed logic schemes.

Communications Connections

The following paragraphs describe the communication connections for the BE1-CDS240. Section 11, *ASCII Command Interface,* provides information about using the relay communication interface and lists all communication commands along with a description and the syntax for each command.

RS-232 Connectors

Front and rear panel RS-232 connectors are Data Communication Equipment (DCE) DB-9 female connectors. Connector pin numbers, functions, names, and signal directions are shown in Table 12-2 and Figure 12-27. RS-232 cable connection diagrams are provided in Figures 12-28 through 12-31. Optional Clear to Send (CTS) and Request to Send (RTS) connections are required only if hardware handshaking is enabled.

Table 12-2. RS-232 Pinouts (COM0 and COM1)

Name	Function	Name	Direction
1	Shield	----	N/A
2	Transmit Data	(TXD)	From relay
3	Receive Data	(RXD)	Into relay
4	N/C	----	N/A
5	Signal Ground	(GND)	N/A
6	N/C	----	N/A
7	N/C	----	N/A
8	N/C	----	N/A
9	N/C	----	N/A

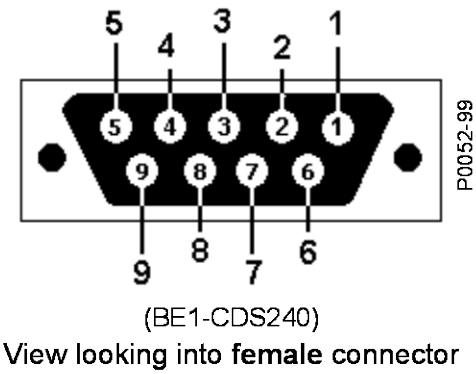


Figure 12-27. RS-232 Pinouts

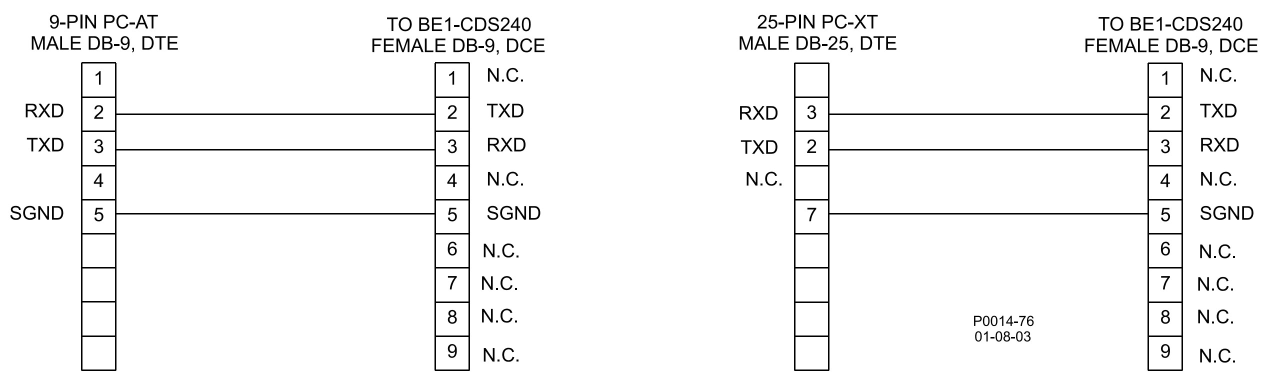


Figure 12-28. Personal Computer to BE1-CDS240

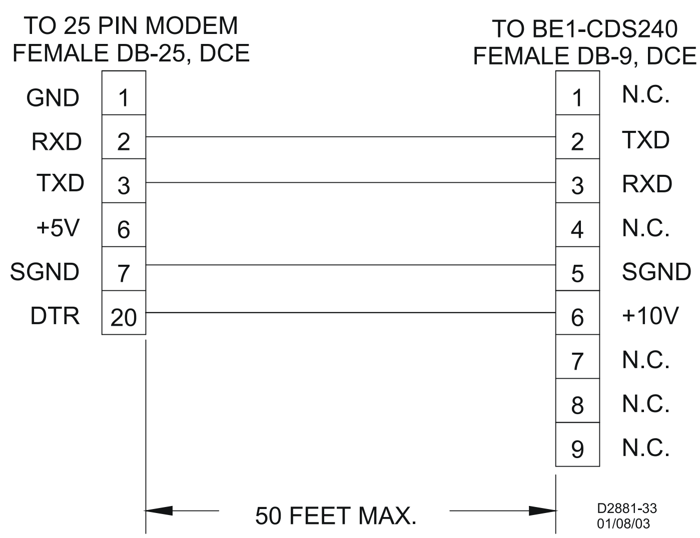


Figure 12-29. Modem to BE1-CDS240

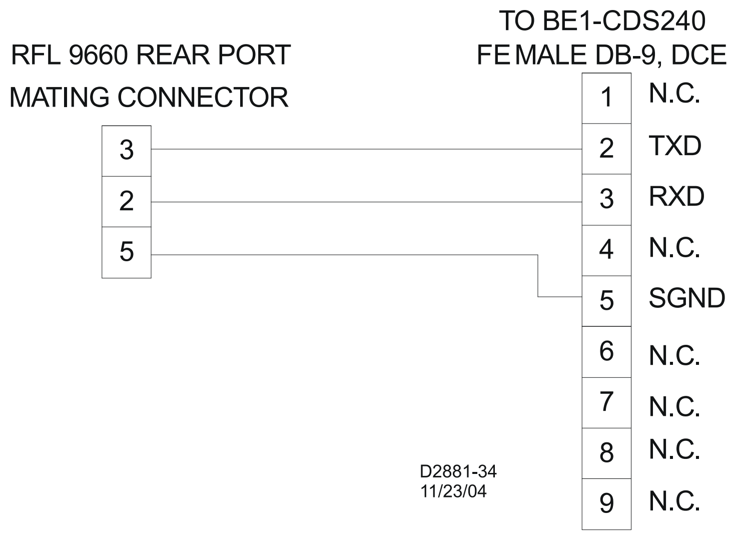


Figure 12-30. RFL9660 Protective Relay Switch to BE1-CDS240 Cable

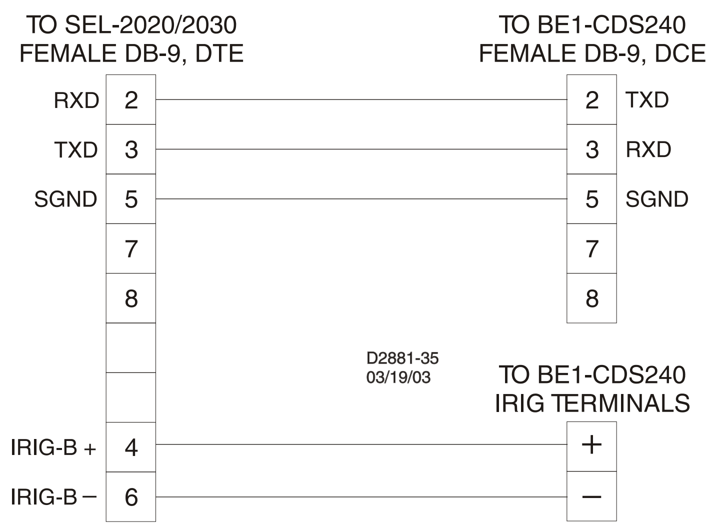


Figure 12-31. SEL 2020/2030 to BE1-CDS240 Relay

RS-485 Connectors

RS-485 connections are made at a three-position terminal block connector which mates with a standard communication cable. A twisted pair cable is recommended. Connector pin numbers, functions, names, and signal directions are shown in Table 12-3. An RS-485 connection diagram is provided in Figure 12-32.

Table 12-3. RS-485 Pinouts (COM 2)

Terminal	Function	Name	Direction
B8 (A)	Send/Receive A	(SDA/RDA)	In/Out
B7 (B)	Send/Receive B	(SDB/RDB)	In/Out
B6 (C)	Signal Ground	(GND)	N/A

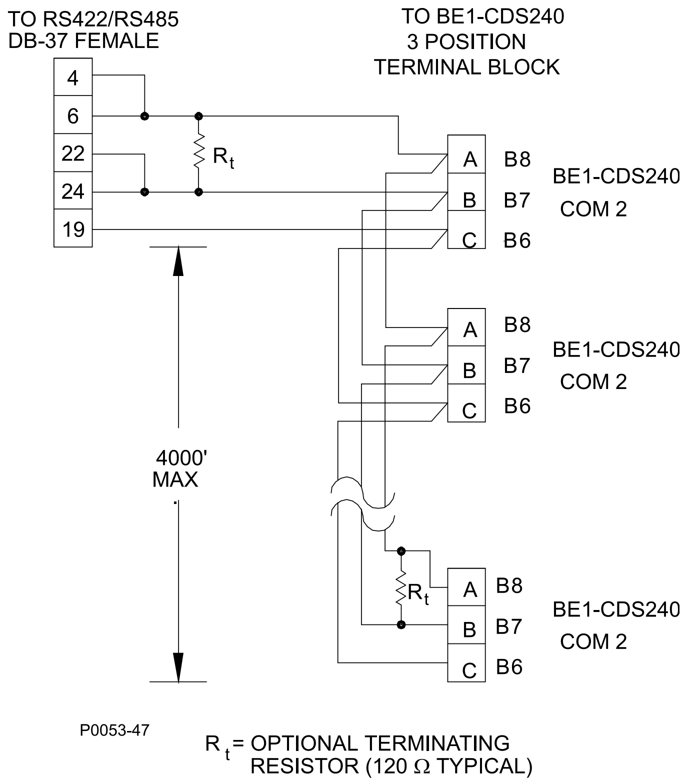


Figure 12-32. RS-485 DB-37 to BE1-CDS240

IRIG Input and Connections

The IRIG input is fully isolated and supports IRIG Standard 200-98, Format B002. The demodulated (dc level-shifted) input signal must be 3.5 volts or higher to be recognized as a high logic level. The maximum acceptable input voltage range is +10 volts or –10 volts (a 20 volt range). Input burden is nonlinear and rated at approximately 4 kΩ at 3.5 Vdc and approximately 3 kΩ at 20 Vdc.

IRIG connections are located on a terminal block shared with the RS-485 and input power terminals. Terminal designations and functions are shown in Table 12-4.

Table 12-4. IRIG Terminal Assignments

Terminal	Function
A1	(+) Signal
A2	(-) Reference

SECTION 13 • TESTING AND MAINTENANCE

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SECTION 13 • TESTING AND MAINTENANCE

General

The need to test protective relays to confirm performance as designed by relay manufacturers will always exist. This section provides guidelines for performing those tests and others. It also provides guidelines for performing maintenance on, and troubleshooting the BE1-CDS240 relay. Included are discussions on testing philosophies and methods, requirements, and expected outcomes. For assistance in conducting relay self-tests and troubleshooting using internal diagnostics, contact Basler Electric, Customer Service.

Testing Philosophies

Testing is generally divided into several categories and is known by various names:

- Acceptance (or integrity)
- Commissioning
- Periodic (or maintenance)
- Functional (application)
- Performance

While all types of tests may be performed, they are not generally performed by all users. Likewise, the degree to which you will conduct each type of test depends on need, economics, and perceived system value.

Acceptance Testing

Acceptance (or integrity) testing is intended to confirm through basic tests, that a particular relay that has been manufactured and shipped meets published core specifications. Some of the more rudimentary procedures will provide a good foundation for application-specific tests that may be delved into during functional or commissioning tests. Generally, while basic in nature, these tests validate proper relay manufacturing and shipping and usually precede any functional or commissioning tests.

Basler Electric performs detailed acceptance testing on all devices to verify all functions meet published specifications. All products are packaged and shipped using strict standards and will remain intact and precise during shipping. The BE1-CDS240 relay is a microprocessor-based relay whose operating characteristics will not change over time. The relay will not experience changes in operating characteristics during transit. However, it remains material that you perform these basic acceptance tests to verify the device has not suffered any degradation in transit. Basler Electric warrants all products against any decay in performance outside of the published specified tolerances that result from problems created during transit.

Commissioning Testing

Commissioning testing verifies all physical connections and functional aspects of the protective relay for a new installation. All of the following connections or functions can be verified during commissioning tests:

- Proper connection and sensing of current and voltage signals as applicable
- Connections of I/O contacts
- I/O sensing versus virtual sensing
- Setting validation
- Proper operation of equipment (main or auxiliary)
- Proper alarming (to SCADA) and/or targeting

Periodic Testing

Periodic (or maintenance) testing can be performed at regularly scheduled intervals or upon an indication of problems or questionable operations within the relay. Verifying the integrity of the relay performance (short of playback of recorded events) may be necessary by performing certain tests similar to those accomplished in the acceptance and/or functional tests. Verification that the relay is measuring signals faithfully, relay logic is appropriate and that protective elements and equipment (main or auxiliary) operate correctly are goals that can be achieved during this type of testing.

Basler Electric recommends that all captured fault records and sequence of event records be analyzed and kept on file as in-service periodic test results for this particular device. This is an indication that all protective elements and associated equipment are operating satisfactorily.

It is not the intent of this manual to elaborate on every conceivable test possible since this would encroach on individual preferences, techniques, and philosophies. It is the intent to pursue relevant testing methods to verify this relay meets published design specifications and applicability.

Functional Testing

Functional (or application) testing is significantly more comprehensive in nature and is intended to test suitability for a particular application. Functional testing also provides a means to familiarize the user with the logic and operation of this device. Test setups are generally more involved and often times include ancillary equipment beyond voltage or current source type equipment. While economics may at times prohibit full functional testing, it is recommended that some application testing be performed when published specifications lack appropriate detail to satisfy application-testing requirements.

Basler Electric performs a thorough and comprehensive functional test of all relays before shipping. This ensures that this device is within specified tolerances, measures accurately, and operates correctly as designed.

Performance Testing

Performance testing can be accomplished through the capture and playback of system fault records. In actual applications, this type of test realizes further confirmation of faithful relay responses during system disturbances. For specific power system disturbances, relays can be subjected to a recreation of captured events with the aid of equipment capable of replicating COMTRADE record files. In these instances, there is significant merit in testing relays in this manner to assess relay performance. Correct response of relay action in a performance test is supplemental verification of the conclusions drawn from functional (or application) tests.

This type of testing verifies not only whether or not the device operated correctly for a particular system disturbance but also offers additional confirmation of your protection philosophy in this application. It is beyond the scope of this manual to develop performance tests for this device. For assistance in developing these types of tests, please consult Basler Electric and your test equipment manufacturer.

Testing and Troubleshooting Aids

Under test or in-service, the BE1-CDS240 provides several ways to check operations, targets or events. A continuous self-test monitors the system health and status. The most basic reporting function is targets. Targets may be viewed through ASCII command interface or through the front panel human-machine interface (HMI). Fault Summary Reports, Sequence of Events Recorder (SER) Reports, and Oscillographic Records yield more detail.

Each time a system disturbance occurs in or around this relay's zone of protection, it is a test of the relay performance during the fault. If a questionable operation (or lack of) results in the need for troubleshooting, you have several ways in which to troubleshoot the relay, the installation, and the overall application.

Relay Self-Test

All internal circuitry and software that affect the relay core functionality are monitored by the continuous self-test diagnostics. For specific relay trouble alarms, the self-test diagnostics force the microprocessor to reset and try to correct the problem. If unsuccessful, OUTA operates, the Relay Trouble LED on the front panel turns ON, all of the output relays are disabled, internal logic Point ALMREL is set, and the relay is taken off line. For more information on self-test diagnostics and relay trouble alarms, see Section 6, *Reporting and Alarms, Alarms Function.*

Status and Event Reporting Features

General status reporting is available through the ASCII command interface using the RG-STAT (report general, status) command or the front panel HMI with LCD display. This report assembles all of the information required to determine the relay status. For more information on general status reporting, see Section 6, *Reporting and Alarms, General Status Reporting, General Status Report.* Several different HMI screens display the same information. Section 6, *Reporting and Alarms, General Status Reporting, General Status Report,* details the location and number of each of the HMI screens for every line in the general status report.

Fault reporting and target data is dependent on the proper setting of trip, pickup, and logic trigger expressions (via the SG-TRIGGER command) and the assignment of protective elements to be logged as targets (via the SG-TARG command).

The SER function of the relay records protective element output state changes, overcurrent element pickup, or dropout, input/output contact state changes, logic triggers, setting group changes and setting changes. For more information on event reporting, see Section 6, *Reporting and Alarms, Sequence of Events Recorder Function*.

The following is a summary of ASCII commands where target and event data may be viewed:

- RF provides a directory of fault summary reports in memory
- RF-# provides a summary report giving targets, timing and event data
- RG-TARG provides target data only
- RS provides a summary of sequence of events records
- RS-F# provides a detailed SER report for the selected fault event #
- RS-# provides a detailed SER report on the last # events

The following summarizes the reporting capabilities of the relay through the front panel HMI:

- *Flashing Trip LED*: Flashes during pickup of protective elements based on the pickup logic expression set in the SG-TRIGGER command.
- *Trip LED* (sealed-in): Stays illuminated after trip logic goes TRUE based on the trip logic expression set in the SG-TRIGGER command.
- *\STAT\TARGETS\DETAILS* (Screen 1.1.1): Provides target data.
- *\STAT\ALARMS* (Screen 1.2.1): Provides alarm data (including BKR FAIL, REC FAIL and REC LO)
- *\REPRT\FAULT\M_REC\DETAILS* (Screen 4.1.1.1): Provides targets and fault summary data.
- *\REPRT\SEQ* (Screen 4.2): Provides the number of new events logged by the SER since the last new counter reset (resettable only through ASCII command RS=0), events must be viewed using RS and RS-# commands listed in the previous paragraph.

For more information on HMI menu trees, see Section 10, *Human-Machine Interface*.

While the design of the relay facilitates obtaining and verifying targets and event data, it is not always necessary to utilize the relay functions to determine if the device operated while testing. You may simply use an ohmmeter or continuity tester to monitor the output contact status.

Acceptance Testing

Although Basler Electric performs detailed acceptance testing on all new relays, it is generally recommended that you perform each of the following acceptance test steps when you receive the relay. Performing these steps tests each function of the BE1-CDS240 relay to confirm that no degradation of performance occurred because of shipping.

Test Setup

When performing the test setups (connections) for each of the following steps, refer to Figure 13-1 for terminal locations.

Test Equipment

Suitable test equipment requires a minimum of two current source elements, a three phase voltage source, a source for relay power and contact wetting voltage, and circuit monitoring with timing algorithms.

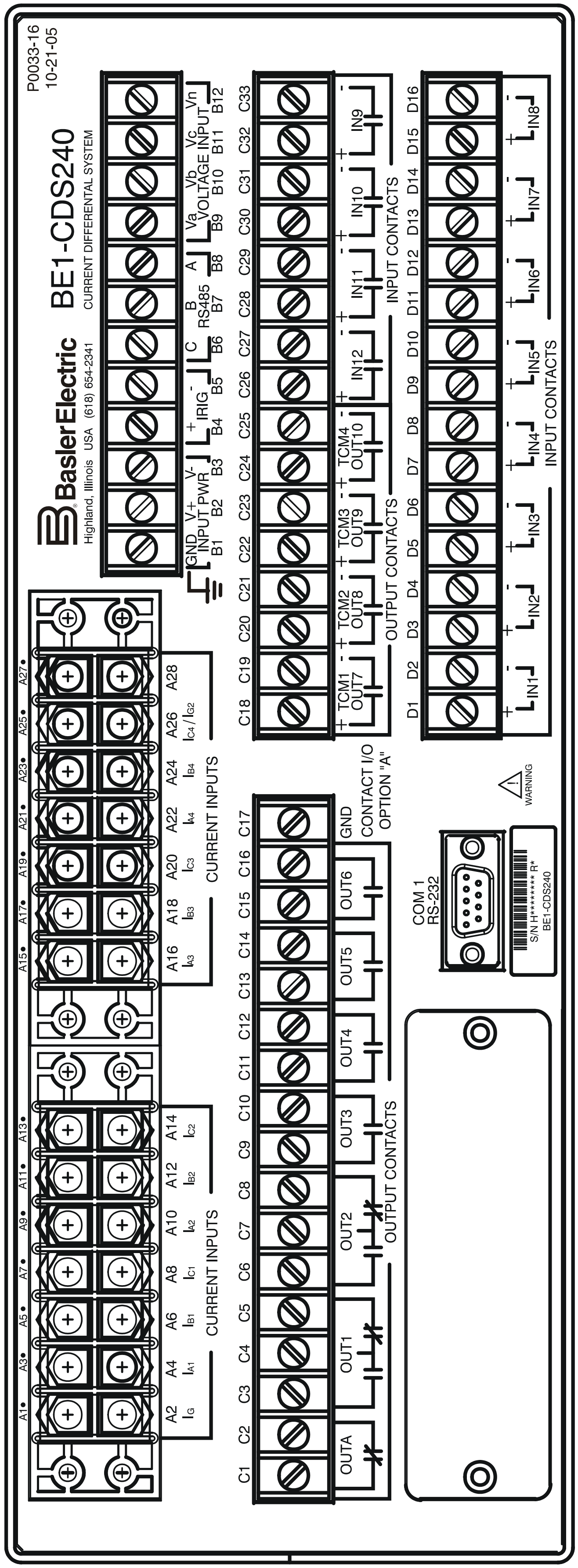


Figure 13-1. Horizontal or Vertical Rear View Terminal Connections (I/O Option "A" Shown)

Power Up

Purpose: To verify that the relay performs the power-up sequence.

Step 1: Apply voltage to input power terminals B2 and B3. Table 13-1 shows the appropriate voltage for each relay style.

Table 13-1. Voltage Input

Style Number	Voltage Input
BE1-CDS240-xx3N**1**xxNxxx	48/125 Vac/dc
BE1-CDS240-xx3N**2**xxNxxx	125/250 Vac/dc
BE1-CDS240-xx3N**3**xxNxxx	24 Vdc

Step 2: Verify that the *Power* LED is on and that characters are displayed on the HMI display. Upon power-up, the relay will perform a brief self-test.

During this brief test, all front panel LEDs will flash momentarily, the display will indicate each step of the self test, relay model, software version and then settle into the default display screen. Contact Basler Electric, Customer Service if anything appears out of the ordinary or if LCD code error messages appear.

Communications

Purpose: To verify that the BE1-CDS240 relay communicates through all ports:
Reference Commands: ACCESS, EXIT

To communicate with the BE1-CDS240 through any of the three ports, you may use either a VT-100 terminal or a personal computer (PC) with a serial port and suitable communications software. There is a VT100 terminal emulation program embedded in BESTCOMS™, under the *Communication* pull-down menu. The relay communication default settings for terminal emulation are:

- Baud Rate = 9,600 bps
- Data Bits = 8
- Stop Bit =1
- Parity = none
- Flow Control = Xon/Xoff.

See Appendix C for more information on Terminal and HyperTerminal setups for Windows® operating systems.

Note: The preferred method to communicate is by using "Basler Terminal" which can be accessed through BESTCOMS by clicking on the Communications tab and then Terminal (VT100 Emulation).

Set Up the Relay to Communicate with the PC

Step 1: Depress the *UP* arrow pushbutton twice to get to the top level of the menu tree. Depress the *LEFT* or *RIGHT* arrow pushbuttons until the \SETUP\GENERAL SETTINGS Screen appears. Next, depress the *DOWN* arrow pushbutton two times to get to the sublevel menu \SETUP \COM \COM0 Screen. With the *RIGHT* arrow pushbutton, scroll one screen to the right. These are the settings for the relay rear RS-232 (COM 1) port. Verify that the baud rate is 9,600 bps.

Step 2: Connect the serial cable between the terminal or PC and the rear RS-232 port (COM 1) on the relay.

Step 3: Initiate the communication program for your computer/terminal.

Step 4: Transmit the command **ACCESS=** (You may use the shortcut keystrokes and just enter a=.)

RESULT: The relay should respond with **ACCESS GRANTED: GLOBAL**.

Step 5: Transmit **EXIT**.

Step 6: Repeat Steps 1, 2 and 3 for the front RS-232 port (COM 0).

Step 7: Connect the male end of the terminal cable to the RS-232 Port on a RS-232/485 converter box. Connect the RS-485 output of the converter box to the relay RS-485 terminals (COM 2) and repeat Steps 1, 2 and 3.

Style Number and Serial Number Verification

Purpose: To verify that the BE1-CDS240 relay model number, style number, and current software program version matches the unit/unit labels.

Reference Commands: RG-VER

Step 1: Through any communications port, transmit the command RG-VER. The BE1-CDS240 relay should respond with the model number, style number, application program version and date, DSP program version and date, boot program version and date, and the relay serial number. Verify that all reported data is current, appropriate and matches the label on the relay front panel.

IRIG Verification

Purpose: To verify that the BE1-CDS240 relay acquires and updates IRIG time and date information.

Reference Commands: RG-DATE, RG-TIME

Step 1: Connect a suitable IRIG source to relay terminals B4 and B5.

Step 2: Upon receiving the IRIG signal, the relay clock will be updated with the current time, day, and month. Verify this on Screen \STAT\SCRNS\SCRN on the front panel human-machine interface (HMI) or by sending the RG-TIME and RG-DATE commands to the relay through any communications port.

NOTE

The following tests may be skipped if it is critical to expedite the installation of this device. The commissioning tests later in this section overlap these tests and will verify proper contact sensing input and control output changes.

Contact Sensing Inputs and Control Outputs

Purpose: To verify that the BE1-CDS240 relay senses hardware inputs and activates contact outputs.

Reference Commands: ACCESS, CO-OUT, CS-OUT, EXIT, RG-STAT

NOTE

Each BE1-CDS240 relay is delivered with the eight sensing jumpers installed for operation in the higher end of the control voltage range. For contact sensing inputs at the lower end of the control voltage range, change the jumpers to the Low position or completely remove the jumper. For more information see Section 12, *Installation, Contact Sensing Input Jumpers*.

Step 1: Verify that the position of the contact-sensing jumpers is correct before applying wetting voltage to any input contacts. The number of inputs is dependent of the relay style number. The “A” option has 12 and the “E” option has 8. (See Section 1, *General Information*, Figure 1-8.) The “E” style option is used as an example.

Step 2: Refer to Table 13-2 as a reference. Apply an external voltage source above the appropriate voltage turn-on range listed in Table 13-2 but below the power supply maximum voltage to Contact Sensing Inputs IN1, IN2, IN3, IN4, IN5, IN6, IN7, and IN8.

Table 13-2. Contact Sensing Turn-On Voltage

Nominal Control Voltage	Contact Sensing Turn-On Voltage		
	Jumper (L) Position	**Jumper (H) Position**	**Jumper Not Installed**
24 Vdc	N/A	N/A	Approx. 5 Vdc
48/125 Vac/dc	26 to 38 Vac/dc	69 to 100 Vac/dc	N/A
125/250 Vac/dc	69 to 100 Vac/dc	138 to 200 Vac/dc	N/A

Step 3: To verify that all inputs have been detected, transmit the command RG-INPUT to retrieve INPUT (12345678) information. Or, alternatively, transmit the command RG-STAT and review the

response at the tail end of the line INPUT (12345678). You may also view the input status on HMI Screen 1.4.1, \STAT\OPER\INPUT.

Step 4: Transmit the commands ACCESS=, CS-OUT=ENA, CO-OUT=ENA, EXIT and YES to enable the output control override capability of the relay in order to pulse each output contact.

Step 5: From the HMI keypad, navigate to the Screen \CTRL\OUT (Output Control Override) to override control of the outputs via the keypad.

Step 6: Once you have accessed the screen, press the *Edit* pushbutton. Select an output to override by using the *LEFT/RIGHT* arrow pushbuttons. Once selected, use the *UP/DOWN* arrow pushbuttons to choose the type of action (P, 1 or 0) for the selected contact output. Select the pulse (P) action for the alarm contact (A). Pressing the *Edit* pushbutton again will force the alarm output contact action.

Step 7: Verify that the sequence of events recorder logged the events by sending the command RS-2 to the relay (requesting the last two events it logged). The close-open pulse action should be listed as two separate events.

Step 8: Repeat Step 6 for all desired output contacts and then verify that the sequence of events recorder logged the events.

Current Circuit Verification

Purpose: To verify that the relay internal CT circuits accurately measure currents and polarities.

Reference Commands: M-I, SG-TARG, SG-TRIGGER, RS

For all tests in this section, ASCII metering commands, HMI Metering and the *Metering* Screen of BESTCOMS include angles for each current and voltage quantity. The zero reference for current and voltage angle measurement is based on the following:

- When voltage and current are applied to the relay, VA is the 0° reference for all angle measurements (VAB for 3-wire connections).
- In the absence of phase A or AB voltage, winding 1 A-phase current, IA1 is the 0° reference for all angle measurements. In the absence of phase A or AB voltage and IA1, winding 2 A-phase current, IA2 is the 0° reference for all angle measurements, and so on through IA4 for a 4-winding relay.
- In the absence of all other quantities, the calculated positive sequence current (I1) derived from the CT's associated with a specific transformer winding becomes the 0° reference for all angle measurements.

Step1: Connect a single-phase current source between Terminals A1 (polarity) and A25 (non-polarity). Jumper A1 to 3, 4 to 5, 6 to 7, 8 to 9, 10 to 11, 12 to 13, 14 to 16, 15 to 18, 17 to 20, 19 to 22, and 21 to 24. Note that CT circuits 3 and 4 polarities are reversed. Refer to Figure 13-2 for connections.

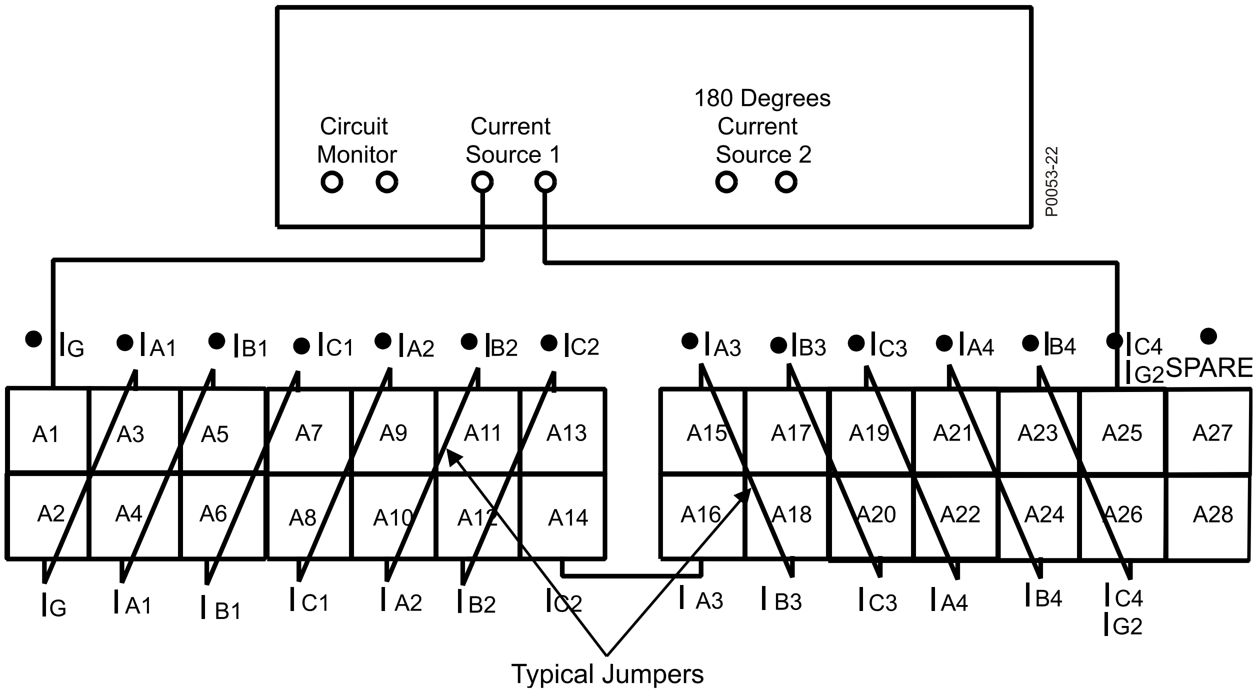


Figure 13-2. Series Current Connection Diagram

Step 2: Apply 5 amperes of current to 5 ampere rated CT inputs (or 1 ampere to 1 ampere rated CT inputs).

Step 3: Transmit the command M1-I to the relay or navigate to the front panel HMI Screen \METER\CRNT\CT_1\I_MEAS (3.2.1.1) and \METER\CRNT\CT_1\I_CALC (3.2.1.2) and verify the values listed in Table 13-3.

Table 13-3. Circuit 1 Metering Quantities

CT Secondary	I_{A1}, I_{B1}, and I_{C1}	I_{N1}	I_{Q1}
5 A	5.0 A (± 1%) @ 0°	15.0 A (± 1%) @ 0°	0.0 A (± 1%)
1 A	1.0 A (± 1%) @ 0°	3.0 A (± 1%) @ 0°	0.0 A (± 1%)

Step 4: Transmit the command M2-I to the relay or navigate to the front panel HMI Screen \METER\CRNT\CT_2\I_MEAS (3.2.2.1) and \METER\CRNT\CT_2\I_CALC (3.2.2.2) and verify the values listed in Table 13-4.

Table 13-4. Circuit 2 Metering Quantities

CT Secondary	I_{A2}, I_{B2}, and I_{C2}	I_{N2}	I_{Q2}
5 A	5.0 A (± 1%) @ 180°	15.0 A (± 1%) @ 180°	0.0 A (± 1%)
1 A	1.0 A (± 1%) @ 180°	3.0 A (± 1%) @ 180°	0.0 A (± 1%)

Step 5: Transmit the command M3-I to the relay, or navigate to the front panel HMI Screen \METER\CRNT\CT_3\I_MEAS (3.2.3.1) and \METER\CRNT\CT_3\I_CALC (3.2.3.2) and verify the values listed in Table 13-5.

Table 13-5. Circuit 3 Metering Quantities

CT Secondary	I_{A3}, I_{B3} and I_{C3}	I_{N3}	I_{Q3}
5 A	5.0 A (±1%) @ 180°	15.0 A (±1%) @ 180°	0.0 A (±1%)
1 A	1.0 A (±1%) @ 180°	3.0 A (±1%) @ 180°	0.0 A (±1%)

Step 6: Transmit the command M4-I to the relay or navigate to the front panel HMI Screen \METER\CRNT\CT_4\I_MEAS (3.2.4.1) and \METER\CRNT\CT_2\I_CALC (3.2.4.2) and verify the values listed in Table 13-6.

Table 13-6. Circuit 4 Metering Quantities

CT Secondary	I_{A4}, I_{B4} and I_{C4}	I_{N4}	I_{Q4}
5 A	5.0 A (±1%) @ 180°	15.0 A (±1%) @ 180°	0.0 A (±1%)
1 A	1.0 A (±1%) @ 180°	3.0 A (±1%) @ 180°	0.0 A (±1%)

Step 7: Transmit the command M5-I to the relay or navigate to the front panel HMI Screen \METER\CRNT\CT_5\I_MEAS (3.2.5.1) and \METER\CRNT\CT_2\I_CALC (3.2.5.2) and verify the values listed in Table 13-7.

Table 13-7. Circuit 5 Metering Quantities (Virtual Current)

CT Secondary	CT CKT 1 & 2 (I_{A5}, I_{B5} and I_{C5})	I_{N5}	I_{Q5}
5 A	10.0 A (±1%) @ 0°	30.0 A (±1%) @ 0°	0.0 A (±1%)
1 A	2.0 A (±1%) @ 180°	60.0 A (±1%) @ 0°	0.0 A (±1%)

Step 8: Transmit the command M6-I to the relay or navigate to the front panel HMI Screen \METER\CRNT\CT_6\I_MEAS (3.2.6.1) and \METER\CRNT\CT_2\I_CALC (3.2.6.2) and verify the values listed in Table 13-8.

Table 13-8. Circuit 6 Metering Quantities (Virtual Current)

CT Secondary	CT CKT 3 & 4 (I_{A6}, I_{B6} and I_{C6})	I_{N6}	I_{Q2}
5 A	5.0 A (±1%) @ 180°	15.0 A (±1%) @ 180°	0.0 A (±1%)
1 A	1.0 A (±1%) @ 180°	3.0 A (±1%) @ 180°	0.0 A (±1%)

Step 9: For the independent ground input, transmit the command M-IG to the relay or navigate to the Screen \METER\CRNT\GND\I_MEAS (3.2.7.1) on the front panel HMI and verify that I_G = 5.0 A (±1%) @ 0˚ (for a 5 A secondary rated CT inputs) or 1.0 A (±1%) @ 0˚ (for a 1 A secondary rated CT inputs).

Step 10: Remove current from the relay.

Three-Phase Voltage Circuit Verification

Step 1: Connect an ac voltage source at nominal frequency between relay Terminals B9 (A-phase) and B12 (Neutral terminal). Apply 100 volts and verify voltage-measuring accuracy by transmitting the M command to the relay. Readings should be: M-VA = 100 volts, M-VAB = 100 volts, M-VCA

= 100 volts, M-3V0 = 100 volts and M-V2 = 33.4 volts (applied divided by 3), all at ±1.0%. HMI Screens 3.1.1, 3.1.2 and 3.1.3 can also be monitored to verify voltage measurements.

Step 2: Connect an ac voltage source at nominal frequency between relay terminals B10 (B-phase) and B12 (Neutral terminal). Apply 100 volts and verify voltage-measuring accuracy by transmitting the M command to the relay. Readings should be: M-VB = 100 volts, M-VAB = 100 volts, M-VBC = 100 volts, M-3V0 = 100 volts and M-V2 = 33.4 volts (applied divided by 3), all at ±1.0%. HMI Screens 3.1.1, 3.1.2 and 3.1.3 can also be monitored to verify voltage measurements.

Step 3: Connect an ac voltage source at nominal frequency between relay Terminals B11 (C-phase) and B12 (Neutral terminal). Apply 100 volts and verify voltage-measuring accuracy by transmitting the M command to the relay. Readings should be: M-VC = 100 volts, M-VBC = 100 volts, M-VCA = 100 volts, M-3V0 = 100 volts and M-V2 = 33.4 volts (applied divided by 3), all at ±1.0%. HMI Screens 3.1.1, 3.1.2 and 3.1.3 can also be monitored to verify voltage measurements.

Step 4: Connect relay terminals B9 (A-phase), B10 (B-phase) and B11 (C-phase) together. Connect an ac voltage source at nominal frequency to the three jumpered terminals and the Neutral terminal (B12).

Step 5: Apply the voltage values listed in Table 13-9 and verify voltage measuring accuracy by transmitting the M command to the relay. HMI Screen 3.1.1 can also be monitored to verify voltage measurements.

Table 13-9. Voltage Circuit Verification Values

Applied Voltage	Measured Voltage	
	Lower Limit	**Upper Limit**
80 volts	79.2 V	80.8 V
100 volts	99.0 V	101.0 V
120 volts	118.8 V	121.2 V
140 volts	138.6 V	141.4 V
160 volts	156.8 V	163.2 V

Power Reading Verification

Use the same voltage connections as in the previous test, polarity voltage jumpered to B9, B10, and B11, neutral tied to B12. Use the same current connection as in Steps 3 and 4 of Current Circuit Verification. That is, polarity current in 9 out 16 with 10 and 11, 12 and 13, 14 and 15 jumpered together.

NOTE

Power readings in this procedure are based on a 5-amp relay. For 1-amp values, divide by 5.

Step 1: Apply 100 volts at angle 0 degrees and 1 or 5 amps (depending on the current rating) at angle 0 degrees to the relay. Verify the accuracy of the power reading by transmitting the M command to the relay. Power should be 1.5 kw ±1.0% and reactive should read near 0 vars. HMI Screens 3.4.1 and 3.4.2 can also be monitored to verify power and reactive readings. The apparent power should be 1.5 kVA ±1.0% at unity power factor.

Step 2: Reverse the current polarity and apply the same values as in Step 2. Note that the power reading is –1.5 kW, which indicates "power in" to the zone being protected.

Step 3: Return the current polarity back to Step 1 position. Apply 100 volts at angle 0 degrees, and 5 amps at angle –90 degrees (I lag E by 90 degrees) to the relay, and verify reactive power accuracy by transmitting the M command to the relay. Power should be nearly 0 kW, and reactive should read 1.5 kvar ±1.0%. HMI Screen 3.4.1 can also be monitored to verify power and reactive values. Apparent power and power factor can also be viewed on HMI Screen 3.4.1. Note power factor reads near 0 with a negative sign indicating a lagging power factor angle.

Step 4: Reverse the current polarity and apply the same values as in Step 4. Note that the reactive power reading is –1.5 kvar, which indicates reactive power in to the device being protected. Also note that the power factor angle is near 0 with a positive sign indicating a leading power factor angle.

Step 5: Repeat Step 2 and 4 for current values of 10 and 20 amps. Corresponding power reading should be 3 kW/kvar and 6 kW /kvar ±1.0%.

Commissioning Testing

Because the commissioning of this relay may be a new installation or a retrofit, special precautions should be taken to ensure that all tests are performed with safety as the utmost concern. Any CT circuit signals that are routed through this device as part of a protection scheme including discrete relays or as a stand-alone device should be shorted and isolated from this relay during these tests until the final instrument transformer current circuit check.

If this relay is being installed in an existing installation, please be aware of the equipment monitoring features of this device, especially if the monitoring logic will be utilized. Make note of any pretest operation levels, duty levels, etc. on existing equipment (e.g., breakers or transformers). As the user, you may set the initial values into the relay to duplicate monitored values in the existing equipment.

Because of the multifunction capabilities of the BE1-CDS240 relay, it may be necessary to temporarily disable some of the protective elements while testing others or to change setting logic to test a specific function. Always remember to enable these functions and install operation settings before placing the relay in service. To guard against placing the relay in service with unwanted operational or logic settings, it is a good practice to save a copy of the original setting file before the testing process begins. When testing is complete, the saved copy could then be loaded into the relay, which would guarantee that no setting changes or testing modifications would remain in the relay.

To assist you in the commissioning testing of this relay, refer to the previous paragraphs in this section on *Testing and Troubleshooting Aids,* and Section 6, *Reporting and Alarms,* for various ways to retrieve or interpret reporting status, alarms, and targets.

Refer to the other Sections of the instruction manual for assistance on any particular functions of the relay. If you require further assistance, contact Basler Electric field application personnel or the factory.

Protection and Control Function Verification

Before placing the relay in service, it should be verified that the desired protection and control functions are enabled and connected to the correct CT input circuits, that the programmable logic settings provide the proper interconnection of these functions and that each has the desired set points. This can be accomplished by a detailed review of the settings as read out of the relay before placing it in service. Or, it may be desirable to verify the settings by test.

CAUTION
Because this is a numerical relay with characteristics defined by software, it is not necessary to verify that each phase element of a protective function responds. By testing a single phase of each function and varying the phase input tested for each function, it is possible to verify the entire relay. For example, to verify the phase overcurrent elements, one could test phase A for the 51P element and phase B for the 50TP element, etc.

Before testing each protection and control function, the logic settings should be examined to determine:

- The mode setting for the function so that you know what the relay is supposed to do.
- Which virtual output logic expressions contain the logic variables that represent the outputs of the function under test so that the proper contact can be monitored.
- The input logic expressions for the function under test (especially the block input because it renders the function disabled if the block input is asserted).

- That the fault reporting settings are properly set such that the relay properly indicates pickup and trip states and records targets. These settings are set from the ASCII command interface using the SG-TRIGGER and SG-TARG setting commands. See Section 6, *Reporting and Alarms, Fault Reporting Functions,* for more details.

Testing Phase Differential Protection with Internal Compensation

The internal phase and zero-sequence compensation features of the relay can combine the currents from multiple CT input circuits and/or subtract out the zero-sequence components before their use by the phase differential function. Thus, the testing of this function with the internal compensation features can be somewhat complicated. For this reason, a detailed test procedure is provided for verifying the set points of this function with internal compensation. See Sidebar 13-1 in this section for more information on how the internal compensation features work.

The CDS240 is a four winding differential relay. Testing the complete 87T scheme would require 12 controllable current sources. For simplicity, testing will be performed by evaluating sequential pairs of input circuits (Inputs 1 verses Inputs 2, Inputs 2 verses Inputs 3, etc). This will confirm proper operation of the complete scheme. The complete set of Input Circuit “pairs” is: CT1-CT2, CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4.

Step 1: Record settings for the following tests:

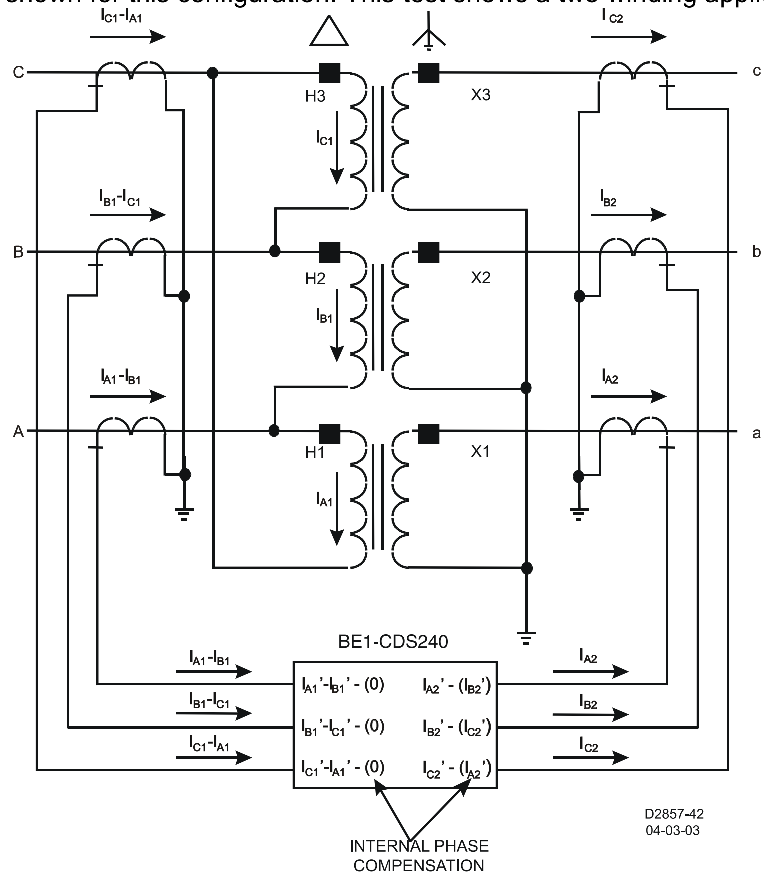
The settings for the following tests should be recorded before starting the test. You will refer to these settings throughout the test procedure.

- *Angle Compensation and Ground Source* compensation can be determined by matching the SG-CTP(1,2,3, or 4) settings or Screen 6.3.1.1 with Table 3-3 in Section 3 and reading the right two columns to determine what angle compensation is applied.
- *Tap Compensation* settings in each setting group can be determined from Screens 5.x.1.2 or 5.x.1.3 on the HMI. Or, check the S#-TAP87 settings from the ASCII command interface if manual tap adjust is used. If automatic tap adjust is used, it will be necessary to use the settings and Equations 4-1 and 4-2 from Section 4, *Protection and Control Functions, Differential Protection*. BESTCOMS can also be used to change settings. See Section 14, *BESTCOMS Software*.
- *Restrained Minimum Pickup, Slope, and Unrestrained Pickup* settings can be determined from Screens 5.x.1.1 on the HMI. Or, use the S#-87 settings from the ASCII command interface.

Alternatively, all of these parameters can be determined from reading the Current Check Record provided by the Differential Alarm Function. To use this method, use the commands in Table 13-10.

Table 13-11 lists the currents that will be seen by each 87 phase differential element after phase and zero-sequence compensation. This table is based upon the internal compensation chart in Section 3, *Input and Output Functions, Input Current*. Examination of this table shows that for most cases, test current injection using only one or two current sources will result in currents being applied to more than one 87 phase element. See Sidebar 13-1 for more information on testing and compensated currents. The following test procedures will enable you to determine the test points and which phases will be tested.

When the internal phase and zero-sequence compensation feature of the BE1-CDS240 is used, confusing test results can occur unless the compensation is taken into consideration. The best way to illustrate how the BE1-CDS240 relay performs internal phase compensation and thus, what to expect under test situations, is by looking at an application example. The application below shows a delta/grounded-wye transformer with wye connected CTs. The currents flowing into and out of the transformer and reflected through the CTs are shown for this configuration. This test shows a two winding application for simplicity.



Isolating the box marked BE1-CDS240, we see that, for the A phase 87 element, the relay subtracts the measured Ib from the measured Ia on the transformer wye side to compensate for the measured IA-IB delta currents that are flowing in the line phases on the transformer delta side. Remember that these currents are the compensating currents when the relay is in service for this application.

Under a test scenario, any set of balanced, 180° out of phase, single-phase, input currents that we apply to the two phase A connections will result in balanced currents in the 87A element. However, the 87C element will also see a compensating –IA2 current that will cause it to operate. Table 13-11 shows the compensated currents that with the various compensation settings will be applied to each 87 phase element.

The relay can also remove the zero-sequence component of the current if a zero-sequence source exists on an input that is not delta compensated. When this compensation is applied during testing, it has a similar effect as subtracting I0 from the phases not under test. This also causes them to operate.

You must be aware of this compensating effect in order to understand what operations and targets to expect when testing a BE1-CDS240 relay with internal phase compensation settings. To prevent unwanted phases from tripping during the slope test that starts from a balanced condition, delta test injection connections are recommended as shown in Table 13-11 and Figures 13-4 to 13-11. Tables 13-12 through 13-14 also show what equation to use to calculate the test points for the minimum pickup (minpu) and slope tests for each possible configuration of compensation.

Table 13-10. Commands to Initiate a Differential Check Record

Command	Purpose
A=<reports password if used>	Gains write access to the relay.
CS-GROUP=0; CO-GROUP=0	Override logic and make sure that relay is in Setting Group 0.
RA-DIFF=TRIG;	Trigger current check record.
RA-DIFF	Read record and record for Setting Group 0.
CS-GROUP=1; CO-GROUP=1	Make sure that relay is in Setting Group 1.
RA-DIFF=TRIG;	Trigger current check record.
RA-DIFF	Read record and record for Setting Group 1.
CS-GROUP=2; CO-GROUP=2	Make sure that relay is in Setting Group 2.
RA-DIFF=TRIG;	Trigger current check record.
RA-DIFF	Read record and record for Setting Group 2.
CS-GROUP=3; CO-GROUP=3	Make sure that relay is in Setting Group 3.
RA-DIFF=TRIG;	Trigger current check record.
RA-DIFF	Read record and record for Setting Group 3.
CS-GROUP=0; CO-GROUP=0	Return relay to Setting Group 0.
CS-GROUP=L; CO-GROUP=L	Return setting group control to logic control.
E	Exit.

Table 13-11. Phase and Zero-Sequence Compensated Currents

Angle Compensation and Ground Source Settings		87A Element		87B Element		87C Element	
CT1	**CT2**	**CT1**	**CT2**	**CT1**	**CT2**	**CT1**	**CT2**
WYE (NONE)	WYE (NONE)	IA	IA	IB	IB	IC	IC
WYE (NONE)	WYE G	IA	IA-I0	IB	IB-I0	IC	IC-I0
WYE (NONE)	DAB	IA	(IA-IB)/√3	IB	(IB-IC)/√3	IC	(IC-IA)/√3
WYE (NONE)	DAC	IA	(IA-IC)/√3	IB	(IB-IA)/√3	IC	(IC-IB)/√3
WYE G	WYE (NONE)	IA-I0	IA	IB-I0	IB	IC-I0	IC
WYE G	WYE G	IA-I0	IA-I0	IB-I0	IB-I0	IC-I0	IC-I0
WYE G	DAB	IA-I0	(IA-IB)/√3	IB-I0	(IB-IC)/√3	IC-I0	(IC-IA)/√3
WYE G	DAC	IA-I0	(IA-IC)/√3	IB-I0	(IB-IA)/√3	IC-I0	(IC-IB)/√3
DAB	WYE (NONE)	(IA-IB)/√3	IA	(IB-IC)/√3	IB	(IC-IA)/√3	IC
DAB	WYE G	(IA-IB)/√3	IA-I0	(IB-IC)/√3	IB-I0	(IC-IA)/√3	IC-I0
DAB	DAB	(IA-IB)/√3	(IA-IB)/√3	(IB-IC)/√3	(IB-IC)/√3	(IC-IA)/√3	(IC-IA)/√3
DAB	DAC	(IA-IB)/√3	(IA-IC)/√3	(IB-IC)/√3	(IB-IA)/√3	(IC-IA)/√3	(IC-IB)/√3
DAC	WYE (NONE)	(IA-IC)/√3	IA	(IB-IA)/√3	IB	(IC-IB)/√3	IC
DAC	WYE G	(IA-IC)/√3	IA-I0	(IB-IA)/√3	IB-I0	(IC-IB)/√3	IC-I0
DAC	DAB	(IA-IC)/√3	(IA-IB)/√3	(IB-IA)/√3	(IB-IC)/√3	(IC-IB)/√3	(IC-IA)/√3
DAC	DAC	(IA-IC)/√3	(IA-IC)/√3	(IB-IA)/√3	(IB-IA)/√3	(IC-IB)/√3	(IC-IB)/√3

Note: Table 13-11 is based on internal angle compensation and not CT compensation. The table also shows one set of input pairs (CT1 and CT2). All tests should be repeated with the other input pairs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Phase Differential Restrained Minimum Pickup Trip

The test current will be a function of the internal angle and zero-sequence compensation and the tap compensation. For the following test, you will apply a single-phase test current to one CT input circuit at a time. It is only necessary to apply one phase per input to verify response and correctly entered settings. For example, apply A phase for CT circuit 1 and 2 for Setting Group 0, B phase for CT circuit 1 and 2 for Setting Group 1, etc., to verify all phases and all set points. Repeat tests for each of the CT input pairs.

Step 1: Calculate test points for minimum-pickup test.

- Calculate the test points using the compensation settings recorded in Step 1 and the appropriate equations shown in Tables 13-12 through 13-14. Record the calculated test point for each setting group before running the test.
- Record the phases that will respond to the test.

Table 13-12. Differential Element Minpu Response to IA Test Current

CT Input Compensation		Element		
Angle Comp	**Ground Source**	**87A**	**87B**	**87C**
Wye (None)	0 = No	Minpu* Tap	N/a	N/a
Wye (None)	1 = Yes	1.5* Minpu* Tap	3* Minpu* Tap	3* Minpu* Tap
DAB	N/a	√3* Minpu* Tap	N/a	√3* Minpu* Tap
DAC	N/a	√3* Minpu* Tap	√3* Minpu* Tap	N/a

Table 13-13. Differential Element Minpu Response to IB Test Current

CT Input Compensation		Element		
Angle Comp	**Ground Source**	**87A**	**87B**	**87C**
Wye (None)	0 = No	N/a	Minpu* Tap	N/a
Wye (None)	1 = Yes	3* Minpu* Tap	1.5* Minpu* Tap	3* Minpu* Tap
DAB	N/a	√3* Minpu* Tap	√3* Minpu* Tap	N/a
DAC	N/a	N/a	√3* Minpu* Tap	√3* Minpu* Tap

Table 13-14. Differential Element Minpu Response to IC Test Current

CT Input Compensation		Element		
Angle Comp	**Ground Source**	**87A**	**87B**	**87C**
Wye (None)	0 = No	N/a	N/a	Minpu* Tap
Wye (None)	1 = Yes	3* Minpu* Tap	3* Minpu* Tap	1.5* Minpu* Tap
DAB	N/a	N/a	√3* Minpu* Tap	√3* Minpu* Tap
DAC	N/a	√3* Minpu* Tap	N/a	√3* Minpu* Tap

Step 2: Test minimum pickup.

Slowly ramp up test current until the relay trips. Monitor an appropriate contact per the logic settings and the trip LED. Record the value. Record if the proper phases targeted and if the test was passed. The accuracy should be ±4% or 0.75 milliamperes for 5-ampere units and ±4% or 25 milliamperes for 1-ampere units.

Step 3: Repeat for each set of input pairs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Phase Differential Restrained Slope Trip

This test will verify the percentage restraint characteristic. Since each current input circuit and phase protective element was verified in the preceding test, it is only necessary to test and verify the slope characteristic on one phase element for each setting group. It is recommended, however, to check the operation for each set of input pairs (CT1-CT2, CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

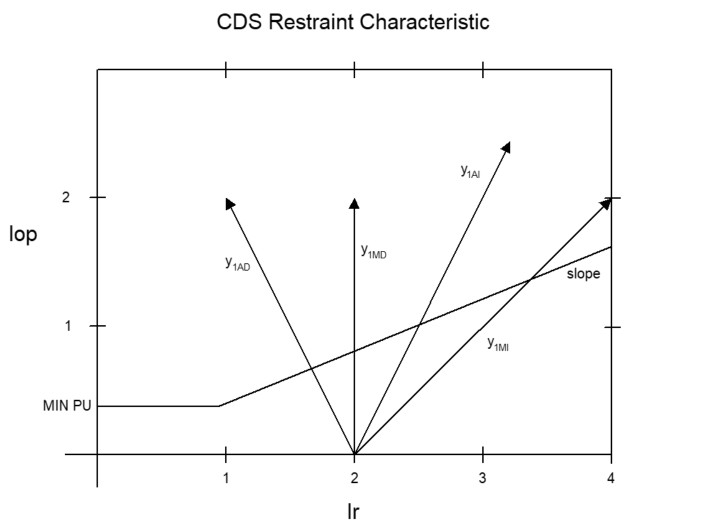
The restrained slope test requires that you start from a balanced condition. To create the `Iop` (differential) current, you will vary one test current upward or downward from this balanced condition. The test point at which a trip should occur will depend upon whether you set the relay to operate on percent of maximum restraint current or percent of average restraint current. It will also depend upon whether the `Iop` is to be developed by increasing or decreasing one current source from balance. See Figure 13-3 for details.

Step 4: Calculate the test starting point (balanced) for restrained slope test.

Step 4-1: Select and record the appropriate test connection from Table 13-15.

Step 4-2: Calculate the balanced starting test currents that are to be applied to each input circuit of the relay. Use the appropriate equation from Table 13-11, *Test Current*, and record values before starting the test. The equations provide a convenient starting balance point at two times tap. Do this for each setting group.

Step 4-3: Check that the starting (balanced) test current at two times tap is not above the maximum continuous current rating of the relay. If it is, adjust both starting test currents downward until both are below this level. Use the same adjustment factor on both currents such that they remain balanced.



y_{1MD} = I1 decreasing with maximum restraint

y_{1MI} = I1 increasing with maximum restraint

y_{1AD} = I1 decreasing with average restraint

y_{1AI} = I1 increasing with average restraint

Iop = |I1 - I2|

Ir = max(|I1|,|I2|) for max restraint

Ir = (|I1|+|I2|)/2 for average restraint

Condition	Restraint	Min PU?	Trip If Min PU	Trip If Slope
I1 = I2 Decrease I1	Maximum	I2<min pu/slope	I1 = I2 - min pu	I1 = I2*(1 - slope)
I1 = I2 Increase I1	Maximum	I2<min pu(1/slope - 1)	I1 = I2 + min pu	I1 = I2/(1 - slope)
I1 = I2 Decrease I1	Average	I2<min pu(1/slope + 1/2)	I1 = I2 - min pu	I1 = I2(1 - (2*slope/(2+slope)))
I1 = I2 Increase I1	Average	I2<min pu(1/slope - 1/2)	I1 = I2 + min pu	I1 = I2(1 + (2*slope/(2-slope)))

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Figure 13-3. Test Currents for Restrained Trip Test

Note: Figure 13-3 shows one set of input pairs (I1 and I2). All tests should be repeated with the other input pairs (I1-I3, I1-I4, I2-I3, I2-I4, and I3-I4).

Table 13-15. Starting Test Currents and Test Connections for Slope Test

Angle / I0 Comp.		Test Current		Test Con.	Element		
CT1	CT2	CT1	CT2	Figure	87A	87B	87C
WYE	WYE	2* tap	2* tap	13-4, A	Y	N	N
WYE	WYE	2* tap	2* tap	13-4, B	N	Y	N
WYE	WYE	2* tap	2* tap	13-4, C	N	N	Y
WYE	WYE/G	2* tap	2* tap	13-5, A	Y	Y	N
WYE	WYE/G	2* tap	2* tap	13-5, B	N	Y	Y
WYE	WYE/G	2* tap	2* tap	13-5, C	Y	N	Y
WYE	DAB	2* tap	2* √3*tap	13-6, A	Y	N	Y
WYE	DAB	2* tap	2* √3*tap	13-6, B	Y	Y	N
WYE	DAB	2* tap	2* √3*tap	13-6, C	N	Y	Y
WYE	DAC	2* tap	2* √3*tap	13-7, A	Y	Y	N
WYE	DAC	2* tap	2* √3* tap	13-7, B	N	Y	Y
WYE	DAC	2* tap	2* √3* tap	13-7, C	Y	N	Y
WYE/G	WYE	2* tap	2* tap	13-5, A	Y	Y	N
WYE/G	WYE	2* tap	2* tap	13-5, B	N	Y	Y
WYE/G	WYE	2* tap	2* tap	13-5, C	Y	N	Y
WYE/G	WYE/G	2* tap	2* tap	13-5, A	Y	Y	N
WYE/G	WYE/G	2* tap	2* tap	13-5, B	N	Y	Y
WYE/G	WYE/G	2* tap	2* tap	13-6, C	Y	N	Y
WYE/G	DAB	2* tap	2* √3* tap	13-6, A	Y	N	Y
WYE/G	DAB	2* tap	2* √3* tap	13-6, B	Y	Y	N
WYE/G	DAB	2* tap	2* √3* tap	13-6, C	N	Y	Y
WYE/G	DAC	2* tap	2* √3* tap	13-7, A	Y	Y	N
WYE/G	DAC	2* tap	2* √3* tap	13-7, B	N	Y	Y
WYE/G	DAC	2* tap	2* √3* tap	13-7, C	Y	N	Y
DAB	WYE	2* √3* tap	2* tap	13-8, A	Y	N	Y
DAB	WYE	2* √3* tap	2* tap	13-8, B	Y	Y	N
DAB	WYE	2* √3* tap	2* tap	13-8, C	N	Y	Y
DAB	WYE/G	2* √3* tap	2* tap	13-8, A	Y	N	Y
DAB	WYE/G	2* √3* tap	2* tap	13-8, B	Y	Y	N
DAB	WYE/G	2* √3* tap	2* tap	13-8, C	N	Y	Y
DAB	DAB	2* √3* tap	2* √3* tap	13-4, A	Y	N	Y
DAB	DAB	2* √3* tap	2* √3* tap	13-4, B	Y	Y	N
DAB	DAB	2* √3* tap	2* √3* tap	13-4, C	N	Y	Y
DAB	DAC	2* √3* tap	2* √3* tap	13-9, A	N	Y	Y
DAB	DAC	2* √3* tap	2* √3* tap	13-9, B	Y	N	Y
DAB	DAC	2* √3* tap	2* √3* tap	13-9, C	Y	Y	N
DAC	WYE	2* √3* tap	2* tap	13-10, A	Y	Y	N
DAC	WYE	2* √3* tap	2* tap	13-10, B	N	Y	Y
DAC	WYE	2* √3* tap	2* tap	13-10, C	Y	N	Y
DAC	WYE/G	2* √3* tap	2* tap	13-10, A	Y	Y	N
DAC	WYE/G	2* √3* tap	2* tap	13-10, B	N	Y	Y
DAC	WYE/G	2* √3* tap	2* tap	13-10, C	Y	N	Y
DAC	DAB	2* √3* tap	2* √3* tap	13-11, A	N	Y	Y
DAC	DAB	2* √3* tap	2* √3* tap	13-11, B	Y	N	Y
DAC	DAB	2* √3* tap	2* √3* tap	13-11, C	Y	Y	N
DAC	DAC	2* √3* tap	2* √3* tap	13-4, A	Y	N	Y
DAC	DAC	2* √3* tap	2* √3* tap	13-4, B	N	Y	Y
DAC	DAC	2* √3* tap	2* √3* tap	13-4, C	Y	Y	N

Note: Table 13-15 shows one set of input pairs (CT1 and CT2). All tests should be repeated with the other input pairs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Table 13-16. Connection Terminals for Figures 13-4 through 13-11

Reference	CDS240 Terminals			
	CT1	CT2	CT3	CT4
X2	A2	A5	A8	A11
X3	A3	A6	A9	A12
X4	A3	A6	A9	A12
X5	A4	A7	A10	A13
X6	A4	A7	A10	A13
X9	A2	A5	A8	A11
X10	A2	A5	A8	A11
X11	A3	A6	A9	A12
X12	A3	A6	A9	A12
X13	A4	A7	A10	A13
X14	A4	A7	A10	A13

Note: Table 13-16 shows the CDS240 connection terminals for each pair of inputs related to Figures 13-4 through 13-11.

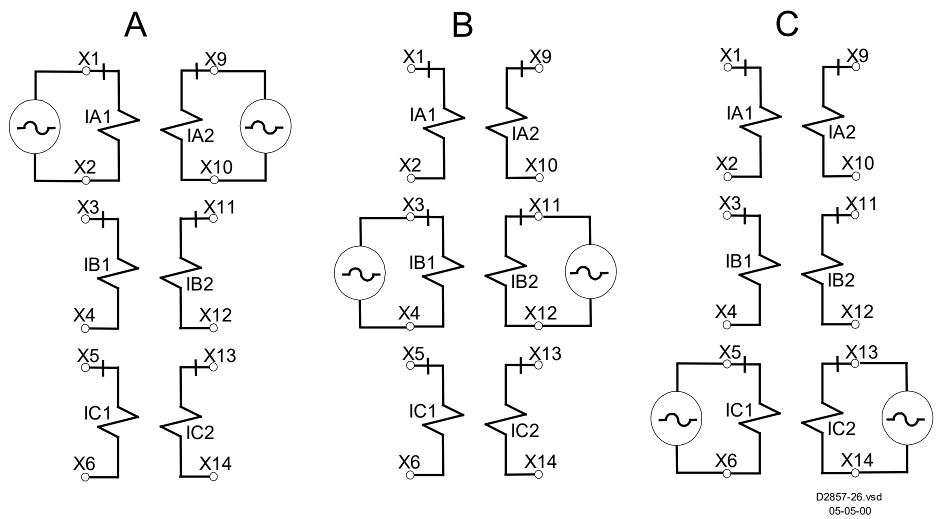


Figure 13-4. Test Connection Diagrams for Table 13-15

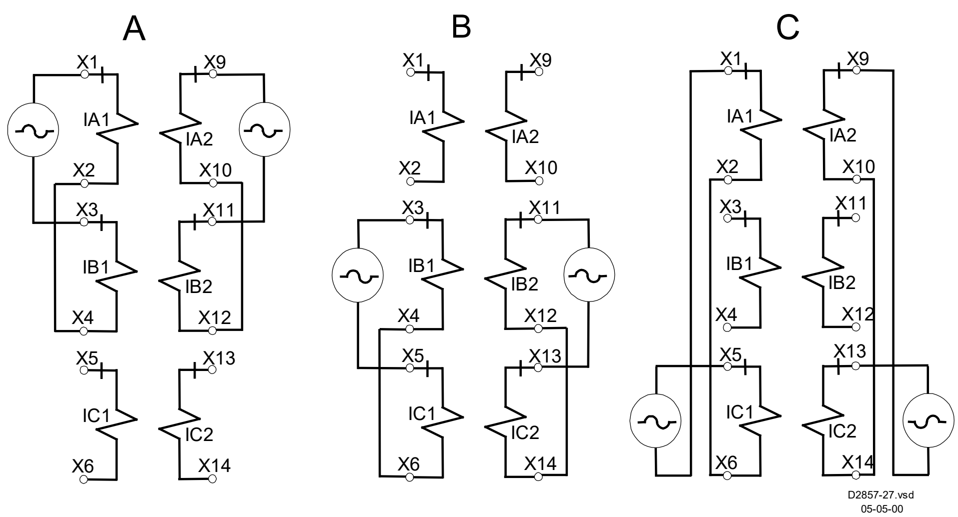


Figure 13-5. Test Connection Diagrams for Table 13-15

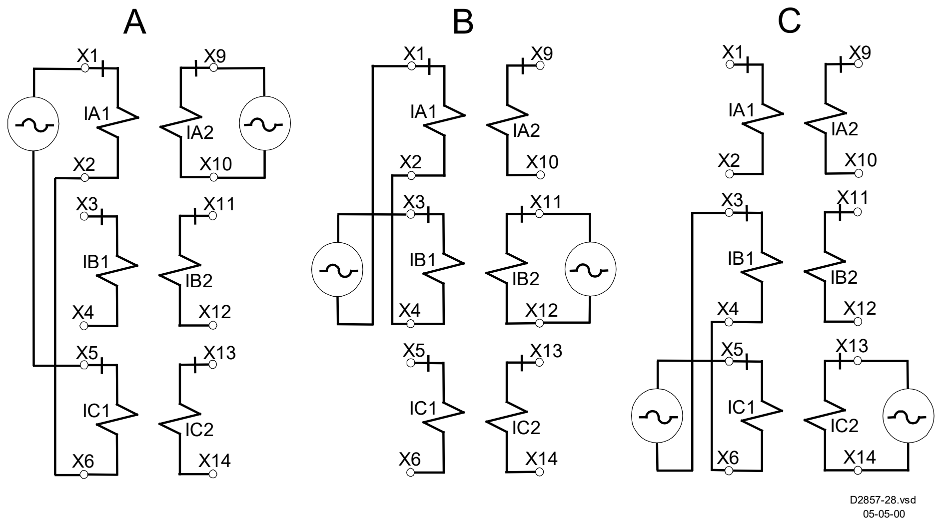


Figure 13-6. Test Connection Diagrams for Table 13-15

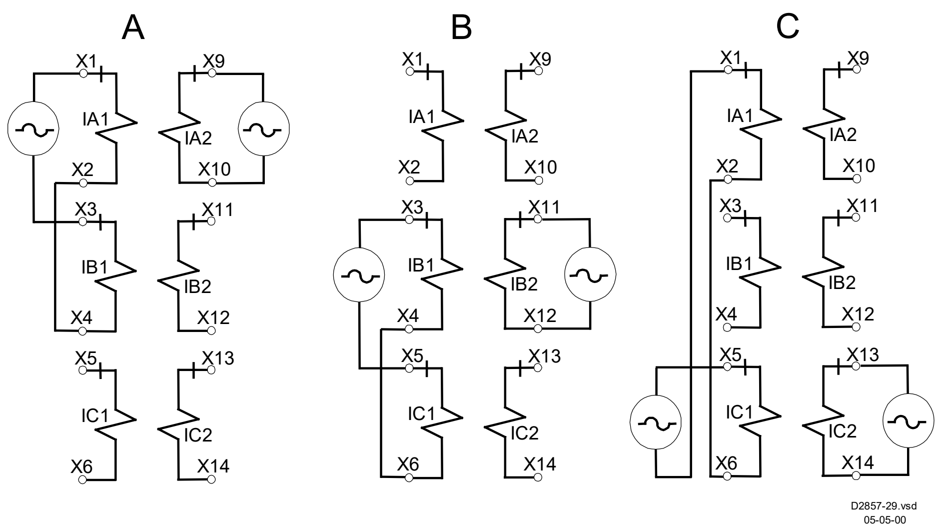


Figure 13-7. Test Connection Diagrams for Table 13-15

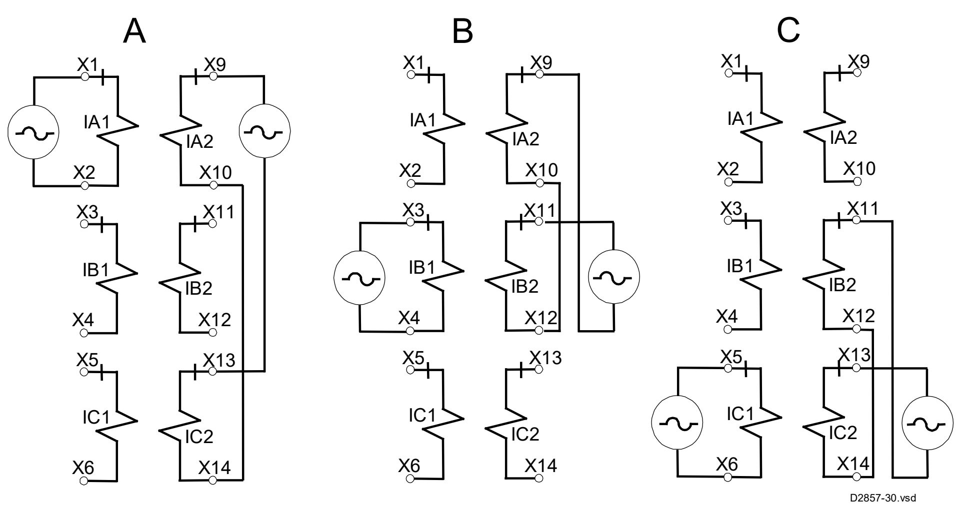


Figure 13-8. Test Connection Diagrams for Table 13-15

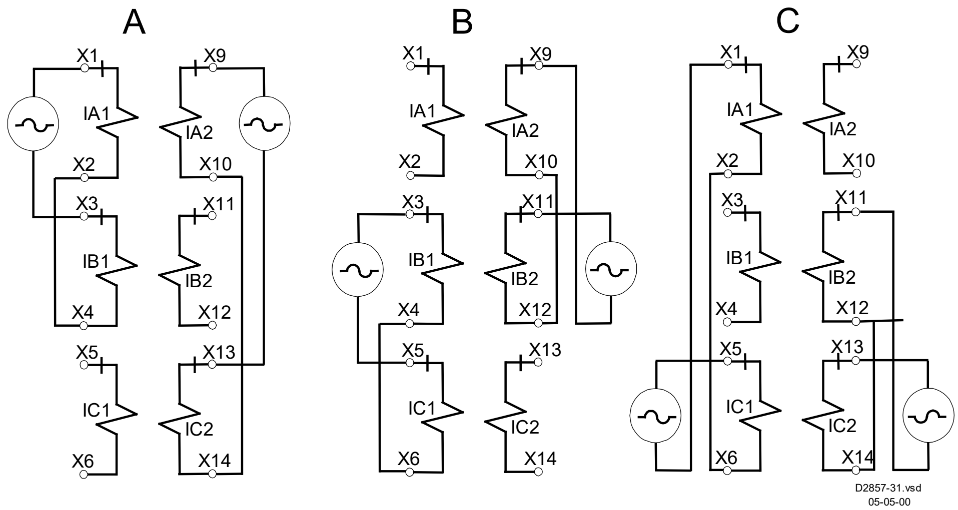


Figure 13-9. Test Connection Diagrams for Table 13-15

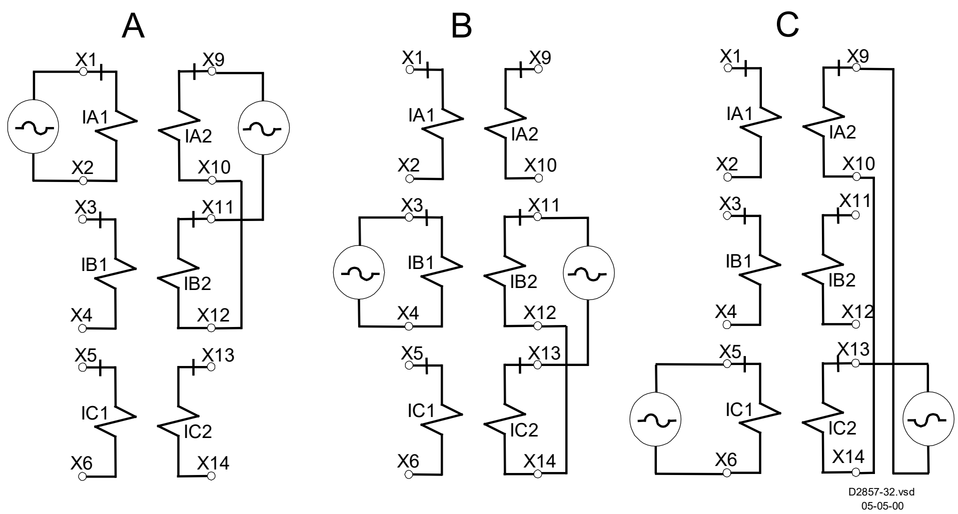


Figure 13-10. Test Connection Diagrams for Table 13-15

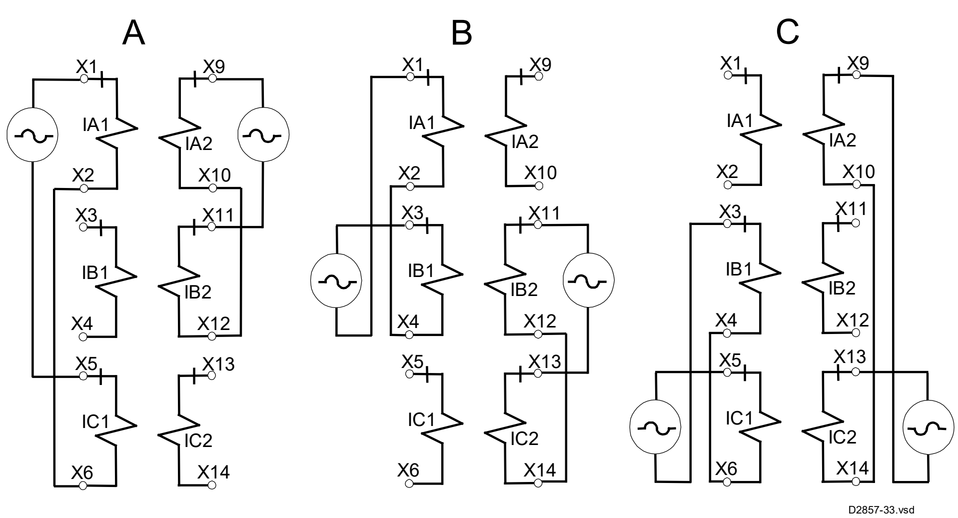


Figure 13-11. Test Connection Diagrams for Table 13-15

> **NOTE**
>
> It is necessary to convert the slope setting from percent to decimal for use in the equations used in Step 4-4.

Step 4-4: Check that the starting (balanced) test current will not result in a minimum pickup trip. Use the appropriate equation under the column heading Min PU in Figure 13-3. If it will result in a minimum pickup, adjust both starting test currents upward until they are above minimum pickup. Use the same adjustment factor on both currents such that they remain balanced.

Step 4-5: Record the phases that are expected to respond.

Step 4-6: Verify that the current sources are configured such that they are 180 degrees out of phase with each other.

Step 5: Calculate test points (restrained trip) for restrained slope test.

The test point at which a trip should occur will depend upon whether you set the relay to operate on percent of maximum restraint current or percent of average restraint current. It will also depend upon whether the Iop (differential current) is to be developed by increasing one current source from balance or by decreasing one current source from balance.

Step 5-1: Use the starting current calculated in Step 4 and the appropriate equation under the column heading Trip If Slope in Figure 13-3 to calculate the test point for each setting group and record that point before starting the test.

Step 5-2: Record the phases that are expected to respond.

Step 6: Test the slope for each setting group.

Step 6-1: Slowly ramp the test current on CT input circuit 1 in desired direction until the relay trips.

Step 6-2: Monitor an appropriate contact per the logic settings and the trip LED, and record the trip values for each setting group.

Step 6-3: Record whether the proper phases targeted and if the test was passed. The accuracy should be ±4% of the setting or 0.75 milliamperes, whichever is greater, for 5-ampere units and ±4% or 25 milliamperes, whichever is greater, for 1-ampere units.

Step 7: Repeat for each set of input pairs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Phase Differential Unrestrained Trip

The following test is similar to the restrained minimum pickup test. For this test, you will apply a single-phase test current to one CT input circuit at a time. It is only necessary to apply one phase per input to verify response and settings correctly entered. For example, apply phase A for CT circuits 1 through 4 for Setting Group 0, phase B for CT Circuit 1 and 2 for Group 1, etc. to verify all phases and all set points.

Step 8: Calculate test points for the unrestrained test.

Step 8-1: Calculate the test points using the compensation settings recorded in Step 1 and the appropriate equations shown in Tables 13-12 through 13-14. In this case, substitute the unrestrained pickup setting for the restrained minimum pickup setting in the equations. Record the calculated test point for each setting group before running the test.

> **NOTE**
>
> Depending upon the settings in the relay, disabling the restrained differential element to test the unrestrained differential element may be necessary.

Step 8-2: Record the phases that will respond to the test.

Step 9: Begin the unrestrained pickup test.

Step 9-1: Begin to slowly ramp up the test current until the relay trips.

Step 9-2: Monitor an appropriate contact per the logic settings and the Trip LED and record the value.

Step 9-3: Record whether the proper phases targeted and if the test was passed. The accuracy should be ±3% of the setting or 0.75 milliamperes, whichever is greater, for 5-ampere units and ±3% of the setting or 25 milliamperes, whichever is greater, for 1-ampere units.

Verify Other Set Points as Appropriate

Consult *Functional Testing* in this section of the manual for guidelines on how to test other functions to verify set points of other protection and control functions.

Digital I/O Connection Verification

Contact Sensing Inputs

Purpose: To verify contact sensing input settings and connections.

Reference Commands: SN-IN, SG-IN

Step 1: Verify contact sensing input settings.

- Transmit the SN-IN1 command to verify the input 1 user-defined name, Energized State label, and De-Energized State label.
- Transmit the SN-IN1 command for each of the remaining seven contact sensing inputs that are used in your system. Add the number of an input to the SN-IN command to check that input's name and labels.
- Verify the recognition and debounce settings for each contact sensing input by using the SG-IN command. When the SG-IN command is transmitted, the relay responds with the recognition and debounce settings for each input. Reported settings use the format SG-IN1=recognition, debounce.

Step 2: Verify contact sensing input connections.

- Operate (or cause to operate) each contact associated with all contact sensing inputs that are used in your system. You may operate them individually and verify that the BE1-CDS240 recognized the contact operation or operate all of them and then verify the operation.

To verify that all inputs have been recognized, transmit the command RG-INPUT to retrieve INPUT (12345678) information. Or, alternatively, transmit the command RG-STAT and review the response at the tail end of the line INPUT (12345678). You may also view the input status on HMI Screen 1.4.1, \STAT\OPER\INPUT.

Output Contacts

Purpose: To verify output settings and connections.

Reference Commands: SN-VO, SL-VO, SG-HOLD

Step 1: Verify output settings.

- Transmit the SN-VOA command to verify the virtual output A user-defined name, TRUE label, and FALSE label.
- Transmit the SN-VOA command for Virtual Outputs 1 through 15. Add the number of an output to the SN-VO command to check that output's name and labels.
- Transmit the SL-VO command to obtain a list of all virtual outputs and their Boolean logic equations. Verify that the desired virtual output equations match the reported equations.
- Verify the programmable hold timer setting for each hardware output by transmitting the command SG-HOLD. The output hold timer setting for each output is reported as enabled (1) or disabled (0).

Step 2: Verify output connections.

- Output logic override control cannot be accessed from the HMI. Transmit the commands ACCESS=, CS-OUT=ENA, CO-OUT=ENA, EXIT and YES to enable the output logic control override capability of the relay in order to operate each output contact.
- Transmit the commands listed in Table 13-17. When the operate command is transmitted, the corresponding output changes state for 200 milliseconds and returns to the normal state. Monitor the specific output contacts in whatever manner you require to verify that the output connections are valid. Remember, you have to gain access before you begin issuing commands and again if the access time-out expires.

NOTE

In verifying output connections, we pulse the hardware outputs for 200 milliseconds. If you have a specific output that requires a longer operate time to verify operation, substitute a 1 or 0 (depending on the output logic) for the P in the commands listed in Table 13-17. After the output connection is verified, it is important to return the output to logic control using the commands CS-OUTn=L; CO-OUTn=L <enter>.

- If desired, you may disable the control override capability by transmitting the commands ACCESS=, CS-OUT=DIS, CO-OUT=DIS, EXIT and YES to the relay.

Table 13-17. Output Control Override Commands

Output	Terminals	Commands
ALARM (N.C.)	C1 and C2	CS-OUTA=P,CO-OUTA=P
OUT1 (NC/NO)	C3, C4 and C5	CS-OUT1=P,CO-OUT1=P
OUT2 (NC/NO)	C6, C7 and C8	CS-OUT2=P,CO-OUT2=P
OUT3 (N.O.)	C9 and C10	CS-OUT3=P,CO-OUT3=P
OUT4 (N.O.)	C11 and C12	CS-OUT4=P,CO-OUT4=P
OUT5 (N.O.)	C13 and C14	CS-OUT5=P,CO-OUT5=P
OUT6 (N.O.)	C15 and C16	CS-OUT6=P,CO-OUT6=P
OUT7 (N.O.)	C18 and C19	CS-OUT7=P,CO-OUT7=P
OUT8 (N.O.)	C20 and C21	CS-OUT8=P,CO-OUT8=P
OUT9 (N.O.)	C22 and C23	CS-OUT9=P,CO-OUT9=P
OUT10 (N.O.)	C24 and C25	CS-OUT10=P,CO-OUT10=P
OUT11 (N.O.)	C26 and C27	CS-OUT11=P,CO-OUT11=P
OUT12 (N.O.)	C28 and C29	CS-OUT12=P,CO-OUT12=P
OUT13 (N.O.)	C30 and C31	CS-OUT13=P,CO-OUT13=P
OUT14 (N.O.)	C32 and C33	CS-OUT14=P,CO-OUT14=P

Virtual 43 Switches

Purpose: To verify the operation, labels and logic settings of the virtual 43 switches.

Reference Commands: SN-43, SL-43, RG-43STAT, RG-STAT, CS/CO-43

NOTE

If virtual 43 switches are not used, skip the eight associated steps and go to the next test.

Step 1: Transmit the SN-43 command to verify the Virtual Selector Switch 43 name, TRUE label, and FALSE label. This information is reported using the format SN-x43=name, TRUE label, FALSE label.

Step 2: Repeat Step 1 for Virtual Selector Switches 143 through 743. Use the number of a switch in the SN-43 command to retrieve name and label information for that switch.

Step 3: Use the SL-x43 command to obtain the logic setting of Virtual Switches 43 through 743. Logic settings for virtual switches can also be obtained by using the SL command. Verify that the desired virtual selector switch setting matches the reported setting.

Step 4: Transmit the RG-43STAT command to obtain the position of the eight virtual selector switches. Alternately, the virtual selector switch positions can be obtained through the RG-STAT command or HMI Screens 2.1.1 through 2.1.8, \CTRL\43\43 through \CTRL\43\743.

Step 5: Obtain write access to the relay by using the ACCESS= command. For each virtual selector switch enabled in your logic scheme, change the switch position by entering CS-x43=1 (TRUE), 0 (FALSE) or P (Pulse) followed by CO-x43=1,0 or P. The syntax of the CS-x43 and CO-x43 commands must match or the CO-x43 command won't be executed.

Step 6: Verify each switch position change by using the CO-x43 command or through HMI Screens \CTRL\43\43 through \CTRL\43\743.

Step 7: Leave each Virtual 43 Switch in the desired position for placing the protection and control system in service.

Step 8: Verify the 43 Switch activity by viewing the sequence of events reports with the RS-### command.

Virtual 101 Switches

Purpose: To verify the operation and logic setting for the 101 switches, 101, 1101, 2101, 3101.

Reference Commands: SB-LOGIC, SL-x101, RG-x101STAT, RG-STAT, CS/CO-x101

Step 1: Verify the breaker label and breaker-closed logic expression with the SB-LOGIC command.

Step 2: Use the SL-x101 command to read the logic mode of the each 101 Switch. The switch is either enabled (1) or disabled (0).

Step 3: Verify the virtual control switch status by using the RG-x101STAT, RG-STAT or CO-x101 commands or HMI Screens 2.2, \CTRL\BKR.

Step 4: Transmit the command ACCESS= to obtain write access to the relay. Change the switch position by entering CS-x101=T (Trip) or C (Close) followed by CO-x101=T (Trip) or C (Close). The syntax of the CS-x101 and CO-x101 commands must match or the CO-x101 command won't be executed.

Step 5: Verify the switch position change as you did in Step 3.

Step 6: Repeat Step 4 to return the x101 Switch to the desired position for your application.

Step 7: Verify the x101 switch activity by viewing the sequence of events reports with the RS-### command.

Reporting and Alarm Functions

Just prior to placing the relay in service, the following reporting and alarm functions should be reset and verified. For information on how to use the ASCII command interface or the front panel HMI to enter or edit relay settings, refer to Section 10, *Human-Machine Interface*, and Section 11, *ASCII Command Interface*.

Clock Display

Set the real-time clock to the current date and time. If an IRIG input is used, day and time are automatically synced to the IRIG source. Remember that the IRIG time code signal does not contain the current year information.

Purpose: To verify that the reporting and alarm functions are set/reset as required for the system installation.

Reference Commands: RG-TIME, RG-DATE

For clock setting details, refer to Section 6, *Reporting and Alarms, Clock, Setting the Clock*. To use the front panel HMI, go to Screen 1.4.6.

Demand Functions

If the relay Demand Functions feature is enabled, reset the peak current demand registers to zero or an existing value.

Purpose: To set the demand registers as required for the system installation.

Reference Commands: RD-PI, RD-PI<p>

Refer to Section 6, *Reporting and Alarms, Demand Functions,* for setting details. To use the front panel HMI, go to Screen 4.4.3.

Transformer Monitoring

If the relay Transformer Through-Fault and Duty Monitoring features are enabled, reset the counter and duty registers to zero or an existing value.

Purpose: To set the transformer counter and duty registers as required for the system installation.

Reference Commands: RT-TFCNTR, RT-DUTY

Refer to Section 6, *Reporting and Alarms, Transformer Monitoring,* for setting details. To use the front panel HMI, go to Screen 4.5.1.

Breaker Monitoring

If the relay Breaker Monitoring feature is enabled, reset the counter and duty registers to zero or an existing value.

Purpose: To set the breaker counter and duty registers as required for the system installation.

Reference Commands: RB-OPCNTR, RB-DUTY

Refer to Section 6, *Reporting and Alarms, Breaker Monitoring,* for setting details. To use the front panel HMI, go to Screen 4.3.1.

Relay Trouble Alarms

Reset and verify that the relay trouble alarm is not ON. Alarm information can be read by transmitting the ASCII commands RA or RG-STAT. To clear (reset) a relay trouble alarm, first gain write access to the reporting functions (R password) and then initiate the RA=0 or RA-REL=0 commands or press the *Reset* key while the front panel HMI Screen 1.2, \STAT\ALARMS\ALARM is displayed.

Purpose: To verify that all alarms are cleared and no alarms are active before initially loading the system.

Reference Commands: RA, RG-STAT, RA=0, RA-REL=0

Refer to Section 6, *Reporting and Alarms, Major/Minor/Logic Programmable Alarms,* for information on setting alarms and retrieving and resetting alarm reports. To use the front panel HMI, go to Screen 1.2, \STAT\ALARMS\ALARM.

Major/Minor/Logic Programmable Alarms

Reset and verify that the relay Major/Minor/Logic Programmable alarms are not ON. Alarm information can be read by transmitting the ASCII commands RA or RG-STAT. To clear (reset) a relay Major/Minor/Logic alarm, first gain write access to the reporting functions (R password) and then initiate the RA=0 or RA-MAJ/MIN/LGC=0 commands or press the *Reset* key while the front panel HMI Screen 1.2.1, \STAT\ALARMS\DETAILS is displayed.

Purpose: To verify that all Major/Minor/Logic Programmable alarms are cleared and no alarms are active before initially loading the system.

Reference Commands: RA, RG-STAT, RA=0, RA-MAJ/MIN/LGC =0

Refer to Section 6, *Reporting and Alarms, Major/Minor/Logic Programmable Alarms,* for information on setting alarms and retrieving and resetting alarm reports. To use the front panel HMI, go to Screen 1.2.1, \STAT\ALARMS\DETAILS.

Targets

Reset and verify that there is no target information. Target information can be read by transmitting the ASCII command RG-TARG. To clear (reset) a relay target, first gain write access to the reporting functions (R password) and then initiate the RG-TARG=0 command or press the *Reset* key while the front panel HMI Screen 1.1, \STAT\TARGETS is displayed.

Purpose: To verify that all targets are cleared before initially loading the system.

Reference Commands: RG-TARG, RG-TARG=0

Refer to Section 6, *Reporting and Alarms, Fault Reporting, Targets,* for information on setting targets and retrieving and resetting target information. To use the front panel HMI, go to Screen 1.1, \STAT\TARGETS.

Fault Summary Reports

Reset and verify that new fault summary directory records are set to zero. To reset the new fault summary directory records, first gain write access to the reporting functions (R password) and then initiate the RF-NEW=0 command two times. Verify that there are no new fault summary records by initiating the RF command and observe that the NEW FAULTS line indicates zero or view the front panel HMI Screen 4.1, \REPRT\FAULT.

Purpose: To verify that there is no new fault records before initially loading the system.

Reference Commands: RF, RF-NEW=0

Refer to Section 6, *Reporting and Alarms, Fault Reporting, Fault Summary Reports,* for information on retrieving fault summary reports.

Sequence of Events Recorder (SER) Function

Reset SER registers and verify that there are no SER events. SER directory reports can be read by transmitting the ASCII command RS or through the front panel HMI Screen 4.2. To clear (reset) SER registers, first gain write access to the reporting functions (R password) and then initiate the RS-NEW=0 command.

Purpose: To verify that all SER registers are cleared before initially loading the system.

Reference Commands: RS, RS-NEW=0

Refer to Section 6, *Reporting and Alarms, Sequence of Events Recorder Function,* for information on retrieving and resetting SER records.

System Report Documentation

After completing all previous steps in *Commissioning Testing* and before placing the protection system in service, it is important to create a record of the relay settings and system status at the time of commissioning. This report should be kept for comparison in future maintenance procedures.

To create the settings record, transmit the ASCII S command and then use normal personal computer techniques to save or print the SER report that is returned.

To create the status record, transmit the ASCII RG-STAT command and then use normal personal computer techniques to save or print the status report that is returned.

Purpose: To create a permanent status and settings record for future reference before initially loading the system.

Reference Commands: S, RG-STAT

Refer to Section 6, *Reporting and Alarms, General Status Reporting,* and *Sequence of Events Recorder Function,* for information on retrieving and resetting SER records.

In Service Current Circuit Verification

To verify correct CT circuit connections, internal phase, zero-sequence and tap compensation settings for the differential functions, it is recommended that the load be placed on the protected zone and a differential check record be triggered, recorded, and examined. See Section 6, *Reporting and Alarms, Differential Current Monitoring Function,* for more information on differential check records.

To assist you in performing this procedure, an *Annotated Differential Check Record* and an *In Service Current Circuit Verification Form* is provided on the following pages. It is recommended that this form be copied, completed (filled out) and that the differential check record retrieved from the relay be captured to a file and printed. These two documents should then be placed with the commissioning records for future reference.

Test Scenarios

The protected circuit should be loaded prior to triggering a differential check record. It is desirable that the loading be great enough to result in relay currents that are above the minimum sensitivity of the differential current diagnostic function but not great enough to cause a trip if there is a problem in the installation. The minimum sensitivity of the differential current diagnostic function is 150 milliamperes of secondary current for 5-ampere relays and 30 milliamperes of secondary current or 1 ampere relays.

When you put initial loading on the differential zone of protection, one of four scenarios may result:

1. Everything is **correct** and there is **no differential alarm** or **trip.**

2. There is a **problem** with the settings or installation but the initial loading is too low so there is **no differential alarm** or **trip.**
3. There is a **problem** with the settings or installation and the initial loading is great enough to cause a **differential alarm** but not a trip.

NOTE

If the load picked up results in differential current greater than the alarm set point (scenario 3), a record will be generated automatically by the differential alarm function. If this occurs, it is still recommended to manually trigger generation of a new differential check record so that you are assured that you are looking at up-to-date data.

4. There is a **problem** with the settings or installation and the initial loading is great enough to cause a **trip**.

NOTE

If the load picked up results in a trip (scenario 4), examine the fault summary and oscillography records to determine the cause of the trip. If it is not a fault, re-energize the transformer and pick up less of a load; or block the differential trip, re-energize the transformer and pick up the load. After the load is picked up, trigger a differential check record. Once the problem has been corrected, unblock the differential element. A Microsoft® Excel spreadsheet template (CDSFAULT.xlt) is available from the web site www.basler.com. The magnitude and angle of the currents recorded in the fault summary report at the time of the trip can be entered into this spreadsheet along with the pertinent differential and connections settings. The spreadsheet will then calculate the differential currents after compensation, which makes it easier to diagnose and correct the problem.

Annotated Differential Check Record

```
CDS240 DIFFERENTIAL CHECK RECORD
STATION ID          : SUBSTATION_1
RELAY ID            : BE1-CDS240
USER1 ID            : USER1_ID
USER2 ID            : USER2_ID
RELAY ADDRESS       : 0
REPORT DATE         : 04/24/03
REPORT TIME         : 15:22:22.669
ACTIVE GROUP        : 0

PHASE 87 SETTINGS     CTR    CT CON   TX CON   GROUNDED   ABC SWAP   DIFF CKT
CT CKT1               200    WYE      WYE      NO         ABC        PRI
CT CKT2               200    WYE      WYE      NO         ABC        SEC
CT CKT3               240    WYE      DAC      NO         ABC        SEC
CT CKT4               200    WYE      WYE      NO         ABC        SEC

MINPU                 0.2 * TAP
SLOPE                 40 %
ALARM                 75 %
URO                   6 * TAP

COMPENSATION          ANGLE   ROTATE   ABC SWAP   GROUND   TAP
CT CKT1               DAB     NO       NO         YES      2.000
CT CKT2               DAB     NO       NO         YES      4.000
CT CKT3               WYE     R2       NO         NO       16.700
CT CKT4               DAB     NO       NO         YES      2.000

ALARMS                PHASE A             PHASE B             PHASE C
DIFFERENTIAL          OK                  OK                  OK
LOW CURRENT           NO                  NO                  NO
POLARITY              OK                  OK                  OK
ANGLE COMP            OK                  OK                  OK
MISMATCH              OK                  OK                  OK

MEASUREMENTS          PHASE A             PHASE B             PHASE C
MEASURED PRI I
CT CKT1                167 @ 0             167 @ 240           167 @ 120
CT CKT2                201 @ 180           201 @ 60            201 @ 300
CT CKT3                126 @ 150           126 @ 30            126 @ 270
CT CKT4                 54 @ 180            54 @ 60             54 @ 300
MEASURED SEC I
CT CKT1               0.84 @ 0            0.84 @ 240          0.84 @ 120
CT CKT2               1.00 @ 180          1.00 @ 60           1.00 @ 300
CT CKT3               0.52 @ 150          0.52 @ 30           0.52 @ 270
CT CKT4               0.27 @ 180          0.27 @ 60           0.27 @ 300
ANGLE COMPENSATED I
CT CKT1               0.84 @ 30           0.84 @ 270          0.84 @ 150
CT CKT2               1.00 @ 210          1.01 @ 90           1.01 @ 330
CT CKT3               1.00 @ 210          1.01 @ 90           1.01 @ 330
CT CKT4               1.00 @ 210          1.00 @ 90           1.01 @ 330
TAP COMPENSATED I
CT CKT1               0.42 @ 30           0.42 @ 270          0.42 @ 150
```

Examine

Plot these currents

P0004-46
05-07-03

In-Service Current Circuit Verification Form

Time and Date: ____

Station ID: ____________________________ Relay ID: ________________________________

User1 ID: ____________________________ User2 ID: ________________________________

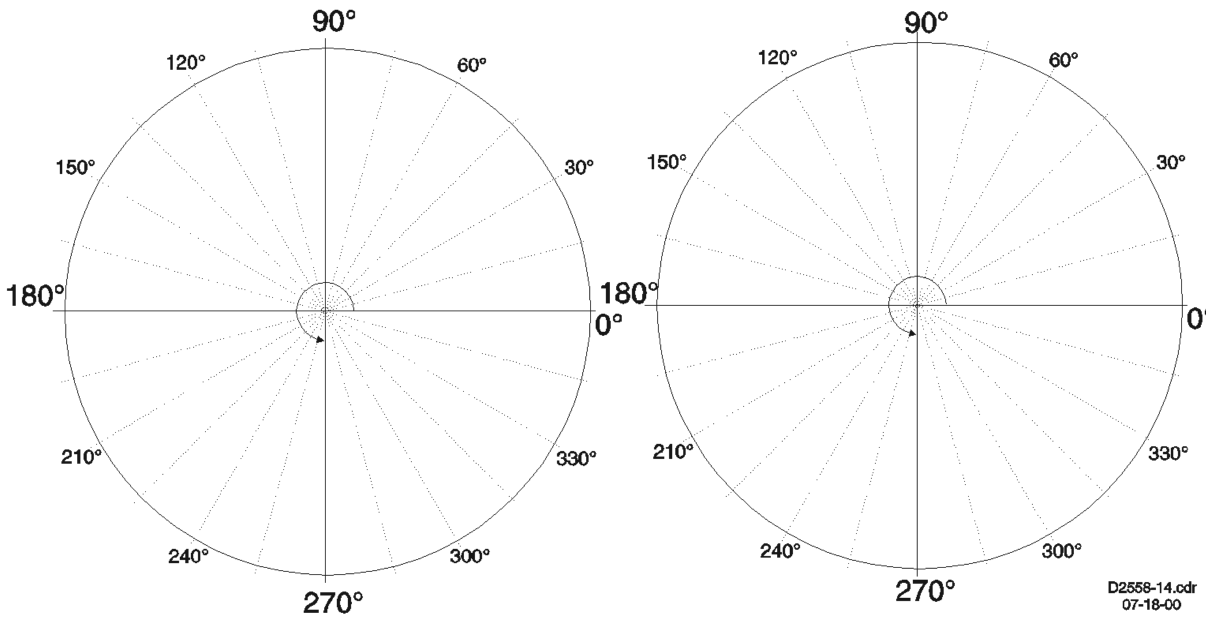
Trigger Differential Check Record

To trigger and retrieve a current check record, use the following commands:

A=
RA-DIFF=TRIG
RA-DIFF

Examine Differential Check Record

1. Examine the *Measurements* portion of the report. Plot on the appropriate polar graph, the currents under the differential check record lines *Measured I Pri* and *Tap Comp I* for each phase and CT input circuit.



Plot Primary Currents   Plot Compensated Currents

2. Examine the plotted currents:
   - — Is the phase-sequence for both CT circuits the same as expected?
   - — Does the phase-sequence match the phase-sequence setting (SG-PHROT) or HMI Screen 6.3.3?
   - — Examine the angle and tap compensated currents on the polar graph from the line labeled *Tap Comp I*. For each phase, determine if the currents are approximately the same magnitude for each CT input circuit and approximately 180 degrees out of phase? Some small amount of mismatch is expected due to excitation and possible LTC or other tap adjust differences.
3. Examine the *Alarms* portion of the report:
   - — The line marked *Differential* will report *Alarm* for any phase where the differential current is above the alarm threshold on that phase.
   - — The lines marked *Polarity, Angle Comp* and *Mismatch* will report *Alarm* or *OK* as determined by the current circuit diagnostic function if the currents are above the minimum sensitivity. The diagnostic function for these lines operates even if the differential current is not above the alarm threshold.

Periodic Testing

Because the relay has extensive internal self-test capabilities, periodic testing of the protection system can be greatly reduced. The relay characteristics are a function of the programming instructions that do not drift over time. Thus, the user may wish to verify that the:

- Set points that were proven during the commissioning have not been changed.
- Inputs and outputs are properly interfacing with the rest of the protection and control system.
- Power system analog parameters used by the protection and control functions are being measured accurately.

These are things that the self-test capability cannot completely determine.

Settings Verification

Verification of the relay settings can be accomplished in several ways depending upon the user's preferences and practices. This step may not be required if the settings changed alarm point is programmed to an output and is being monitored. This way, any unexpected setting changes would be logged and investigated. Some settings verification possibilities include:

- Repeating the Protection and Control Function commissioning tests.
- If a file of the settings recorded upon commissioning is available, the settings can be read out of the relay, captured to a similar file, and compared using software tools.
- The settings can be verified by simple inspection of the settings versus those recorded upon commissioning.

Digital I/O Connection Verification

Verification of the relay digital I/O connections can be accomplished in several ways depending upon the user's preferences and practices.

- Repeating the digital I/O connection verification commissioning tests.
- Monitoring SER, Status and Fault reports for proper sensing of digital signals and proper tripping during normal operation.

NOTE

If protection systems are redundant such that multiple relays will trip a given breaker or device for a fault, simply monitoring fault reports may not indicate a failed output contact. The relay may report that it energized an output. However, tripping was actually accomplished by the redundant relay. With this situation, actually testing the contact is recommended.

Analog Circuit Verification

Verification of the relay analog measurement circuits can be accomplished in several ways depending upon the user's preferences and practices. Some of these ways are:

- Repeating portions of the acceptance or commissioning tests and injecting known test signals into the relay.
- Using the metering functions of the relay and comparing the measurements to those provided by other similar devices that are measuring the same signals. Redundant relays and/or metering devices can provide this source of independent confirmation of the measured signals. If the relay is connected to an integration system, this can even be automated and done on a routine basis.

NOTE

If you are going to verify the analog measurement circuits by comparison to independent devices, you should ensure that the two devices use similar measurement algorithms. For example, the measurements of a fundamental sensing relay cannot be compared with the measurements of an RMS sensing device.

Maintenance of Backup Battery for Real-Time Clock

The backup battery for the real-time clock is an optional feature available in BE1 numeric products. A 3.6V, 0.95 Ah lithium battery is used to maintain clock function during extended loss of power supply voltage (over eight hours). In mobile substation and generator applications, the primary battery system that supplies the relay power supply may be disconnected for weeks or even months between uses. Without battery backup for the real time clock, clock functions would cease after eight hours (capacitor backup).

The backup battery should be replaced after five years of operation. The recommended battery is a lithium 3.6V, 0.95 Ah battery (Basler p/n: 9318700012 or Applied Power p/n: BM551902). Use the following instructions to replace the battery:

Step 1: Remove the unit from the case.

Step 2: Disconnect the battery cable.

Step 3: Locate the battery. The battery is located on the bottom side of a horizontal unit or the left side of a vertical unit. See Figures 13-12 and 13-13 for battery location.

Step 4: Using a 5/16" nut driver, remove the nut holding the battery strap in place. Then remove the old battery, being careful not to hang the leads on the printed circuit board components. Consult local ordinances for proper battery disposal.

Step 5: Install the new battery by following Steps 1 through 4 in reverse order.

WARNING!
Do not short-circuit, reverse battery polarity, or attempt to recharge the battery.

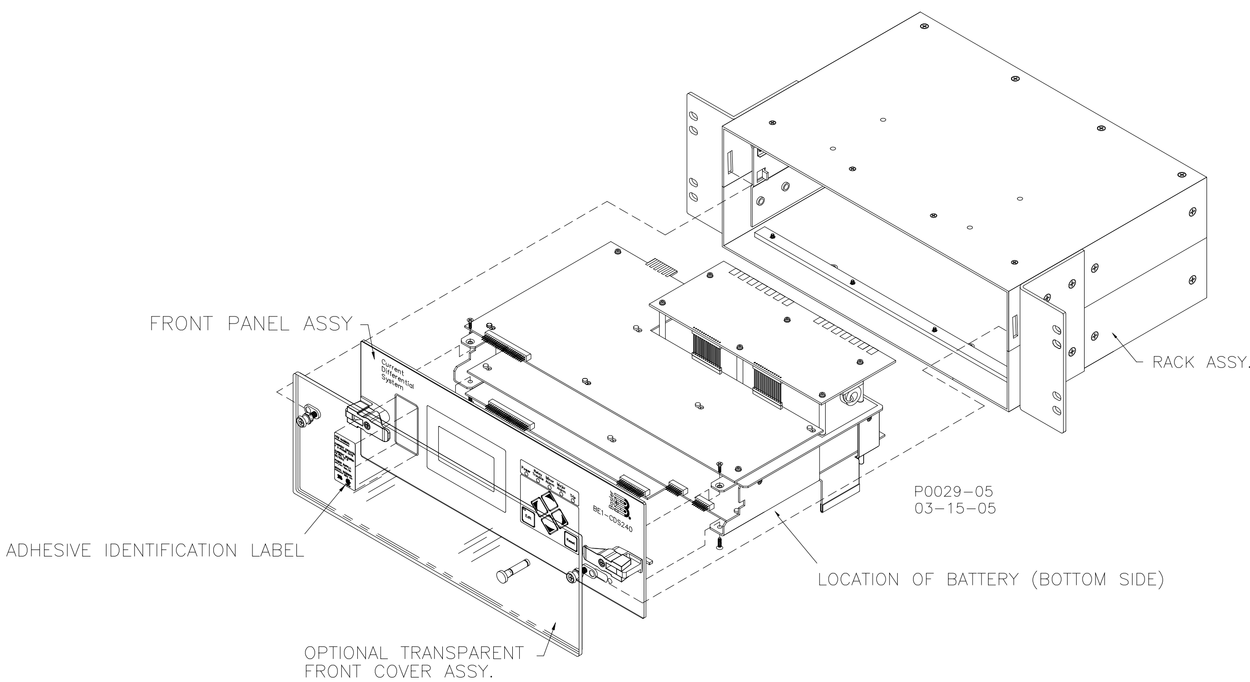


Figure 13-12. Location of Battery, Top View

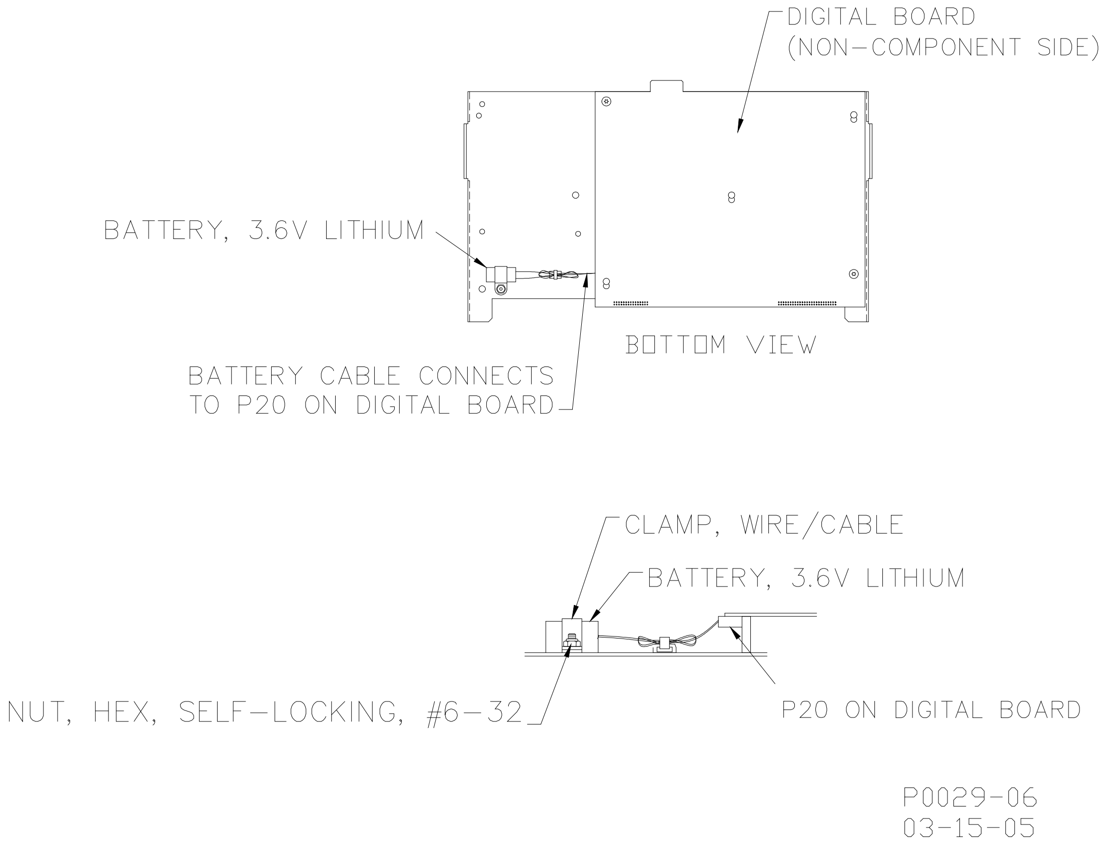


Figure 13-13. Location of Battery, Bottom View

Care and Handling

The BE1-CDS240 Current Differential System requires no preventive maintenance. The fully numeric design of the relays requires no circuit-board level calibration.

There is no need to disturb the circuit interconnections within the assembly. Repair of the assembly by replacement of individual circuit boards is not recommended. The printed circuit boards are constructed using surface-mount technology and are not intended to be field serviceable.

Before returning the assembly for repair, contact the Basler Electric Technical Services Department at 618 654-2341 for a return authorization number.

Storage

This device contains long-life aluminum electrolytic capacitors. For devices that are not in service (spares in storage), the life of these capacitors can be maximized by energizing the device for 30 minutes once per year.

Updating Firmware and Software

Future enhancements to relay functionality may make a firmware update desirable. Enhancements to relay firmware typically coincide with enhancements to BESTCOMS software for that relay. When a relay is updated with the latest version of firmware, the latest version of BESTCOMS software should also be obtained.

Updating Relay Firmware

If a firmware upgrade is desired, contact Basler Electric technical support to request download access.

Once the appropriate firmware is obtained, it can be uploaded to a relay using the *BESTload* software utility provided on the CD-ROM originally supplied with the relay.

Updating BESTCOMS™ Software

Firmware enhancements often include the addition of relay settings or the modification of existing settings.

BESTCOMS software is revised to accommodate the new or changed settings. When firmware is updated, the latest version of BESTCOMS should also be obtained. If a CD-ROM was obtained from Basler Electric, then that CD-ROM will contain firmware and the corresponding version of BESTCOMS software. BESTCOMS can also be downloaded from the Basler Electric web site (http://www.basler.com).

Functional Testing

NOTE

Functional testing is NOT required for this unit. It is only necessary if the user wants to perform a comprehensive assessment to determine suitability for an application.

Functional testing provides a comprehensive assessment of this relay to determine suitability for your application. Functional testing goes beyond the more basic tests found in acceptance testing but does not go into the detail for each function as in *Commissioning Testing*.

Test each of the following functions to verify that this relay measures accurately, is within specified tolerances, and operates correctly as designed. In addition, these tests are suitable for assisting in systematic trouble-shooting in the event of a questionable operation. Revisiting a functional test of a specific function of the relay can help verify whether the relay is indeed operating within the manufacturer's specified tolerance. For further assistance, contact Basler Electric, Customer Service Department.

As covered in Section 3, *Inputs and Outputs*, each virtual output can be mapped to any hardware output. For ease of testing, map each Virtual Output VO1 through VO14 to hardware Outputs OUT1 through OUT14 prior to beginning tests. This is accomplished by entering SL-OUT1=VO1, SL-OUT2=VO2, etc. and entering exit (E) and Yes to save.

Phase Differential (87)

The CDS240 is a four winding differential relay. Testing the complete 87T scheme would require 12 controllable current sources. For simplicity, testing will be performed by evaluating sequential pairs of input circuits (Inputs 1 verses Inputs 2, Inputs 2 verses Inputs 3, etc). This will confirm proper operation of the complete scheme. The complete set of Input Circuit "pairs" is: CT1-CT2, CT1-CT3, CT1-CT4, CT2-CT3, CT3-CT4, CT3-CT4.

Minimum Pickup

Purpose: To verify the minimum pickup of the 87 elements.

Reference Commands: SL-87, S<g>-87, S<g>-TAP87, SG-CTP

Step 1: Connect one current source to Terminals A2 (A-phase, input 1). See Figures 13-1 and 13-2. An ohmmeter or continuity tester may be used to monitor output contact status.

Step 2: To prepare the 87 elements for testing, transmit the commands in Table 13-18 to the relay.

Table 13-18. Pickup Test Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=RDIFF	Name custom logic for this test.
SL-87=1,0	Enables 87.
SL-VO1=87RT	Enables OUT1 to close for 87 restrained trip.
SG-CTP1=1,WYE	Ctr = 1, ct = wye
SG-CTP2=1,WYE	Ctr = 1, ct = wye
SG-CTP3=1,WYE	Ctr = 1, ct = wye

Command	Purpose
SG-CTP4=1,WYE	Ctr = 1, ct = wye
SG-TRIGGER=87RT, 7RPU,0	Enable 87RT to log and trigger fault recording.
E	Exit.
Y	Save settings.

Step 3: Send to the relay the commands listed in Table 13-19.

NOTE

The tap settings listed in the S#-TAP87 command are within the range of settings for a 5 ampere sensing input type relay. If your relay is a 1-ampere sensing input type, change the TAP 1 and TAP 2 values to 1.0.

Table 13-19. S#-87 Commands

Command	Purpose
A=	Gain access.
S#-TAP87=MANUAL, 5.00,5.00	Set TAP 1 = 5.00 and TAP 2 = 5.00.
E	Exit.
Y	Save settings.

Step 4: Apply current to phase A, input 1 and slowly ramp up until OUT1 closes. The relay should pick up at a value of minimum pickup x TAP (see Figure 13-14).

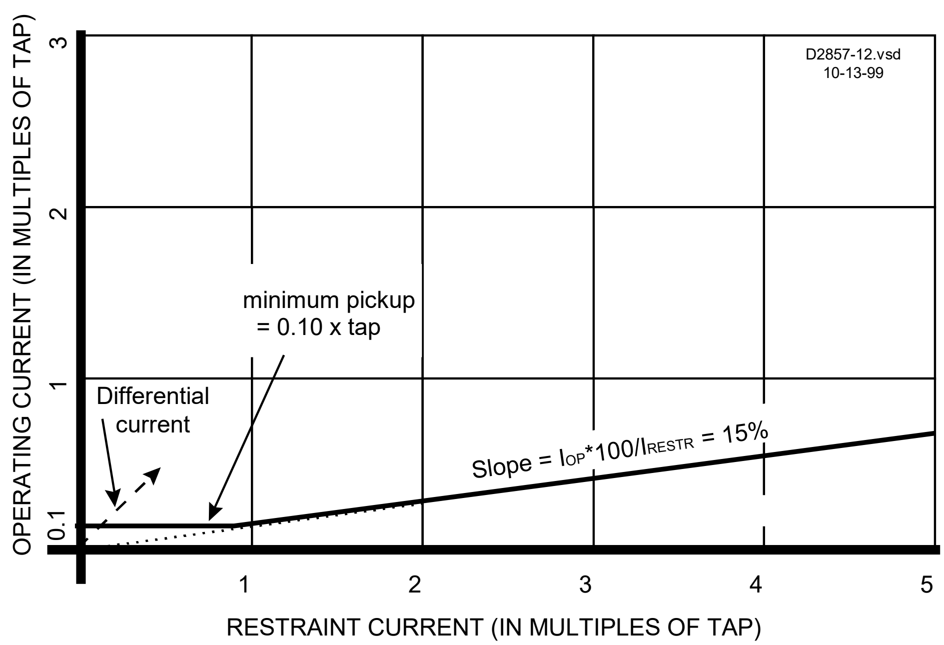


Figure 13-14. Minimum Pickup Characteristic

Step 5: Verify that pickup occurred within the specified accuracy of the relay (see Table 13-15) as indicated by the low and high limits in Table 13-20.

Table 13-20. Sensing Input Type Accuracy

CT Secondary Rating	Accuracy
5 A	± 4% of setting or 75 milliamperes whichever is greater.
1 A	± 4% of setting or 25 milliamperes whichever is greater.

Step 6: Decrease the phase A, input 1 current until the relay drops out. Remove current.

NOTE

Testing all inputs at various sensitivity settings is optional.

Table 13-21. Minimum Pickup Accuracy Limits

Sensing Type	Phase Inputs	Terminals	MINPU	Tap 1/Tap 2 values	Pickup (A)	Low Limit (A)	High Limit (A)
5 A	A1	A3*, A4	0.10	5.00/5.00	0.50	0.425	0.575
	B1	A5*, A6	0.50	5.00/5.00	2.50	2.400	2.600
	C1	A7*, A8	1.00	5.00/5.00	5.00	4.800	5.200
	A2	A9*, A10	0.10	5.00/10.0	1.00	0.925	1.075
	B2	A11*, A12	0.50	5.00/10.0	5.00	4.800	5.200
	C2	A13*, A14	1.00	5.00/10.0	10.0	9.600	10.40
	A3	A15*, A16	0.10	5.00/10.0	1.00	0.925	1.075
	B3	A17*, A18	0.50	5.00/10.0	5.00	4.800	5.200
	C3	A19*, A20	1.00	5.00/10.0	10.0	9.600	10.40
	A4	A21*, A22	0.10	5.00/10.0	1.00	0.925	1.075
	B4	A23*, A24	0.50	5.00/10.0	5.00	4.800	5.200
	C4	A25*, A26	1.00	5.00/10.0	10.0	9.600	10.40
1 A	A1	A3*, A4	0.10	1.00/1.00	0.10	0.075	0.125
	B1	A5*, A6	0.50	1.00/1.00	0.50	0.475	0.525
	C1	A7*, A8	1.00	1.00/1.00	1.00	0.960	1.040
	A2	A9*, A10	0.10	1.00/2.00	0.20	0.175	0.225
	B2	A11*, A12	0.50	1.00/2.00	1.00	0.960	1.040
	C2	A13*, A14	1.00	1.00/2.00	2.00	1.952	2.080
	A3	A15*, A16	0.10	1.00/2.00	0.20	0.175	0.225
	B3	A17*, A18	0.50	1.00/2.00	1.00	0.960	1.040
	C3	A19*, A20	1.00	1.00/2.00	2.00	1.952	2.080
	A4	A21*, A22	0.10	1.00/2.00	0.20	0.175	0.225
	B4	A23*, A24	0.50	1.00/2.00	1.00	0.960	1.040
	C4	A25*, A26	1.00	1.00/2.00	2.00	1.952	2.080

Step 7: Repeat Steps 3 and 4 by connecting the current sources to the phases indicated in Table 13-21 and substitute for MINPU (in the S#-87 command) and TAP values in the S#-TAP87 command (using the HMI, navigate to the \PROT\SGn\87\87 Screen to change MINPU values and \PROT\SGn\87\TAP Screen to change TAP 1 and TAP 2 values) to verify linearity over the range of MINPU values.

Step 8: (Optional.) Confirm that the relay acknowledged each change of state of OUT1 (87 restrained trip) by using the RS command. Gain write access to the relay (a=) and reset the new events counter by sending an RS=0 command to the relay.

NOTE

The action listed in Step 8 will not be introduced again in these tests. It is up to the user to decide whether it is necessary to do this check after each test.

Step 9: (Optional.) Repeat Steps 2 through 8 for Setting Groups 1 through 3. Use the CS/CO-GROUP command to change setting groups.

Step 10: (Optional.) Repeat for each pair of CT inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Restrained Pickup

The following tests verify the functional operation of the restrained 87 element. See Sidebar 13-2 for more information on the percentage differential restraint operating principle.

Purpose: To verify the accuracy of the restraint operation of the 87 element.

Reference Commands: SL-87, SL- VO, SG-CTP, S<g>-87, S<g>-TAP87.

Step 1: Connect one current source to terminals A3* and A4 (A-phase, Input 1) and a second current source to terminals A9* and A10 (A-phase, input 2). Ensure that the two current sources are 180° out of phase. See Figure 13-15 for a connection diagram.

An ohmmeter or continuity tester may be used to monitor output contact status.

Step 2: Send the commands listed in Table 13-22 to the relay to prepare the 87 elements for pickup testing.

Table 13-22. Commands To Prepare For Pickup Testing

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=RDIFF	Name custom logic for this test.
SL-87=1,0	Enables 87.
SL-VO1=87RT	Enables OUT1 to close for 87 restrained trip.
SG-CTP1=1,WYE	Ctr = 1, ct = wye
SG-CTP2=1,WYE	Ctr = 1, ct = wye
SG-TRIGGER=87RT, 7RPU,0	Enable 87RT to log and trigger fault recording.
E	Exit.
Y	Save settings.

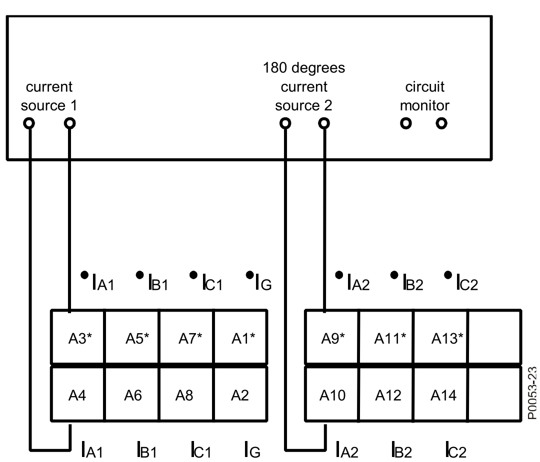


Figure 13-15. Connections for Restraint Verification (Only Inputs 1 and 2 are shown for simplicity)

Sidebar 13-2. Percentage Differential Restraint Operating Principle

The percentage differential restraint characteristic of the BE1-CDS240 relay is illustrated in Section 1, Figure 1-1. The knee of the operating curve for any slope setting is determined by taking the minimum pickup operating characteristic and dividing it by the slope.

For example, for a minimum pickup setting of 0.30 and a slope setting of 15%, the knee of the operating curve is plotted at a point equal to 0.30/0.15 = 2.00 multiples of tap on the maximum restraint current axis. This implies that at these settings, the relay requires greater than 2.00 multiples of tap of *maximum or average* restraint current to operate along the 15% slope characteristic of the relay.

Thus, for restraint currents less than the knee of the curve, the relay will operate at a differential current greater than or equal to the minimum pickup operate setting. Beyond the knee of the curve, the differential current operating characteristic is defined along the slope portion of the curve.

The BE1-CDS240 relay has two distinct operating principles for performing the restraint operation. Maximum restraint uses the maximum of the two compensated currents as the restraint while average restraint, uses the average of the two compensated currents. Either characteristic may be selected via the S<g>-87 command. For more information on the S<g>-87 command, refer to Section 4, *Protection and Control Functions, Differential Protection*.

Step 3: Send to the relay the commands listed in Table 13-23.

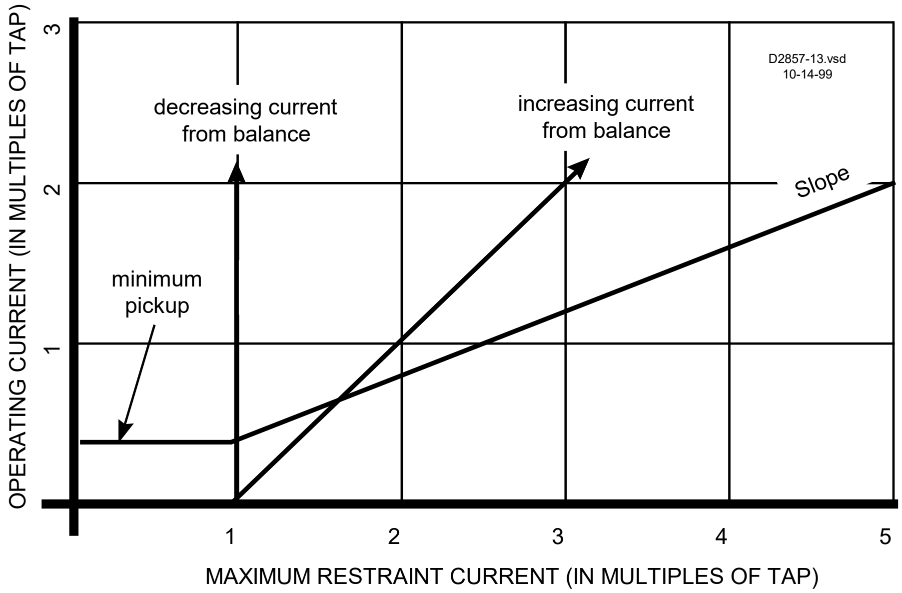
Table 13-23. Setup Commands

Command	Purpose
A=	Gain access.
For 5 A sensing input: S#-TAP87=MANUAL,2.00,3.80	Set Tap 1 = 2.00 and Tap 2 = 3.80.
For 1 A sensing input: S#-TAP87=MANUAL,0.40,0.76	Set Tap 1 = 0.40 and Tap 2 = 0.76.

You can test the relay either by increasing one current from a balanced condition or decreasing it. Refer to the descriptions of both methods and Sidebar 13-3 to evaluate the differences in the two approaches.

Sidebar 13-3. Maximum Restraint Operating Characteristic

Under maximum restraint, the relay will reach the trip or operate point depending on the level of restraint as shown in the associated figure. When only one current is changed, the restraint current can vary depending on the relative changes between currents. When one current is decreased from balance, the maximum restraint has a vertical characteristic. When increasing one current relative to the other, it will shift to the right with a sloping characteristic as it continues to increase toward the trip region of the operate characteristic.



In order to test the restrained pickup function of the BE1-CDS240 relay, you may increase one of two currents initially applied in balance, to create an operate imbalance. In this narrative, the Input 1 current will be the input to be deviated. A similar analysis can be made for deviating Input 2 current.

By increasing input current I_1 from balance, I_{1trip} is defined as

$$I_{1trip} = I_{1balance}/(1-(\frac{slope}{100})) \text{ in per unit}$$ Sidebar 13-3, Equation 1

with the minimum trip point established as

$$I_{1trip\ min} = I_{1balance} + \text{minpu in per unit}$$ Sidebar 13-3, Equation 2

where minpu is the minimum pickup setting.

Sidebar 13-3. Maximum Restraint Operating Characteristic – Continued

Under test and in-service conditions, the following equations determine whether the relay operates along the flat minimum pickup or slope of the operating characteristic. If:

$$I_{\text{restraint at balance}} > \text{minpu} \times \left(\frac{1}{\text{slope}/100} - 1\right)$$ in per unit, use Equation 1, or if

$$I_{\text{restraint at balance}} < \text{minpu} \times \left(\frac{1}{\text{slope}/100} - 1\right)$$ in per unit, use Equation 2.

Example (Increasing One Input from Balance):

Note: For simplicity, this discussion is based on a two input differential application. The principals extend to three and four winding applications.

TAP 1 = 2.00 Minpu = 0.30

TAP 2 = 3.80 Slope = 15%

Input 1 current at balance = 3 per unit (6 amperes)

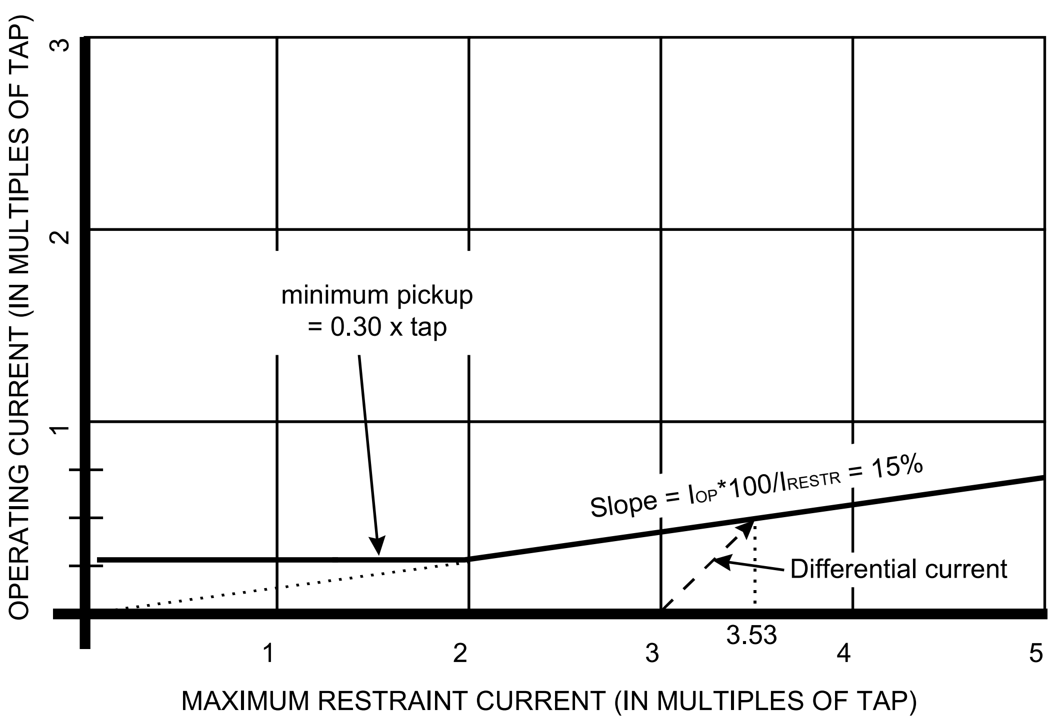
Input 2 current at balance = 3 per unit (11.40 amperes)

Input 1 is being increased relative to a fixed input 2 current. Thus, the maximum restraint used by the relay is Input 1, the larger of the two currents in per unit.

$$I_{\text{restraint at balance}} = 3 > 0.3\left(\frac{1}{0.15} - 1\right) = 1.70 \text{ per unit}$$

Then,

$$I_{1trip} = I_{1balance}/(1-(\frac{\text{slope}}{100})) = 3/(1-0.85) = 3.53 \text{ per unit (see the following figure.)}$$



Maximum Restraint Characteristic Example

You may also use the maximum restraint operating characteristic and test the relay by decreasing one current from a balanced condition. For additional information on testing in this manner, see Sidebar 13-4.

Sidebar 13-4. Maximum Restraint when Decreasing One Input from Balance

A second way to test the restrained pickup of the BE1-CDS240 relay is to decrease one of the currents, initially applied in balance, to create an imbalance. In this narrative, we will again consider a two input application, for simplicity. Input 2 current will be the input deviated. A similar analysis can be made for deviating input 1 current.

By decreasing the input current I_2 from balance, the value of I_{2trip} is defined as:

$$I_{2trip} = I_{2balance} \left(1- \left(\frac{slope}{100}\right)\right) \text{ in per unit}$$ Sidebar 13-4, Equation 1

with the minimum trip point established as:

$$I_{2trip\ min} = I_{2balance} - minpu \text{ in per unit}$$ Sidebar 13-4, Equation 2

where: minpu is the minimum pickup setting.

Under test and in-service conditions, the following equations determine whether the relay operates along the flat minimum pickup or the slope of the operating characteristic. If:

$I_{restraint\ at\ balance} > (minpu/(\frac{slope}{100})$ in per unit, use Equation 1, or, if

$I_{restraint\ at\ balance} < (minpu/(\frac{slope}{100})$ in per unit, use Equation 2.

With the maximum restraint operating principle of the BE1-CDS240 relay, as one input current is decreased from balance, the other input current, remaining the greater of the two currents will be the restraint current (in per unit). Since that current remains fixed while the other is decreased, the operate current plotted against the restraint current will be a vertical line on the operating characteristic diagram.

If you are applying this relay using the ***maximum restraint*** operating characteristic, continue with Step 4. Otherwise, you may proceed directly to Step 12 to test the average restraint operating characteristic.

Step 4: Send the commands listed in Table 13-24 to the relay.

Table 13-24. Setup Commands

Command	Purpose
A=	Gain access.
S#-87=0.35,15,0,0,0,1	Minpu = 0.35, slope = 15%, 2nd = dis, 5th = dis, URO = dis, 2nd harmonic sharing = 1 (yes).
E	Exit.
Y	Save settings.

Step 5: Apply balancing current to phase A, Input 1 and phase A, Input 2 at the magnitude indicated in the first row of either Table 13-20 (5 ampere sensing) or 13-21 (1 ampere sensing) and slowly increase Input 1 until OUT1 closes. Reference the appropriate table to verify pickup accuracy.

Step 6: Repeat for all values and (optionally) reconnect to phases B and C, Inputs 1 and 2 when advancing through the set of test values in the table. It is not necessary to test each phase at all the values listed to verify the response of each phase. On the HMI, navigate to the \PROT\SGn\87\87 Screen to make the listed slope setting changes.

Notice that the test values in Tables 13-25 and 13-26 are intended to show operation on both the minimum operate and slope portion of the operating curve.

Step 7: Verify that pickup occurred within the specified accuracy of the relay. Accuracy when increasing or decreasing the input current is ±4% of setting or 75 milliamperes (whichever is larger) for 5-ampere sensing inputs and ±4% of setting or 25 milliamperes (whichever is larger) for 1 ampere sensing inputs.

Table 13-25. Maximum Restraint Pickup Test Points (5 A Sensing Input)

Sensing Input Type	Minimum Pickup	Slope (%)	Input 1		Input 2		Increasing Input 1 From Balance Pickup (A)			Decreasing Input 2 From Balance Pickup (A)		
			Tap =	2.00	Tap =	3.80						
			Bal. Input (A)	PU	Bal. Input (A)	PU						
5	0.35	15	2.00	1	3.80	1	2.70	±	0.108	2.47	±	0.099
	0.35	15	10.00	5	19.00	5	11.76	±	0.470	16.15	±	0.646
	0.35	30	2.00	1	3.80	1	2.86	±	0.108	2.47	±	0.089
	0.35	30	10.00	5	19.00	5	14.29	±	0.572	13.30	±	0.532
	0.35	45	2.00	1	3.80	1	3.64	±	0.146	2.09	±	0.084
	0.35	45	10.00	5	19.00	5	18.18	±	0.727	10.45	±	0.418
	0.35	60	2.00	1	3.80	1	5.00	±	0.200	1.52	±	0.075
	0.35	60	10.00	5	19.00	5	25.00	±	0.100	7.60	±	0.304

Table 13-26. Maximum Restraint Pickup Test Points (1 A Sensing Input)

Sensing Input Type	Minimum Pickup	Slope (%)	Input 1		Input 2		Increasing Input 1 From Balance Pickup (A)			Decreasing Input 2 From Balance Pickup (A)		
			Tap =	2.00	Tap =	3.80						
			Bal. Input (A)	PU	Bal. Input (A)	PU						
1	0.35	15	0.40	1	0.76	1	0.54	±	0.025	0.49	±	0.025
	0.35	15	2.00	5	3.80	5	2.35	±	0.094	3.23	±	0.129
	0.35	30	0.40	1	0.76	1	0.57	±	0.025	0.49	±	0.025
	0.35	30	2.00	5	3.80	5	2.86	±	0.114	2.66	±	0.106
	0.35	45	0.40	1	0.76	1	0.73	±	0.029	0.42	±	0.025
	0.35	45	2.00	5	3.80	5	3.64	±	0.146	2.09	±	0.084
	0.35	60	0.40	1	0.76	1	1.00	±	0.040	0.30	±	0.025
	0.35	60	2.00	5	3.80	5	5.00	±	0.200	1.52	±	0.061

Step 8: Remove both currents.

Step 9: For each change in slope value indicated, send the commands listed in Table 13-27 to the relay to invoke a change in slope settings (notice the leading comma (,) in the S#-87 command).

Table 13-27. Setup Commands

Command	Purpose
A=	Gain access.
S#-87=,30	Minpu = no change, slope = 30%.
E	Exit.
Y	Save settings.

Step 10: Repeat Steps 2 through 4 for phases B and C unless all phases were tested during the restraint pickup tests in Step 5. If so, proceed with the next step.

Step 11: (Optional.) Repeat Steps 2 through 5 for Setting Groups 1 through 3 using the CS/CO-GROUP command to change setting groups.

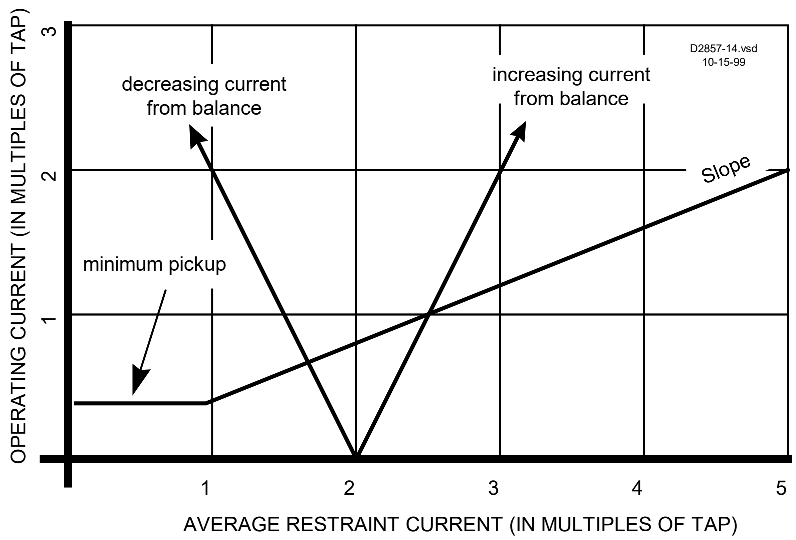
Step 12: (Optional.) Repeat for each pair of CT inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, CT3-CT4).

If you are applying this relay using the **average restraint** operating characteristic, you may begin your testing at Step 12. Otherwise, go back to Step 4 to test for the maximum restraint operating characteristic. For more information on testing using the average restraint operating characteristic, see Sidebar 13-5 and Sidebar 13-6.

Sidebar 13-5. Average Restraint Operating Characteristic

Operating in an average restraint characteristic, the BE1-CDS240 relay reaches the trip or operate point depending on the level of restraint per the diagram below.

As illustrated in the associated diagram, when only one current is changed, the restraint current will vary depending on the relative change in currents. As one current is decreased from balance, the average restraint will shift to the left with a sloping characteristic as the differential current increases to the point of operating. The average restraint will shift to the right with a sloping characteristic when one current is increased relative to the other as the differential current increases.



Average Restraint Operating Characteristic

Sidebar 13-6. Average Restraint when Increasing One Input from Balance

In order to test the restrained pickup function of the BE1-CDS240 relay, you may increase one of two currents initially applied in balance, to create an operate imbalance. In this narrative, the Input 1 current will be the input to be changed. A similar analysis can be made for changing Input 2 current.

By increasing input current I_1 from balance, I_{1trip} is defined as:

$$I_{1trip} = I_{2balance} * (1+((2* \frac{slope}{100})/(2- \frac{slope}{100}))) \text{ in per unit}$$ Sidebar 13-6, Equation 1

with the minimum trip point established as:

$$I_{1trip\ min} = I_{2balance} + minpu \text{ in per unit}$$ Sidebar 13-6, Equation 2

where: minpu is the minimum pickup setting.

Under test and in-service conditions, the following equations determine whether the relay operates along the flat minimum pickup or slope of the operating characteristic. If:

$$I_{restraint\ at\ balance} > minpu \times \left(\frac{1}{slope/100} - 1/2 \right)$$ in per unit, use Equation 1 or if

$$I_{restraint\ at\ balance} < minpu \times \left(\frac{1}{slope/100} - 1/2 \right)$$ in per unit, use Equation 2.

Sidebar 13-6. Average Restraint when Increasing One Input from Balance - Continued

Example (Increasing One Input From Balance):

Tap1 = 2.00 Minpu = 0.30

Tap2 = 3.80 Slope = 15%

Input 1 current at balance = 3 per unit (6 amperes)

Input 2 current at balance = 3 per unit (11.40 amperes)

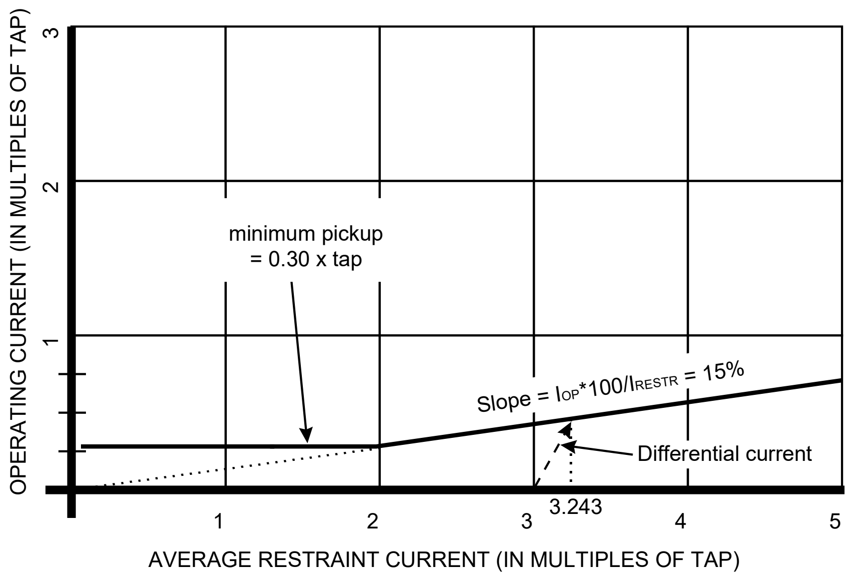
Input 1 is being increased relative to a fixed Input 2 current.

$$I_{restraint\ at\ balance} = 3 > 0.3 \left(\frac{1}{0.15} - 0.5\right) = 1.85 \text{ per unit}$$

Then,

$$I_{1trip} = I_{2balance} * (1+((2*\frac{slope}{100})/(2-\frac{slope}{100}))) = 3(1+0.30/1.85) = 3.486 \text{ per unit}$$

$$I_{restraint} = \frac{I1+I2}{2} = (3.0 + 3.486)/2 = 6.486/2 = 3.243 \text{ per unit (see the following figure).}$$



Average Restraint Characteristic Example

You may also use the average restraint operating characteristic and test the relay by decreasing one current from a balanced condition. For additional information on testing in this manner, see Sidebar 13-7.

Sidebar 13-7. Average Restraint when Decreasing One Input from Balance

A second way to test the restrained pickup of the BE1-CDS240 relay is to decrease one of two currents, initially applied in balance to create an imbalance. In this narrative, Input 1 current will be the input to be changed. A similar analysis can be made for changing Input 2 current.

By decreasing the input current I_1 from balance, the value of I_{1trip} is defined as:

$$I_{1trip} = I_{2balance}\ (1- ((2* \frac{slope}{100})/(2+\frac{slope}{100}))) \quad \text{in per unit}$$

with the minimum trip point established as:

$$I_{1trip\ min} = I_{2balance} - minpu \text{ in per unit}$$

where: minpu is the minimum pickup setting

Under test and in-service conditions, the following equations determine whether the relay operates along the flat minimum pickup or slope of the operating characteristic. If

$$I_{restraint\ at\ balance} > minpu \times \left(\frac{1}{slope/100} + 1/2\right)$$ in per unit, use the 1st equation, or if

$$I_{restraint\ at\ balance} < minpu \times \left(\frac{1}{slope/100} + 1/2\right)$$ in per unit, use the 2nd equation.

Step 13: Send the commands listed in Table 13-28 to the relay.

Table 13-28. Setup Commands

Command	Purpose
A=	Gain access
S#-87=0.35,15,0,0,0,1	Minpu = 0.35, slope = 15% (of average restraint), 2nd = disabled, 5th = disabled, URO= disabled, 2nd harmonic sharing =1 (yes)
E	Exit
Y	Save settings

Step 14: Apply balancing current to phase A Input 1 and phase A Input 2 at the magnitude indicated in each row of either Table 13-29 (5 ampere sensing) or 13-25 (1 ampere sensing) and slowly increase phase A Input 1 until OUT1 closes. Reference the corresponding table to verify pickup accuracy.

Table 13-29. Average Restraint Pickup Test Points (5 A Sensing Input)

Sensing Input Type	Minimum Pickup	Slope (%)	Input 1		Input 2		Increasing Input 1 From Balance Pickup (A)			Decreasing Input 2 From Balance Pickup (A)		
			Tap =	2.00	Tap =	3.80						
			Bal. Input (A)	PU	Bal. Input (A)	PU						
5	0.35	15	2.00	1	3.80	1	2.70	±	0.108	2.47	±	0.099
5	0.35	15	10.00	5	19.00	5	11.62	±	0.465	16.35	±	0.654
5	0.35	30	2.00	1	3.80	1	2.70	±	0.108	2.47	±	0.089
5	0.35	30	10.00	5	19.00	5	13.53	±	0.541	14.04	±	0.562
5	0.35	45	2.00	1	3.80	1	3.16	±	0.126	2.40	±	0.096
5	0.35	45	10.00	5	19.00	5	15.81	±	0.632	12.03	±	0.481
5	0.35	60	2.00	1	3.80	1	3.71	±	0.148	2.04	±	0.096
5	0.35	60	10.00	5	19.00	5	18.57	±	0.743	10.22	±	0.409

Table 13-30. Average Restraint Pickup Test Points (1 A Sensing Input)

Sensing Input Type	Minimum Pickup	Slope (%)	Input 1		Input 2		Increasing Input 1 From Balance Pickup (A)			Decreasing Input 2 From Balance Pickup (A)		
			Tap =	2.00	Tap =	3.80						
			Bal. Input (A)	PU	Bal. Input (A)	PU						
1	0.35	15	0.40	1	0.76	1	0.54	±	0.025	0.49	±	0.025
1	0.35	15	2.00	5	3.80	5	2.32	±	0.093	3.27	±	0.131
1	0.35	30	0.40	1	0.76	1	0.54	±	0.025	0.49	±	0.025
1	0.35	30	2.00	5	3.80	5	2.71	±	0.108	2.81	±	0.112
1	0.35	45	0.40	1	0.76	1	0.63	±	0.025	0.481	±	0.025
1	0.35	45	2.00	5	3.80	5	3.16	±	0.126	2.406	±	0.096
1	0.35	60	0.40	1	0.76	1	0.74	±	0.030	0.408	±	0.025
1	0.35	60	2.00	5	3.80	5	3.71	±	0.148	2.046	±	0.082

Step 15: Repeat for all values and optionally, reconnect to phases B and C, inputs 1 and 2 when advancing through the set of test values in the table. It is not necessary to test each phase at all the values listed to verify the response of each phase. On the HMI option, navigate to the \PROT\SGn\87\87 Screen to make the listed slope setting changes.

Notice that the test values in Tables 13-29 and 13-30 are intended to show operation on both the minimum operate and slope portion of the operating curve. These tables have values for testing the relay either by increasing one current from a balanced condition or decreasing it. Either technique can be utilized to test this function. Refer to the descriptions of both methods to evaluate the differences in the two approaches.

Step 16: Verify that pickup occurred within the specified accuracy of the relay. Accuracy when increasing or decreasing the input current is ±4% of setting or 75 milliamperes (whichever is larger) for 5-ampere sensing inputs and ±4% of setting or 25 milliamperes (whichever is larger) for 1 ampere sensing inputs.

Step 17: Remove both currents.

Step 18: (Optional.) Repeat for each pair of CT inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, CT3-CT4).

Step 19: For each indicated change in slope value, send the commands listed in Table 13-31 to the relay to invoke a change in slope settings (notice the leading comma (,) in the S#-87 command).

Table 13-31. Setup Commands

Command	Purpose
A=	Gain access.
S#-87=,30	Minpu = no change, slope = 30%.
E	Exit.
Y	Save settings.

Step 20: Repeat Steps 13, 14, and 15 for phases B and C unless all phases were tested during the restraint testing in Steps 14 and 15. If so, proceed with the next step.

Step 21: (Optional.) Repeat Steps 2 through 4 and 12 through 14 for Setting Groups 1 through 3 using the CS/CO-GROUP command to change setting groups.

Step 22: (Optional.) Repeat for each pair of CT inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4)

Restrained Time Verification

A timing circuit or a contact monitor with timing algorithm must be used to time the output contact status change. For more information on determining the minimum pickup current, see Sidebar 13-8.

Sidebar 13-8. Determining the Operating Point on the Curve

$$I_{\text{restraint at balance}} <> \text{minpu} \times \left(\frac{1}{\text{slope}/100} - 1\right) \quad \text{in per unit}$$

1 < (0.35 * ((1/0.15)-1))= (0.35 * 5.67) = 1.98 per unit

where the operating point is on the flat part of the curve.

Thus, we use the following to derive the trip condition. Notice the added multiples of tap variable that we know in this case is 1.5 times tap or 1.5 per unit.

$$I_{2\text{trip min}} = I_{2\text{balance}} + \text{minpu} * \text{multiples of tap in per unit}$$

$$I_{2\text{trip min}} = 1 + 0.35 * 1.5 = 1.53 \text{ per unit}$$

where: $I_{2\text{ current}}$ (@ 2 x tap) = tap X $I_{2\text{trip min}}$ = 2.00 * 1.53 = 3.05 amps

Because 1.53 per unit is less than 1.98 per unit, we know that our trip point is on the flat part of the curve and the applied current is actually 1.5 pu.

Step 1: Connect one current source to Terminals A3*, A4 (A-phase, input 1) and a second current source to Terminals A9*, A10 (A-phase, input 2).

Step 2: Send the commands listed in Table 13-32 to the relay to setup a test of the response time of the 87 restrained elements.

Table 13-32. Restrained Element Response Time Setup Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=DIFF	Sets DIFF as custom logic name.
SL-87=1,0	Enables 87.
SL-VO1=87RT	Enables OUT1 to close with 87 restrained trip.

Command	Purpose
SG-CTP1=1,WYE,NA,0	Ctr = 1, ct = wye
SG-CTP2=1,WYE,NA,0	Ctr = 1, ct = wye
SG-CTP3=1,WYE,NA,0	Ctr = 1, ct = wye
SG-CTP4=1,WYE,NA,0	Ctr = 1, ct = wye
SG-TRIGGER=87RT,87RPU,0	Enable 87RT to log and trigger fault recording.
S#-TAP87=MANUAL,2.00,2.00	set Tap 1 = 2.00 and Tap 2 = 2.00.
S#-87=0.35,15,0,0,0,1	Minpu = 0.35, slope = 15%, 2nd = disabled, 5th = disabled, URO= disabled, 2nd harmonic sharing = shared.
E	Exit.
Y	Save settings.

Step 3: Apply 1 multiple of tap current (2 amperes) to both A-phase Input 1 and A-phase Input 2 (at 180° phase relation to Input 1).

Step 4: To force a restrained trip at 1.5 times pickup, you must apply a step change in the current on Input 2 to 3.05 amps. Apply the step change in current to Input 2 and record the time interval between the time the step change was initiated to the time OUT1 output contact closes (the restrained trip (87RT)).

Step 5: Reduce the current to Input 2 until OUT1 Contact opens.

Step 6: Apply 1 multiple of tap current (2 amperes) to both A-phase Input 1 and A-phase Input 2 (at 180° phase relation to Input 1).

Step 7: To force a restrained trip at 5 times pickup, you must apply a step change in the current on input 2 to 8.0 amperes. This value (8.0 amperes) was derived from the following:

$I_{op} = 5 * I_{op\ trip}$

$I_2 – I = 5 * (I_2 * slope)$

$I_2 – I_1 = 5 * (I_2 * 0.15)$

$I_2 – I = 0.75\ I_2$

$0.25\ I_2 = 1$

$I_2 = 4$ per unit

$I_2 = 8$ amperes

Step 8: Apply the step change in current to input 2 and record the time interval between the time the step change was initiated to the time OUT1 Output Contact closes (the restrained trip (87RT)).

Step 9: Reduce the current to Input 2 until OUT1 Contact opens.

Step 10: The time measured in Steps 4 and 8 should be less than those shown in Table 13-33.

Table 13-33. Restrained Trip Operate Times

Function	Differential Current	Time
Restrained trip	1.5 times pu	Less than 3 cycles
Restrained trip	5 times pu	Less than 2 cycles

Step 11: (Optional.) Repeat for each pair of CT inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Second Harmonic Restraint Verification

Purpose: To verify the operation of the 2nd harmonic restraint function of the 87 element.

Reference Commands: SL-87, S(n)-87, S(n)-TAP87, SL-VO, SG-CTP.

Step 1: Parallel a 60 Hz current source and a second 120 Hz current source to Terminals A3, A4 (A-phase, Input 1). Refer to Figure 13-16.

An ohmmeter or continuity tester may be used to monitor output contact status.

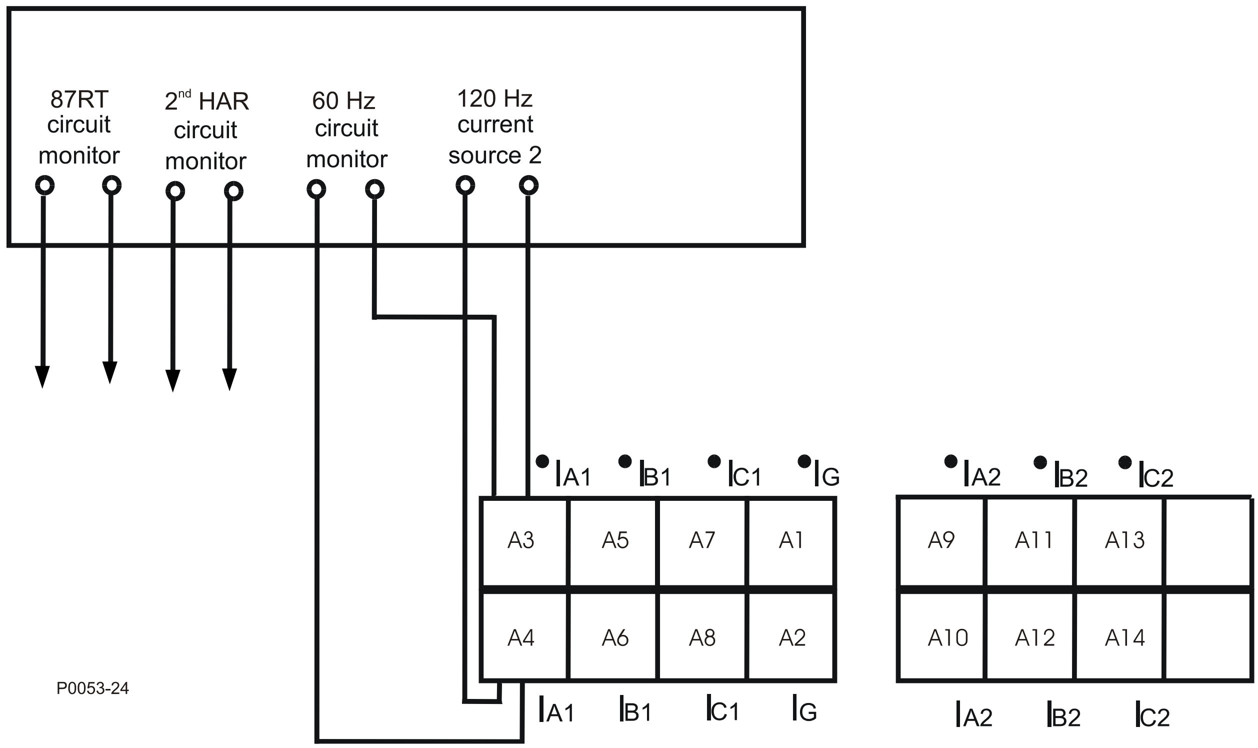


Figure 13-16. Connection for Harmonic Restraint Verification
(Only Inputs 1 and 2 are shown for simplicity)

Step 2: Send the commands listed in Table 13-34 to the relay to setup a test of the pickup of the second harmonic restraint elements.

Table 13-34. Second Harmonic Restraint Elements Setup Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=2HAR	Sets 2HAR as custom logic name.
SL-87=1,0	Enables 87.
SL-VO1=87RT	Enables OUT1 to close with 87 restrained trip.
SG-CTP2=1,WYE	Ctr = 1, ct = wye
SG-CTP3=1,WYE	Ctr = 1, ct = wye
SG-CTP4=1,WYE	Ctr = 1, ct = wye
SG-TRIGGER=87RT,87RPU,0	Enable 87RT to log and trigger fault recording.
S#-TAP87=MANUAL,2.00,3.80	set Tap 1 = 2.00 and Tap 2 = 3.80.
S#-87=0.35,15,18,0,0,1	Minpu = 0.35, slope = 15% ,2nd = 18%, 5th = disabled, URO = disabled, 2nd harmonic sharing = shared.
E	Exit.
Y	Save settings.

Step 3: Apply 2.0 amps of 60 Hz current to the A-phase Input 1. The OUT1 (87RT restrained trip) output contact should close upon application of current.

Step 4: Apply 120 Hz current on the source paralleled to A-phase Input 1 and slowly increase the current from zero until OUT2 closes (and conversely, OUT1 opens).

Step 5: Record the current magnitude from Step 4 that caused OUT 2 to close and OUT1 to open. These output contact changes indicated that the 2nd harmonic restraint function is now restraining the 87RT operation.

Step 6: Remove both 60 Hz and 120 Hz currents.

Step 7: To arrive at a 2nd harmonic inhibit percentage value, divide the magnitude of the applied 2nd harmonic current (120 Hz) by the magnitude of the applied 60 Hz input current. For this particular test, this value should be equal to 0.36 amperes @ 120 Hz ÷ 2 A @ 60 Hz = 18 %. Verify that the 2nd harmonic inhibit function restrains operation at the expected value based on settings from Step 2.

The recommended CT connection for this test is WYE. If the user decides to use a DELTA CT connection with "harmonic sharing enabled" during this test, the 2nd harmonic current will be doubled as a result of delta summation and the relay will operate at 9%. This occurs only during single-phase testing with settings as stated.

Step 8: (Optional.) Repeat Steps 2 through 7 for phases B and C. Because the relay was set for harmonic sharing in the S#-87 command (the last "1" in the string) in Step 2, the harmonic content on all phases is shared or summed. This magnitude is used by the second harmonic comparators for each phase. Thus, the same operation will occur regardless of which phase of the 120-hertz test current is applied.

Step 9: (Optional.) Repeat Steps 2 through 8 for Setting Groups 1 through 3 using the CS/CO-GROUP command to change setting groups.

Step 10: (Optional.) Repeat for each pair of CT inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Fifth Harmonic Restraint Verification

Purpose: To verify the operation of the 5th harmonic restraint function of the 87 element.

Reference Commands: SL-87, S(n)-87, S(n)-TAP87, SL-VO, SG-CTP.

Step 1: Parallel a 60 Hz current source and a second 300 Hz current source to Terminals A3, A4 (A-phase, Input 1). Same as Figure 13-14 except for the applied harmonic frequency.

An ohmmeter or continuity tester may be used to monitor output contact status.

Step 2: Send the commands listed in Table 13-35 to the relay to setup a test of the pickup of the fifth harmonic restraint elements.

Table 13-35. Fifth Harmonic Restraint Elements Setup Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=5HAR	Sets 5HAR as custom logic name.
SL-87=1,0	Enables 87.
SL-VO1=87RT	Enables OUT1 to close with 87 restrained trip.
SL-VO2=5THHAR	Enables OUT2 to close when 5th harmonic restrains 87RT.
SG-CTP1=1,WYE	Ctr = 1, ct = wye
SG-CTP2=1,WYE	Ctr = 1, ct = wye
SG-CTP3=1,WYE	Ctr = 1, ct = wye
SG-CTP4=1,WYE	Ctr = 1, ct = wye
SG-TRIGGER=87RT,87RPU,0	Enable 87RT to log and trigger fault recording.
S#-TAP87=MANUAL,2.00,3.80	set Tap 1 = 2.00 and Tap 2 = 3.80.

Command	Purpose
E	Exit.
Y	Save settings.

Step 3: Apply 2.0 amps of 60 Hz current to the A-phase Input 1. The OUT1 (87RT restrained trip) output contact should close upon application of current.

Step 4: Apply 300 Hz current on the source paralleled to A-phase Input 1 and slowly increase the current from zero until OUT2 closes (and conversely, OUT1 opens).

Step 5: Record the current magnitude from Step 4 that caused OUT 2 to close and OUT1 to open. These output contact changes indicated that the 5th harmonic restraint function is now restraining the 87RT operation.

Step 6: Remove both 60 Hz and 300 Hz currents.

Step 7: To arrive at a 5th harmonic inhibit percentage value, divide the magnitude of the applied 5th harmonic current (300 Hz) by the magnitude of the applied 60 Hz input current. For this particular test, this value should be equal to 0.70 amperes @ 300 Hz ÷ 2 A @ 60 Hz = 35 %. Verify that the 5th harmonic inhibit function restrains operation at the expected value based on settings from Step 2.

Step 8: (Optional.) Repeat Steps 2 through 7 for phases B and C.

Step 9: (Optional.) Repeat Steps 2 through 8 for Setting Groups 1 through 3 using the CS/CO-GROUP command to change setting groups.

Step 10: (Optional.) Repeat for each pair of CT inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Unrestrained Pickup Verification

Purpose: To verify the accuracy of the unrestrained operation of the 87 element.

Reference Commands: SL-87, SL- VO, SG-CTP, S(n)-87, S(n)-TAP87

Step 1: Connect one current source to terminals B1, B2 (A-phase, Input 1). Refer to Figure 13-1. An ohmmeter or continuity tester may be used to monitor output contact status.

Step 2: Send the commands listed in Table 13-36 to the relay to setup a test of the pickup of the 87 elements.

Table 13-36. 87 Elements Pickup Setup Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=UDIFF	Name custom logic for this test.
SL-87=1,0	Enables 87.
SL-VO1=87UT	Enables OUT1 to close with 87 unrestrained trip.
SL-VO2=5THHAR	Enables OUT2 to close when 5th harmonic restrains 87RT.
SG-CTP1=1,WYE	Ctr = 1, ct = wye
SG-CTP2=1,WYE	Ctr = 1, ct = wye
SG-CTP3=1,WYE	Ctr = 1, ct = wye
SG-TRIGGER=87UT,87UT,0	Enable 87UT to log and trigger fault recording.
S#-TAP87=MANUAL,2.00,3.80	Set tap 1 = 2.00 and tap 2 = 3.80.
S#-87=0,15,0,0,0,1	Minpu = disabled, slope = 15%, 2nd = disabled, 5th = disabled, URO = disabled, 2nd harm sharing = shared.
E	Exit.
Y	Save settings.

Step 3: Apply current to A-phase Input 1, increasing the magnitude until OUT1 closes. Since the URO setting is 1 and Tap 1 = 2, this should occur at 2 amperes. Accuracy when increasing or

decreasing the input current is ±4% of setting or 75 milliamperes (whichever is larger) for 5-ampere sensing inputs and ±4% of setting or 25 milliamperes (whichever is larger) for 1 ampere sensing inputs. Verify that pickup occurred within the specified accuracy of the relay.

Step 4: Reduce the input current until OUT1 opens.

Step 5: Using the values in Table 13-37, repeat Step 3 for the other values of unrestrained settings indicated.

Table 13-37. Unrestrained Pickup Accuracy Limits

URO Setting	Tap 1	Pickup (A)	Low Limit (A)	High Limit (A)
1	2.00	2	1.925	2.075
5	2.00	10	9.700	10.30
10	2.00	20	19.40	20.60

Step 6: (Optional.) Repeat Steps 1 through 5 for phases B and C.

Step 7: (Optional.) Repeat Steps 2 through 6 for Setting Groups 1 through 3 using the CS/CO-GROUP command to change setting groups.

Step 8: (Optional.) Repeat for each pair of CT Inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Unrestrained Time Verification

A timing circuit or a contact monitor with timing algorithm must be used to time the output contact status change. For more information on determining the minimum pickup current, refer to Sidebar 13-8.

Step 1: Connect one current source to terminals A3, A4 (A-phase, Input 1) and a second current source to terminals A9, A10 (A-phase, Input 2).

Step 2: Send the commands listed in Table 13-38 to the relay to setup a test of the response time of the 87 unrestrained elements.

Table 13-38. Unrestrained Element Response Time Setup Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=DIFF	Sets DIFF as custom logic name.
SL-87=1,0	Enables 87.
SG-CTP1=1,WYE	Ctr = 1, ct = wye
SG-CTP2=1,WYE	Ctr = 1, ct = wye
SG-CTP3=1,WYE	Ctr = 1, ct = wye
SG-CTP4=1,WYE	Ctr = 1, ct = wye
SG-TRIGGER=87UT,87UT,0	Enable 87UT to log and trigger fault recording.
S#-TAP87=MANUAL,2.00,2.00	Set tap 1 = 2.00 and tap 2 = 2.00.
S#-87=0,15,0,0,2,1	Minpu = 0, slope = 15%, 2nd = disabled, 5th = disabled, URO = 2 times TAP unrestrained pickup, 2nd harm sharing = shared.
E	Exit.
Y	Save settings.

Step 3: Apply 1 multiple of tap current (2 amperes) to both A-phase Input 1 and A-phase Input 2 (at 180° phase relation to Input 1).

Step 4: To force an unrestrained trip at 1.5 times pickup, you must apply a step change in the current on Input 2 to 8.0 amps. Apply step change in current to Input 2 and record the time interval between the time the step change was initiated to the time OUT1 output contact closes (the unrestrained trip (87UT)).

Step 5: Reduce the current to Input 2 until OUT1 contact opens.

Step 6: Apply 1 multiple of tap current (2 amperes) to both A-phase Input 1 and A-phase Input 2 (at 180° phase relation to Input 1).

Step 7: To force an unrestrained trip at 5 times pickup, you must apply a step change in the current on Input 2 to 22 amperes.

Step 8: Apply step change in current to Input 2 and record the time interval between the time the step change was initiated to the time OUT1 output contact closes (the unrestrained trip (87UT)).

Step 9: Reduce the current to Input 2 until OUT1 contact opens.

Step 10: The time measured in Steps 4 and 8 should be less than those shown in Table 13-39.

Table 13-39. Restrained Trip Operate Times

Function	Differential current	Time
Unrestrained trip	1.5 times pu	Less than 2 cycles
Unrestrained trip	5 times pu	Less than 1 cycle

Step 11: (Optional.) Repeat Steps 1 through 10 for phases B and C.

Step 12: (Optional.) Repeat Steps 3 through 11 for Setting Groups 1 through 3 using the CS/CO-GROUP command to change setting groups.

Step 13: (Optional.) Repeat for each pair of CT inputs (CT1-CT3, CT1-CT4, CT2-CT3, CT2-CT4, and CT3-CT4).

Neutral Differential (87ND & 187ND)

Minimum Pickup

Purpose: To verify the accuracy of the restraint operation of the 87ND elements.

Reference Commands: SL-x87ND, SL- VO, SG-CTP, S(n)-87, S(n)-TAP87.

Note: The CDS240 has 2 Neutral Differential elements, 87ND and 187ND. The test procedure is the same; simply modify the commands for the specific element to be tested (replace “x87ND” with either “87ND” or “187ND”, depending on the element tested.

Step 1: Connect current source 1 to Terminals A1* and A1 (ground input). See Figure 13-17. An ohmmeter or continuity tester may be used to monitor output contact status.

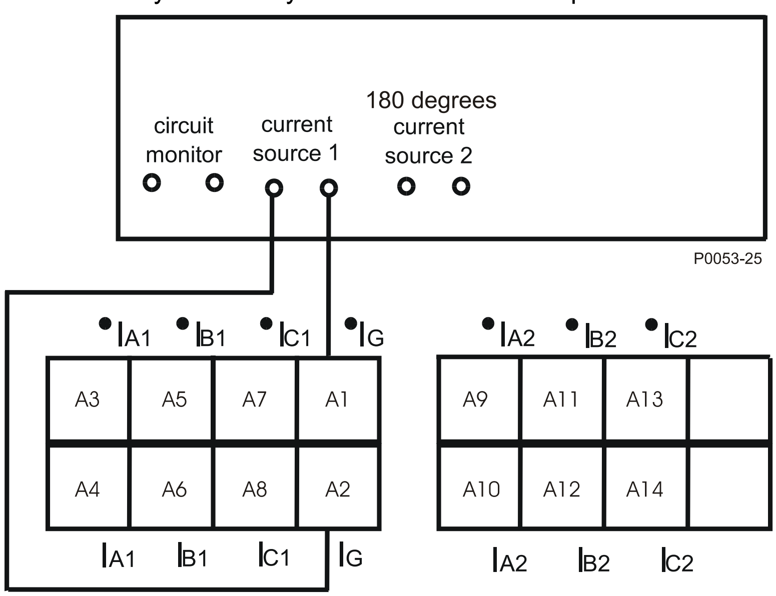


Figure 13-17. Connection for 87ND Minimum Pickup Verification
(Only Inputs 1 and 2 are shown for simplicity)

Step 2: To prepare the 87ND elements for testing, transmit the commands in Table 13-40 to the relay.

Table 13-40. 87ND Pickup Test Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=NDIFF	Name custom logic for this test.
SL-x87ND=2,0	Enables x87ND, mode = IG v. CT2, no blk.
SL-VO1=x87NDT	Enables OUT1 to close for 87ND restrained trip.
SG-CTP2=1,WYE	Input 2 ctr = 1, ct = wye
SG-CTG=1	Ground input ctr = 1.
SG-TRIGGER=87NDT, 87NDPU,0	Enable 87NDT to log and trigger fault recording.
S#-87ND=0.1,15,50m	Minpu = 0.1, slope = 15%, 50 ms (minimum time delay).
E	Exit.
Y	Save settings.

NOTE

With the relay in service, it is necessary to view the 87ND tap factors by accessing the HMI Screen \PROT\SGn\87ND\87ND.

Step 3: The relay auto tap compensation logic will calculate TAPN and TAPG values based on the CT ratios for the designated phase CTs and the ground CT. Since CTR2 and CTRG are both equal to 1:1 for this test, the TAPN and TAPG values are both equal to the minimum settings for either 5 ampere or 1-ampere relays (2.0 and 0.4 respectively). For more information on auto tap compensation, see Sidebar 13-9.

Sidebar 13-9. Auto Tap Compensation

Tap adjustment factors for the 87ND function are automatically calculated based on the equation:

*TAPN * CTRn = TAPG * CTRG*

where CTRn is the CT ratio for the CT designated in the SL-x87ND setting in the active logic. Currents are tap adjusted based on the CT ratios with the driving tap (CT input with the highest CTR) set at the minimum setting (2.0 for 5 ampere sensing relays and 0.4 for 1 ampere sensing relays) and the other tap adjusted to the driving tap based on the equation above. For more information on Auto Tap Compensation, refer to Section 4, *Protection and Control Functions, Differential Protection, 87ND Neutral Differential Function.*

Step 4: Apply current to the ground input and slowly ramp up until OUT1 closes.

Step 5: Accuracy when increasing or decreasing the input current is ±4% of setting or 75 milliamperes (whichever is larger) for 5 ampere sensing inputs and ±4% of setting or 25 milliamperes (whichever is larger) for 1 ampere sensing inputs. Verify that pickup occurred within the specified accuracy of the relay.

Step 6: Decrease the current to the ground input until the relay drops out.

Step 7: Repeat for all other values shown in Table 13-41 by substituting for minpu in the S#-x87ND command or by navigating to Screen \PROT\SGn\87ND\87ND and editing the MIN PICKUP value.

Table 13-41. Minimum Pickup Accuracy Limits (87ND)

Sensing Type	MINPU X TAP	Calculated TAPG	Pickup (A)	Low Limit (A)	High Limit (A)
5 A	0.10	2.00	0.20	0.125	0.275
	0.50	2.00	1.00	0.925	1.075
	1.00	2.00	2.00	1.920	2.080
1 A	0.10	0.40	0.04	0.015	0.065
	0.50	0.40	0.20	0.175	0.225
	1.00	0.40	0.40	0.375	0.425

Step 8: (Optional.) Repeat Steps 2 through 8 for Setting Groups 1 through 3, using the CS/CO-GROUP command to change setting groups.

Step 9: (Optional.) Repeat for 187 element and selection of associated CT inputs (CT1, CT2, CT3, CT4).

Restrained Pickup Verification (87ND & 187ND)

Purpose: To verify the accuracy of the restraint operation of the x87ND elements.

Reference Commands: SL-x87ND, SL- VO, SG-CTP, S(n)-87, S(n)-TAP87.

Step 1: Connect one current source to terminals A9 and A10 (A-phase Input 2) and a second source at 180° to terminals A1 and A2 (ground input). See Figure 13-18. An ohmmeter or continuity tester may be used to monitor output contact status.

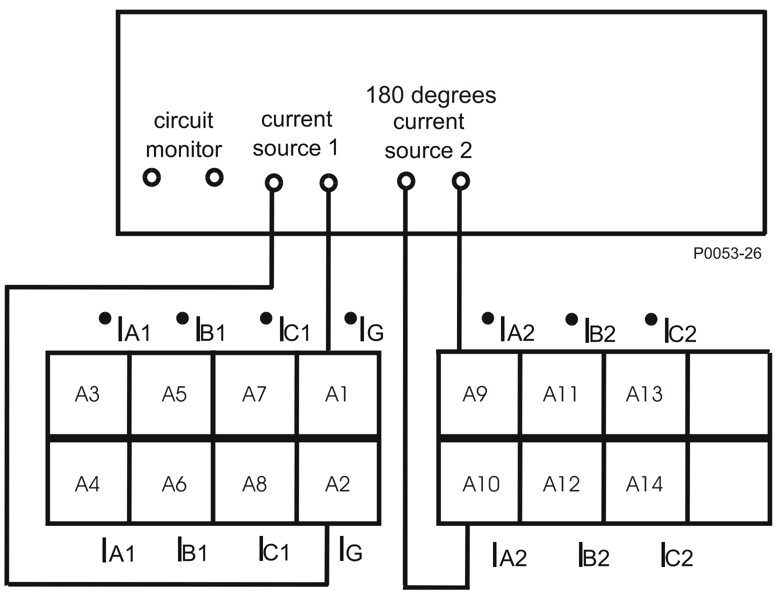


Figure 13-18. Connection for 87ND Restraint Pickup Verification (Only Inputs 1 & 2 are shown for simplicity)

Step 2: To prepare the x87ND element for testing the restraint operation accuracy, transmit the commands in Table 13-42 to the relay.

Table 13-42. 87ND Restraint Operation Accuracy Test Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=NDIFF	Name custom logic for this test.
SL-87=0	Disables 87.
SL-x87ND=2,0	Enables x87ND, mode = IG v. CT2, no blk.
SL-VO1=x87NDT	Enables OUT1 to close for 87ND restrained trip.
SG-CTP2=1,WYE	Input 2 ctr = 1, ct = wye
SG-TRIGGER=x87NDT, x87NDPU,0	Enable 87NDT to log and trigger fault recording.
S#-x87ND=0.35,15,50m	Minpu = 0.35, slope = 15%, minimum time delay.
E	Exit.
Y	Save settings.

NOTE

The ground differential function always uses the maximum restraint principle as its operating characteristic. Thus, the slope setting is simply a number between 15 and 60.

Step 3: The auto tap compensation logic of the relay will calculate TAPN and TAPG values based on CT ratios for the designated phase CTs and the ground CT. Since CTR2 and CTRG are both equal to 1:1 for this test, the TAPN and TAPG values are both equal to the minimum settings for either 5 ampere or 1-ampere relays (2.0 and 0.4 respectively).

Step 4: Input current values for this step are provided in Table 13-43 or 13-44. Apply balancing current to phase A Input 2 (represented as the Neutral column) and the ground input as indicated in each row and slowly increase phase A Input 2 until OUT1 closes.

Step 5: Remove both currents.

Step 6: Verify the restrained pickup accuracy as listed in the appropriate table (Tables 13-38 or 13-39).

Step 7: (Optional.) Repeat Steps 2 through 6 for Setting Groups 1 through 3 using the CS/CO-GROUP command to change setting groups.

Step 8: (Optional.) Repeat for 187 element and selection of associated CT inputs (CT1, CT2, CT3, CT4).

NOTE

Tables 13-43 and 13-44 show values for testing the relay either by increasing Input 2 (neutral) current or by decreasing the ground input current. Both methods are shown for convenience and either method may be used. For differences in measurement of the two methods, refer to the paragraphs in this section, *Functional Testing*, *Restrained Pickup,* and Sidebar 13-3, *Maximum Restraint Operating Characteristic*.

Table 13-43. Restraint Pickup Test Points (87ND – 5 Ampere Sensing Input)

Sensing Input Type	Minimum Pickup	Slope (%)	Neutral (Input 2) Calc. Tap = 2.00 Bal. Input (A)	PU	Ground Calc. Tap = 2.00 Bal. Input (A)	PU	Increasing Input 2 From Balance Pickup (A)			Decreasing I_G From Balance Pickup (A)		
5	0.35	15	2.00	1	2.00	1	2.70	±	0.108	1.30	±	0.075
5	0.35	15	10.00	5	10.00	5	11.76	±	0.470	8.50	±	0.340
5	0.35	30	2.00	1	2.00	1	2.86	±	0.108	1.30	±	0.075
5	0.35	30	10.00	5	10.00	5	14.29	±	0.572	7.00	±	0.280
5	0.35	45	2.00	1	2.00	1	3.64	±	0.146	1.10	±	0.075
5	0.35	45	10.00	5	10.00	5	18.18	±	0.727	5.50	±	0.220
5	0.35	60	2.00	1	2.00	1	5.00	±	0.200	0.80	±	0.075
5	0.35	60	10.00	5	10.00	5	25.00	±	0.100	4.00	±	0.160

Table 13-44. Restraint Pickup Test Points (87ND – 1 Ampere Sensing Input)

Sensing Input Type	Minimum Pickup	Slope (%)	Input 1 Tap = 2.00 Bal. Input (A)	PU	Input 2 Tap = 3.80 Bal. Input (A)	PU	Increasing Input 1 From Balance Pickup (A)			Decreasing Input 2 From Balance Pickup (A)		
1	0.35	15	0.40	1	0.40	1	0.54	±	0.025	0.26	±	0.025
1	0.35	15	2.00	5	2.00	5	2.35	±	0.094	1.70	±	0.068
1	0.35	30	0.40	1	0.40	1	0.57	±	0.025	0.26	±	0.025
1	0.35	30	2.00	5	2.00	5	2.86	±	0.114	1.40	±	0.056
1	0.35	45	0.40	1	0.40	1	0.73	±	0.029	0.22	±	0.025
1	0.35	45	2.00	5	2.00	5	3.64	±	0.146	1.10	±	0.044
1	0.35	60	0.40	1	0.40	1	1.00	±	0.040	0.16	±	0.025
1	0.35	60	2.00	5	2.00	5	5.00	±	0.200	0.80	±	0.032

Instantaneous Overcurrent (50T)

Pickup and Dropout Verification (50T/150T/250T/350T/450T/550T/650T/750T)

Purpose: To verify the accuracy of the operation of the 50T/150T/250T elements.

Reference Commands: SL-50T/150T/250T/350T/450T/550T/650T/750T, SL-GROUP, SL-VO

Step 1: Connect a current source to Terminals A3* and A4 (A phase Input 1).

Step 2: To initially prepare the 50T/150T/250T/350T/450T/550T/650T/750T elements for testing, transmit the commands in Table 13-45 to the relay.

Table 13-45. 50T/150T/250T Overcurrent Test Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=PU50	Name custom logic for this test.
SL-50T=1,0	Enables 50TP/50TN/50TQ, CT Input 1.
SL-VO1=50TPT	Enables OUT1 to close for 50T P trip.
SL-VO2=50TNT	Enables OUT2 to close for 50T N trip.
SL-VO3=50TQT	Enables OUT3 to close for 50T Q trip.
SG-CTP1=1,WYE	Input 1 ctr = 1, ct = wye
SG-TRIGGER=50TPT+ 50TNT,+50TQT50TPPU+50TNPU,+50TQN,0	Enable 50TP+50TN+50TQ to log and trigger fault recording.
E	Exit.
Y	Save settings.

Step 3: Send the first appropriate row of the setting commands S0-50TP, S0-50TN, and S0-50TQ from Table 13-46 to the relay. Using the HMI, you may also go to the front panel interface Screen \PROT\SG0\50T\50T and edit the S0-50TP, S0-50TN, and S0-50TQ settings.

Table 13-46. Instantaneous 50T Element Test Values

Sensing Input Type	Phase	Negative-Sequence	Neutral	Comments
5 A	S0-50TP=0.5,0	S0-50TQ=0,0	S0-50TN=0.5,0	Note 1
	S0-50TP=5.0,0	S0-50TQ=1.67,0	S0-50TN=5.0,0	Note 2
	S0-50TP=25.0,0	S0-50TQ=8.33,0	S0-50TN=25.0,0	Note 2
1 A	S0-50TP=0.1,0	S0-50TQ=0,0	S0-50TN=0.1,0	Note 1
	S0-50TP=1.0,0	S0-50TQ=0.33,0	S0-50TN=1.0,0	Note 2
	S0-50TP=5.0,0	S0-50TQ=1.67,0	S0-50TN=5.0,0	Note 2

Notes for Table 13-46:

1. Sets 50TP and 50TN to pick up at 0.5 amperes test current and 50TQ is disabled.
2. Sets all 50T<x> to pick up at 0.5 amperes test current.
3. See Sidebar 13-10 for more information on negative-sequence pickup.

Step 4: Slowly ramp up current on the phase A input until OUT1, OUT2, and OUT3 close. (In accordance with Note 1 for Table 13-46, OUT3 will not close when 50TQ is disabled.) Verify that pickup occurred within the specified accuracy of the relay as listed in Table 13-47.

Table 13-47. Instantaneous 50T Element Accuracy

Sensing Type	Pickup Accuracy - Phase and Neutral
A or B (1 ampere nominal systems)	±2% of setting or ±10 milliamperes
D, E, or F (5 ampere nominal systems)	±2% of setting or ±50 milliamperes

Step 5: After pickup occurs, slowly ramp the current down until OUT1, OUT2 and OUT3 open. Verify that dropout occurred as specified (95% ±2%).

Step 6: Repeat Steps 3, 4, and 5 for all values in Table 13-47. Optionally, reconnect the current source to B-phase (A5*, A6) and C-phase (A7* A8) inputs to test the response of all phases for each succeeding test.

Step 7: (Optional.) Repeat Steps 3 through 6 for phases B and C of the relay unless each phase was tested in Step 4. If so, skip this step and proceed to Step 8.

Step 8: (Optional.) Repeat Steps 1 through 7 for the 150T, 250T, 350T, 450T, 550T, 650T, and 750T elements. Use Table 13-48 or 13-49 as a reference for substituting the commands used in Step 1.

Table 13-48. Instantaneous Overcurrent 150T Element Test Logic

Replace These Commands	With These Commands For 150T Element Tests
SL-50T=1,0	SL-150T=1,0
SL-VO1=50TPT	SL-VO1=150TPT
SL-VO2=50TNT	SL-VO2=150TNT
SL-VO3=50TQT	SL-VO3=150TQT
SG-TARG=50T	SG-TARG=150T
SG-TRIGGER=50TPT+50TNT+50TQT, 50TPPU+ 50TNPU,+50TQPU,0	SG-TRIGGER=150TPT+150TNT+150TQT,150TPPU+ 150TNPU+150TQTPU,0

Table 13-49. Instantaneous Overcurrent 250T/350T/450T/550T/650T/750T Element Test Logic

Replace These Commands	With These Commands For x50T Element Tests (where x = 3,4,5,6,7)
SL-50T=1,0	SL-x50T = 1,0
SL-VO1=50TPT	SL-VO1 = x50TPT
SL-VO2=50TNT	SL-VO2 = x50TNT
SL-VO3=50TQT	SL-VO3 = x50TQT
SG-TARG=50T	SG-TARG = x50T
SG-TRIGGER=50TPT+50TNT+50TQT, 50TPPU+50TNPU+50TQPU,0	SG-TRIGGER = x50TPT+x50TNT+x50TQT,x50TPPU+ x50TNPU+x50TQTPU,0

Step 9: (Optional.) Repeat Steps 1 through 8 for the each x50T element in Setting Groups 1, 2 and 3. Use the following information as a guide to program the 50T/ 150T/ 250T/ 350T/ 450T/ 550T/ 650T/ 750T elements in higher order setting groups.

In order to program the pickup of the elements in a higher order-setting group, you would replace the *0* in the S*0*-50TP, S*0*-50TN, and S*0*-50TQ commands in Table 13-46 with a 1, 2, or 3 for Setting Groups 1, 2, or 3. Using the HMI, you can program each set of values by navigating to the appropriate setting group screen \PROT\SGn\50T\50T where n is equal to the setting group you desire. Refer to the CS/CO-GROUP command in Section 4, *Protection And Control Functions,* for more information on changing the active setting group.

To change from Setting Group 0 to Setting Group 1, execute the following commands:

CS-GROUP=1 select Setting Group 1

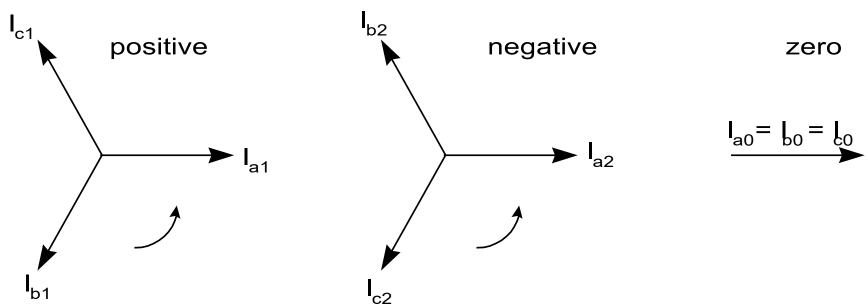
CO-GROUP=1 execute Setting Group 1

Using the basic information in Table 13-46, program the pickup of the elements for Setting Group 1 and, optionally, proceed with Group 1 testing.

Sidebar 13-10. Negative-Sequence Overcurrent Element Pickup

A three-phase electric power system can be modeled using a set of balanced equations known as symmetrical components. These components provide a practical method of analyzing power system operation during unbalanced conditions such as would occur during a fault.

The symmetrical components of a power system are segregated into positive, negative, and zero-sequence components. At any given time, all of these components may be present in load current due to unbalanced load, etc. In practice however, asymmetrical current or voltage conditions are more typical due to unbalanced loads, unbalanced system faults, open conductors, etc. In the case of an unbalanced load, this condition may be detrimental to the operation of a power system and the equipment. Under unbalanced fault conditions, these components will very likely be harmful to equipment and potentially to personnel. Positive-sequence components are comprised of balanced three-phase currents and line-to-neutral voltages supplied by power system generators. Under any of these scenarios, negative-sequence and zero-sequence components will be present. The associated figure shows the sequence components in phasor form.



Sequence Components In Phasor Form

These sequence component quantities are very useful in that they can be measured and used as operating parameters to help safeguard equipment. Proper management of the power system conserves resources and minimizes potentially harmful exposure to the public and operating personnel.

Using symmetrical components, we can say the following about phase currents:

$I_a = I_1 + I_2 + I_0$ (see the associated figure)

$I_b = \alpha^2 I_1 + \alpha I_2 + I_0$

$I_c = \alpha I_1 + \alpha^2 I_2 + I_0$ where α is an operator equal to $1.0 \angle 120°$.

From this we can derive that the equation for negative-sequence current I_2, is

$I_2 = {}^1/_3 (I_a + \alpha^2 I_b + \alpha I_c)$

Under balanced conditions, this value would be zero. If a single-phase input is applied, then a negative-sequence quantity will appear to the relay. If we let $I_b = I_c = 0$, then, $I_2 = I_a \div 3$.

Time Overcurrent (51)

Pickup and Dropout Verification (51/151/251/315/451)

Purpose: To verify the accuracy of the operation of the 51/151/251/351/451 elements.

Reference Commands: SL-51/151/251/351/451, S<n>-51.

Step 1: Connect a current source to Terminals A3* and A4 (A-phase Input 1).

Step 2: To initially prepare the x51 elements for pickup and dropout testing, send the commands in Table 13-50 to the relay.

Table 13-50. 51/151/251 Time Overcurrent Test Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N= 51	Name custom logic for this test.
SL-51=1,0	Enables 51P/51N/51Q, CT Input 1.
SL-VO1=51PT	Enables OUT1 to close for 50P trip.
SL-VO2=51NT	Enables OUT2 to close for 51N trip.
SL-VO3=51QT	Enables OUT3 to close for 51Q trip
SG-CTP1=1,WYE	Input 1 ctr = 1, ct = wye
SG-TRIGGER=51PT+ 51NT+51QT,51PPU+ 51NPU+51QPU,0	Enable 51PT+51NT+51QT to log targets and trigger fault recording
E	Exit
Y	Save settings

Step 3: Transmit to the relay the appropriate row of the setting commands S0-51P from Table 13-51. With the HMI, you may also go to the front panel interface Screen \PROT\SG0\51\51 and edit the 51P, 51N, and 51Q settings.

Table 13-51. Time Overcurrent 51 Element Test Settings

Sensing Input Type	Phase	Neutral	Negative-Sequence
1 A	S0-51P=1.0,0.5,I2	S0-51N=1.0,0.5,I2	S0-51QN=0.33,0.5,I2
5 A	S0-51P=5.0,0.5,I2	S0-51N=5.0,0.5,I2	S0-51QN=1.67,0.5,I2

Step 4: Slowly ramp up current on the phase A input until OUT1, OUT2, and OUT3 close. Verify that pickup occurred within the specified accuracy of the relay as listed in Table 13-52.

Table 13-52. Time Overcurrent 51 Element Accuracy

Sensing Type	Pickup Accuracy - Phase and Neutral
A or B (1 ampere nominal systems)	±2% of setting or ±10 milliamperes
D, E, or F (5 ampere nominal systems)	±2% of setting or ±50 milliamperes

Step 5: After pickup occurs, slowly ramp the current down until OUT1, OUT2 and OUT3 open. Verify that dropout occurred as specified (95% ±2%).

Step 6: Repeat Steps 3, 4, and 5 for all values in Table 13-46. Optionally, reconnect the current source to B-phase (A5*, A6) and C-phase (A7*, A8) inputs to test the response of all phases for each succeeding test.

Step 7: (Optional.) Repeat Steps 3 through 6 for phases B and C of the relay unless each phase was tested in Step 4. If so, skip this step and proceed to Step 8.

Step 8: (Optional.) Repeat Steps 1 through 7 for the 151/251/351/451 elements. Use Table 13-53 or 13-54 as a reference for substituting the commands used in Step 1.

Table 13-53. Time Overcurrent 151 Element Test Logic

Replace These Commands	With These Commands For 151 Element Tests
SL-51=1,0	SL-151=1,0
SL-VO1=51PT	SL-VO1=151PT
SL-VO2=51NT	SL-VO2=151NT
SL-VO3=51QT	SL-VO3=151QT
SG-TARG=51	SG-TARG=151
SG-TRIGGER=51PT+51NT+51QT, 51PPU+ 51NPU,+51QPU,0	SG-TRIGGER=151PT+151NT+151QT,151PPU+ 151NPU+151QTPU,0

Table 13-54. Time Overcurrent 251/351/451 Element Test Logic

Replace These Commands	With These Commands For x51 Element Tests (where x=2,3,4)
SL-51=1,0	SL-x51=1,0
SL-VO1=51PT	SL-VO1=x51PT
SL-VO2=51NT	SL-VO2=x51NT
SL-VO3=51QT	SL-VO3=x51QT
SG-TARG=51	SG-TARG=x51
SG-TRIGGER=51PT+51NT+51QT, 51PPU+ 51NPU,+51QPU,0	SG-TRIGGER=x51PT+x51NT+x51QT,x51PPU+ x51NPU+x51QTPU,0

Step 9: (Optional.) Repeat Steps 1 through 8 for the 51, 151, 251, 351, and 451 elements in Setting Groups 1, 2 and 3. Use the following information as a guide to program the 1/151/251/351/451 elements in higher order setting groups.

In order to program the pickup of the elements in a higher order-setting group, you would replace the *0* in the S*0*-51P, S*0*-51N, and S*0*-51Q commands in Table 13-45 with a 1, 2, or 3 for Setting Groups 1, 2, or 3. With the HMI, you can program each set of values by navigating to the appropriate setting group Screen \PROT\SGn\51\51, where n is equal to the setting group you desire. Refer to the CS/CO-GROUP command in Section 4, *Protection and Control Functions,* for more information on changing the active setting group.

To change from Setting Group 0 to Setting Group 1, execute the following commands:

CS-GROUP=1 Select Setting Group 1

CO-GROUP=1 Execute Setting Group 1

Using the basic information in Table 13-50, program the pickup of the elements for Setting Group 1 and, optionally, proceed with the testing.

Timing Verification (51/151/251/351/451)

Purpose: To verify the accuracy of the timing operation of the 51/151/251/351/451 elements.

Reference Commands: SL-51/151/251.351/451, S<n>-51

Step 1: Connect a current source to Terminals A3* and A4 (A-phase Input 1).

Step 2: To initially prepare the 51/151/251.351/451 elements for testing, send the commands in Table 13-55 to the relay.

Table 13-55. 51/151/251 Overcurrent Timing Test Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N= 51	Name custom logic for this test.
SL-51=1,0	Enables 51P/51N/51Q, CT Input 1.
SL-VO1=51PT	Enables OUT1 to close for 50P trip.
SL-VO2=51NT	Enables OUT2 to close for 51N trip.
SL-VO3=51QT	Enables OUT3 to close for 51Q trip.
SG-CTP1=1,WYE	Input 1 ctr = 1, ct = wye
SG-TRIGGER=51PT+ 51NT+51QT,51PPU+ 51NPU+51QPU,0	Enable 51PT+51NT+51QT to log targets and trigger fault recording.
E	Exit.
Y	Save settings.

Step 3: Transmit to the relay the appropriate row of the setting commands S0-51P from Table 13-56. Using the HMI, you may also go to the front panel interface Screen \PROT\SG0\50T\50T and edit the 51P, 51N, and 51Q settings.

Table 13-56. Time Overcurrent 51 Element Test Settings

Sensing Input Type	Phase	Neutral	Negative-Sequence
1 A	S0-51P=1.0,0.5,I2	S0-51N=1.0,0.5,I2	S0-51Q=0.33,0.5,I2
5 A	S0-51P=5.0,0.5,I2	S0-51N=5.0,0.5,I2	S0-51Q=1.67,0.5,I2

Note: See Sidebar 13-10 for more information on negative-sequence pickup.

Step 4: Using the values listed in Table 13-57, apply the current listed to the A phase current input and measure the time between the application of current and the time it takes for the relay outputs OUT1, OUT2, and OUT3 to close. Verify that the relay performs with the specified limits. An ohmmeter or continuity tester may be used to monitor the output contacts status.

Step 5: After each pickup occurs, slowly ramp current down until OUT1, OUT2, and OUT3 open. Dropout should occur at 95% ±2%.

Table 13-57. Time Overcurrent 51 Element Test Values

Sensing Input Type	Time Dial	Applied Current	Relay Trip	
			Lower Limit	**Higher Limit**
1 A	0.5	1.50 A	0.748 sec	0.827 sec
		5.00 A	0.190 sec	0.240 sec
	5.0	1.50 A	7.244 sec	8.007 sec
		5.00 A	1.798 sec	1.988 sec
	9.9	1.50 A	14.318 sec	15.825 sec
		5.00 A	3.535 sec	3.907 sec
5 A	0.5	7.5 A	0.748 sec	0.827 sec
		25.0 A	0.190 sec	0.240 sec
	5.0	7.5 A	7.244 sec	8.007 sec
		25.0 A	1.798 sec	1.988 sec
	9.9	7.5 A	14.318 sec	15.825 sec
		25.0 A	3.535 sec	3.907 sec

Step 6: Repeat Steps 3, 4 and 5 for all current and time dial settings listed (using the command S0-51P, 51N, and 51Q or by navigating to Screen \PROT\SG0\51\51 to edit the 51P, 51N, and 51Q settings) and, optionally, reconnect the current source to B-phase (A5, A6) and C-phase (A7, A8) inputs to test the response of all phases for each succeeding test.

Step 7: (Optional.) Repeat Steps 2 through 6 for B and C phase elements unless each phase was tested in previous steps. If so, skip this step and proceed to Step 8.

Step 8: (Optional.) Repeat Steps 1 through 7 for the 151, 251, 351, and 451 elements respectively. Use Table 13-51 or 13-52 as a reference for substituting the commands used in Step 1.

Step 9: (Optional.) Repeat Steps 1 through 8 for the 51, 151, 251, 351, and 451 elements in Setting Groups 1, 2, and 3. Use the following information as a guide to program the 51/151/251/351/451 elements in higher order setting groups.

In order to program the pickup of the elements in a higher order-setting group, you would replace the *0* in the S*0*-51P, S*0*-51N, and S*0*-51Q commands in Table 13-50 with either a 1, 2 or 3 for Setting Groups 1, 2 or 3. Or, you can program each set of values by navigating to the appropriate setting group Screen \PROT\SGn\51\51 where n is equal to the setting group you desire. Refer to the CS/CO-GROUP command in Section 4, *Protection and Control Functions,* for more information on changing the active setting group.

To change from Setting Group 0 to Setting Group 1, execute the following commands:

CS-GROUP=1 Select Setting Group 1

CO-GROUP=1 Execute Setting Group 1

Using the basic information in Table 13-50, program the pickup of the elements for Setting Group 1 and, optionally, proceed with the testing.

Volts per Hertz Overexcitation (24)

Purpose: To verify the operating accuracy of the 24 protection element.

Reference Commands: SL-24, SL-VO, SL-GROUP, RG-STAT

Overexcitation, Volts/Hertz Alarm, Integrating Time and Definite Time Pickup Verification

The BE1-CDS240 detects overexcitation conditions with a volts/hertz element that consist of one alarm setting, one integrating time characteristic with selectable exponents (3 sets of time curves as shown in Appendix C, *Overexcitation (24) Inverse Time Curves)* and two definite time characteristics. Note that V/Hz nominal is 69.3 volts (phase to neutral) x square root 3/60 Hz, or 2.001. That is, at nominal voltage and frequency (60 Hz system) 1 pu V/Hz = 2.001.

Step 1: Prepare the 24 pickup function for testing by transmitting the commands in Table 13-58 to the relay. Reset targets.

Table 13-58. V/Hz Alarm, Integrating Time, and Definite Time Test Commands

Command	Purpose
A=	Gain write access
SL-N=NONE	Zero out custom logic settings Overwrite with logic = None settings
Y	Confirm overwrite
SL-N=24	Sets 24 as custom logic name
SG-VTP=1,4W,PN,PN	Set VT phase voltage parameters
SG-NOM=69.3,5.00	Set nominal voltage to 69.3 P to N
SA-MAJ=31	Enables Major Alarm Light for 24 alarm
SL-24=1,0	Enables 24, disables blocking
SG-TRIG=24T, 24PU, 0	Enables 24 to log and trigger fault recording
EXIT;Y	Exit and save settings

Step 2: Using Table 13-59 as a guide, transmit the setting commands to the relay.

Table 13-59. Alarm, Integrating Time, and Definite Time Pickup Settings (Step 2)

Command	Purpose
SA-24=2.05,0.0	Set 24 Alarm at 1.025% of nominal (2.05V/Hz) and time delay = 0.
S0-24=2.1,0.0,0.0,2.0	Set 24 Integrating PU at 1.05% of nominal (2.10 V/Hz), Trip Time Dial = 0, Reset Time Dial = 0, time curve exponent = 2.
S0-24D=0.0,50ms,0.0, 50ms	Sets 24 definite pickups at 0 and time definite time delay at minimum.

Step 3: Prepare to monitor the operation of the 24 Alarm and Trip functions. Alarm operation can be verified by monitoring the Major Alarm LED on the relay's front panel. Operation of 24T by can be verified by monitoring OUT1.

Step 4: Connect a 120 Vac, three-phase, 50 or 60-hertz voltage source (depending on user's nominal frequency) to Terminals B9 (A-phase), B10 (B-phase), B11 (C-phase), and B-12 (neutral). Refer to Figure 13-1 for terminal locations.

Step 5: Apply A-phase voltage at nominal frequency and slowly increase until the Major Alarm LED lights (V/H PU x Freq x % Alarm = PU). Pickup should occur within ±2 percent or 1 volt of the Alarm setting. Continue increasing the A-phase voltage until OUT1 closes (V/H Trip x Freq = PU). Pickup should occur within ±2 percent or 1 volt of the Trip pickup setting. Slowly decrease the A-phase voltage until OUT1 opens. Dropout should occur at 95% or higher of the actual pickup value for both Trip and Alarm.

Step 6: Verify the 24 target on the HMI.

Step 7: (Optional.) Repeat Steps 2 through 6 for higher and lower alarm and trip pickup settings.

Step 8: (Optional.) Repeat Steps 2 through 6 for frequencies other than nominal.

Step 9: (Optional.) Repeat Steps 2 through 8 for the B-phase and C-phase voltage inputs.

Step 10: (Optional.) Repeat Steps 2 through 9 for Setting Group 1.

Step 11: Using Table 13-60 as a guide, transmit the setting commands to the relay.

Table 13-60. Alarm, Integrating Time, and Definite Time Pickup Settings (Step 11)

Command	Purpose
SA-24=0,0.0	Set 24 Alarm at 0 and time delay = 0.
S0-24=0.0,0.0,0.0,2.0	Set 24 Integrating PU at 0, Trip Time Dial = 0, Reset Time Dial = 0, time curve exponent = 2.
S0-24D=2.36,50ms,0.0, 50ms	Set the first 24 definite pickup at 118% of nominal (2.36 V/Hz) and definite time delay at minimum. Set second pickup at 0 and time delay at minimum.

Step 12: Repeat Steps 2 through 10 for the first definite time pickup

Step 13: Using Table 13-60 as a guide, set first definite time setting to 0 and second to 2.36 V/Hz.

Step 14: Repeat Steps 2 through 10 for the second definite time delay.

Overexcitation, Volts/Hertz Integrating Trip Time Verification

The following test uses the (M-1)^2 time curve.

Step 1: Using Table 13-61 as a guide, transmit the setting commands to the relay.

Table 13-61. V/Hz Trip Time Settings

Settings	Purpose
S0-24=2.1,0.5,0.0,2.0	Sets integrating 24 PU at 1.05% of nominal (2.10 V/Hz), Trip Time Dial = 0.5, Reset Time Dial = 0, time curve exponent = 2.

Step 2: Connect a 120 Vac, three-phase, 50 or 60-hertz voltage source (depending on user's nominal frequency) to Terminals B9 (A-phase), B10 (B-phase), B11 (C-phase), and B12 (neutral). Refer to Figure 13-1 for terminal locations.

Step 3: All integrating timing tests are based on % of nominal Volts/Hertz (1 PU value). Refer to Appendix C of the BE1-CDS240 instruction manual for time curves. Apply A-phase voltage at nominal frequency and a value of voltage that equals the V/Hz % of nominal shown in Table 13-62 for Time Dial 0.5. Measure the time between the application of voltage and the closure of OUT1. Verify that the relay operates within ±5% of the values shown in Table 13-62.

Table 13-62. V/Hz Trip Times

Percent of Nominal V/Hz	Time Dial 0.5	Time Dial 1.0	Time Dial 2.0
110%	50 seconds	100 seconds	200 seconds
120%	12.5 seconds	25 seconds	50 seconds
140%	3.1 seconds	6.3 seconds	12.5 seconds

Step 4: Repeat the test for Time Dial 1.0 and 2.0.

Step 5: (Optional.) Repeat Steps 2 through 4 for the B-phase and C-phase voltage inputs.

Step 6: (Optional.) Repeat Steps 2 through 5 for Setting Group 1.

Overexcitation, Volts/Hertz Linear Reset Time Verification

The following reset time test is an approximation. For a more precise test, use a computer driven test set and the integration time equations found in Section 4, *Protection and Control*, *Voltage Protection, 24 Function*, or Appendix C, *Overexcitation (24) Inverse Time Curves*.

Step 1: Using Table 13-63 as a guide, transmit the setting commands to the relay.

Table 13-63. V/Hz Reset Time Pickup Settings

Settings	Purpose
S0-24=2.1,0.5,0.2,2.0	Sets 24 PU at 1.05% of nominal (2.10 V/Hz), Trip Time Dial = 0.5, Reset Time Dial =0.2, time curve exponent = 2.

Step 2: Connect a 120 Vac, three-phase, 50 or 60-hertz voltage source (depending on user's nominal frequency) to Terminals B9 (A-phase), B10 (B-phase), B11 (C-phase), and B12 (neutral). Refer to Figure 13-1 for terminal locations.

Step 3: Apply A-phase voltage at nominal frequency and a value of voltage that equals the V/Hz % of nominal shown in Table 13-64. Measure the time between the application of voltage and the closure of OUT1 (12.5 seconds). Remove the test voltage and reapply after 5 seconds has elapsed.

With a Reset Time Dial setting of 0.2, the total time to reset, after trip is removed, will be approximately 10 seconds. (See Section 4, *Protection and Control, Voltage Protection*, for more details.) Reapplying the test voltage after 5 seconds will yield a trip time of approximately ½ its original value or 6.25 seconds for Trip Time Dial 0.5. This verifies that the reset time delay is working.

Table 13-64. V/Hz Reset Time

Percent of Nominal V/Hz	Time Dial 0.5	Time Dial 1.0	Time Dial 2.0
120%	12.5 seconds	25 seconds	50 seconds

Step 4: Repeat Step 3 for Trip Time Dial 1.0 and 2.0 (½ trip time is approximately 12.5 seconds for Time Dial 1.0, and 25 seconds for Time Dial 2.0. (Still reapply voltage after 5 seconds as reset time dial is still 0.2.)

Step 5: (Optional.) Repeat Steps 2 through 4 for the B-phase and C-phase voltage inputs.

Step 6: (Optional.) Repeat Steps 2 through 5 for Setting Group 1.

Overexcitation, Volts/Hertz Definite Time (24D)Trip Time Verification

The following test uses the (M-1)^2 time curve.

Step 1: Using Table 13-65 as a guide, transmit the setting commands to the relay.

Table 13-65. Definite Time V/Hz Trip Time Settings

Settings	Purpose
S0-24D= 2.36,50ms,0.0, 50ms	Set the first 24 definite pickup at 118% of nominal (2.36 V/Hz) and definite time delay at minimum. Set second pickup at 0 and time delay at minimum.

Step 2: Connect a 120 Vac, three-phase, 50 or 60-hertz voltage source (depending on user's nominal frequency) to Terminals B9 (A-phase), B10 (B-phase), B11 (C-phase), and B12 (neutral). Refer to Figure 13-1 for terminal locations.

Step 3: Definite timing tests are based on % of nominal Volts/Hertz (1 PU value). Apply A-phase voltage at nominal frequency and a value of voltage that equals the V/Hz % of nominal shown in Table 13-66 (118% or 2.36 V/Hz). Measure the time between the application of voltage and the closure of OUT1. Verify that the relay operates within ±0.5% or 1 cycle, whichever is greater, for the TD settings shown in Table 13-66.

Table 13-66. Definite Time (24D) V/Hz Trip Times

Percent of Nominal V/Hz	Minimum Time Delay	Second Time Delay	Third Time Delay
118%	0.50 seconds	5 seconds	20 seconds

Step 4: (Optional.) Repeat Steps 2 through 4 for the B-phase and C-phase voltage inputs.

Step 5: (Optional.) Repeat Steps 2 through 5 for Setting Group 1.

Step 6: Set first definite time pickup setting to 0 and set the second definite time pickup setting to 2.36 V/Hz.

Step 7: Repeat Steps 2 through 5 for the second definite time function.

Undervoltage (27/127) and Overvoltage (59/159)

Phase Undervoltage and Overvoltage Pickup Verification

Step 1: Prepare the 27P and 59P pickup functions for testing by transmitting the commands in Table 13-67 to the relay. Reset targets.

Table 13-67. 27P and 59P Pickup Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=27_59	Sets 27_59 as custom logic name.
SG-VT=1,4W,PN,PN	Set VT phase voltage parameters.
SA-MAJ=0	Disables major Alarm.
SL-27=1,0	Enables 27P, disables blocking.
SL-59=1,0	Enables 59P, disables blocking.
SL-VO1=27T+59T	Enables OUT1 to close for 27 or 59 trip.
SG-TRIG=27T+59TU,27PU+59PU,0	Enables 27 and 59 to log and trigger fault record.
EXIT;Y	Exit and save settings.

Step 2: Using Table 13-68 as a guide, transmit the first row of setting commands (highest 27 PU, lowest 59 PU) to the relay.

Table 13-68. 27 and 59 Pickup Settings

Phase Pickup Settings		Purpose
Undervoltage	Overvoltage	
S0-27=96,50ms	S0-59=132,50 ms	Sets 27 PU at 96 V, 59 at 132 V, TD at min
S0-27=84,50ms	S0-59=144, 50 ms	Sets 27 PU at 84 V, 59 at 144 V, TD at min
S0-27=72,50ms	S0-59=156, 50 ms	Sets 27 PU at 72 V, 59 at 156 V, TD at min

Step 3: Prepare to monitor the 27 and 59 function operation. Operation can be verified by monitoring Out 1.

Step 4: Connect and apply a 120 Vac, three-phase voltage source to terminals B9 (A-phase), B10 (B-phase), B11 (C-phase), and B12 (Neutral). Refer to Figure 13-1 for terminal locations.

Step 5: Slowly decrease the A-phase voltage until OUT1 closes. Pickup should occur within +2 percent or 1 volt of the 27 pickup setting. Slowly increase the A-phase voltage until OUT1 opens. Dropout should occur between 102 and 103 percent of the actual pickup value. Verify the 27A target and the HMI. Reset the target.

Step 6: Continue increasing the A-phase voltage until OUT1 closes. Pickup should occur within +2 percent or 1 volt of the 59 pickup setting. Slowly reduce the A-phase voltage until OUT1 opens. Dropout should occur between 97 and 98 percent of the actual pickup value. Verify 59A target on the HMI.

Step 7: Verify the pickup and dropout accuracy of the middle and upper pickup settings listed in Table 13-68.

Step 8: (Optional.) Repeat Steps 2 through 7 for the B-phase and C-phase voltage inputs.

Step 9: (Optional.) Repeat Steps 2 through 8 for Setting Groups 1, 2, and 3.

Step 10: (Optional.) Repeat Steps 2 through 7 for 127 and 159 elements).

Phase Undervoltage and Overvoltage Timing Verification

Step 1: Using Table 13-69 as a guide, transmit the first row of setting commands to the relay.

Table 13-69. 27, 59 Pickup and Time Delay Settings

Pickup and Time Delay Settings		Purpose
Undervoltage	Overvoltage	
S0-27=72,2s	S0-59=156,2s	Sets 27 PU at 72 V, 59 at 156 V Sets 27 TD, 59P TD at 2 seconds
S0-27=,5s	S0-59=,5s	Sets 27 TD, 59P TD at 5 seconds
S0-27=,10s	S0-59=,10s	Sets 27 TD, 59P TD at 10 seconds

Step 2: Prepare to monitor the 27 and 59 timings. Timing accuracy is verified by measuring the elapsed time between a sensing voltage change and OUT1 closing.

Step 3: Connect and apply a 120 Vac, three-phase voltage source to terminals B9 (A-phase), B10 (B-phase), B11 (C-phase), and B12 (Neutral). Refer to Figure 13-1 for terminal locations.

Step 4: Step the A-phase voltage down to 68 volts. Measure the time delay and verify the accuracy of the 27 time delay setting. Timing accuracy is +5 percent or +3 cycles of the time delay setting.

Step 5: Step the A-phase voltage up to 165 volts. Measure the time delay and verify the accuracy of the 59 time delay setting. Timing accuracy is +5 percent or +3 cycles of the time delay setting.

Step 6: Repeat Steps 5 and 6 for the middle and upper time delay settings of Table 13-69.

Step 7: (Optional.) Repeat Steps 2 through 6 for the B-phase and C-phase voltage inputs.

Step 8: (Optional.) Repeat Steps 2 through 7 for Setting Groups 1, 2, and 3.

Step 9: (Optional.) Repeat Steps 2 through 7 for 127 and 159 elements.

Negative-Sequence Voltage (47)

Negative-Sequence Voltage Pickup Verification

Step 1: Prepare the 47 pickup function for testing by transmitting the commands in Table 13-70 to the relay. Reset targets.

Table 13-70. 47 Pickup Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=47	Sets 47 as custom logic name.
SL-27=0	Disables 27.
SL-59=0	Disables 59.
SL-47=1,0	Enables 47, disables blocking.
SP-60FL=ENA,PN	Removes 60FL block from 47 element.
SL-VO1=47T	Enables OUT1 to close for 47 trip.
SG-TRIG = 47T,47PU, 0	Enables 47 to log and trigger fault recording.
EXIT;Y	Exit and save settings.

Step 2: Using Table 13-71 as a guide, transmit the first row of setting commands to the relay.

Table 13-71. 47 Pickup Settings

Pickup Settings (Negative-Sequence Voltage)	Purpose
S0-47=24, 50ms	Sets 47 PU at 24 V, time delay at minimum
S0-47=30, 50ms	Sets 47 PU at 30 V, time delay at minimum
S0-47=36, 50ms	Sets 47 PU at 36 V, time delay at minimum

Step 3: Prepare to monitor 47 function operation. Operation can be verified by monitoring OUT1.

Step 4: Connect and apply a 50 Vac, single-phase voltage source to terminals B9 (A-phase) and B12 (Neutral). Refer to Figure 13-1 for terminal locations.

Step 5: Negative-sequence voltage is 1/3 the phase voltage. Therefore, for a V2 setting of 24 volts, the applied phase voltage will be 24 x 3 or 72 volts. Slowly increase the A-phase voltage until OUT1 closes. Pickup should occur within ±2 percent or 1 volt of the pickup setting. Slowly decrease the A-phase voltage until OUT1 opens. Dropout should occur between 97 and 98 percent of the actual pickup value. Verify the 47 target on the HMI.

Step 6: Verify the pickup and dropout accuracy of the middle and upper 47 pickup settings.

Step 7: (Optional.) Repeat Steps 2 through 6 for the B-phase and C-phase voltage inputs.

Step 8: (Optional.) Repeat Steps 2 through 7 for Setting Groups 1, 2, and 3.

Negative-Sequence Voltage Timing Verification

Step 1: Using Table 13-72 as a guide, transmit the first row of setting commands to the relay.

Table 13-72. 47 Pickup and Time Delay Settings

Pickup and Time Delay Settings	Purpose
S0-47=36,2S	Sets 47 PU at 36 V, 47 TD at 2 seconds
S0-47=,5S	Sets 47 TD at 5 seconds
S0-47=,10S	Sets 47 TD at 10 seconds

Step 2: Prepare to monitor the 47 timings. Timing accuracy is verified by measuring the elapsed time between a sensing voltage change and OUT1 closing.

Step 3: Connect and apply a 100 Vac, single-phase voltage source to terminals B9 (A-phase) and B12 (Neutral). Refer to Figure 13-3 for terminal locations.

Step 4: Step the A-phase voltage up to 115 volts. Measure the time delay and verify the accuracy of the 47-time delay setting. Timing accuracy is ±5 percent or ±3 cycles of the time delay setting.

Step 5: Repeat Step 4 for the middle and upper time delay settings of Table 13-72.

Step 6: (Optional.) Repeat Steps 2 through 5 for the B-phase and C-phase voltage inputs.

Step 7: (Optional.) Repeat Steps 2 through 6 for Setting Groups 1, 2, and 3.

Over/Underfrequency (81/181/281/381/481/581)

Purpose: To verify the operating accuracy of the 81/181/281/381/481/581 protection elements.

Reference Commands: SL-x81, SL-VO

Pickup Verification

Step 1: Prepare the x81 pickup functions for pickup testing by transmitting the commands in Table 13-73 to the relay.

Table 13-73. x81 Pickup Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=FREQTEST	Sets FREQTEST as custom logic name.
SL-81=1,0	Enables 81, disables blocking.
SL-181=1,0	Enables 181, disables blocking.
SL-281=1,0	Enables 281, disables blocking.
SL-381=1,0	Enables 381, disables blocking.
SL-481=1,0	Enables 481, disables blocking.
SL-581=1,0	Enables 581, disables blocking.
SL-VO1=81T+581T	Enables OUT1 to close for 81 or 581 trip.
SL-VO2=181T	Enables OUT2 to close for 181 trip.
SL-VO3=281T	Enables OUT3 to close for 281 trip.
SL-VO4=381T	Enables OUT4 to close for 381 trip.
SL-VO5=481T	Enables OUT5 to close for 481 trip.
EXIT;Y	Exit and save settings.

Step 2: Transmit the commands in Table 13-74 to the relay. These commands set the pickup value and operating mode (underfrequency or overfrequency) for each of the x81 functions.

Table 13-74. x81 Pickup and Mode Settings

Pickup and Mode Settings	Purpose
S0-81=42,0,U	Sets 81 PU at 42 Hz, underfrequency
S0-181=46,0,U	Sets 181 PU at 46 Hz, underfrequency
S0-281=48,0,U	Sets 281 PU at 48 Hz, underfrequency
S0-481=67,0,O	Sets 481 PU at 67 Hz, overfrequency
S0-581=69,0,O	Sets 581 PU at 69 Hz, overfrequency

Step 3: Prepare to monitor x81 function operation. Operation can be verified by monitoring the programmed output contacts or HMI Screen 1.5.2.

Step 4: Connect and apply a 120 Vac, 60-hertz voltage source to terminals B9 (A-phase) and B12 (Neutral).

Step 5: Slowly decrease the frequency of the applied voltage until OUT3 (281) closes. Pickup should occur within ±0.01 hertz of the pickup setting. Slowly increase the frequency until OUT3 opens. Dropout should occur at 0.02 hertz above or below the pickup setting.

Step 6: Repeat Step 5 for the 181 (OUT2) and 81 (OUT1) functions.

Step 7: Repeat Step 4.

Step 8: Slowly increase the frequency of the applied voltage until OUT4 (381) closes. Pickup should occur within ±0.01 hertz of the pickup setting. Slowly decrease the frequency until OUT4 opens. Dropout should occur at 0.02 hertz above or below the pickup setting.

Step 9: Repeat Step 5 for the 481 (OUT5) and 581 (OUT1) functions.

Step 10: Repeat Steps 5 through 9.

Step 11: (Optional.) Repeat Steps 1 through 11 for Setting Groups 1, 2, and 3.

Time Delay Verification

Step 1: Prepare the x81 functions for time delay testing by transmitting the commands in the first column (2 second TD) of Table 13-75 to the relay. Commands entered in Tables 13-73 and 13-74 should be retained for this test.

Table 13-75. x81 Time Delay Settings

Pickup and Time Delay Settings			Purpose
2 Second TD	5 Second TD	10 Second TD	
S0-81=,2S	S0-81=,5S	S0-81=,10S	Sets 81 TD
S0-181=,2S	S0-181=,5S	S0-181=,10S	Sets 181 TD
S0-281=,2S	S0-281=,5S	S0-281=,10S	Sets 281 TD
S0-381=,2S	S0-381=,5S	S0-381=,10S	Sets 381 TD
S0-481=,2S	S0-481=,5S	S0-481=,10S	Sets 481 TD
S0-581=,2S	S0-581=,5S	S0-581=,10S	Sets 581 TD

Step 2: Prepare to monitor the x81 timings. Timing accuracy is verified by measuring the elapsed time between a frequency change and programmed output closing.

Step 3: Connect and apply a 120 Vac, 60-hertz voltage source to terminals B9 (A-phase) and B12 (Neutral).

Step 4: Step the frequency of the applied voltage down from 60 hertz to a value below the 281 underfrequency setting. Measure the time delay and verify the accuracy of the 281 time delay setting. Timing accuracy is ±0.5 percent or ±1 cycle (plus 3 cycle recognition time) of the time delay setting.

Step 5: Repeat Step 4 for the 181 (OUT2) and 81 (OUT1) elements.

Step 6: Step the frequency of the applied voltage up from 60 hertz to a value above the 381 overfrequency setting. Measure the time delay and verify the accuracy of the 281 time delay setting. Timing accuracy is ±0.5 percent or ±1 cycle (plus 3 cycle recognition time) of the time delay setting.

Step 7: Repeat Step 6 for the 481 (OUT5) and 581 (OUT1) elements.

Step 8: Transmit the commands in the second column (5 Second TD) of Table 13-75 to the relay.

Step 9: Repeat Steps 2 through 7 with a time delay setting of 5 seconds.

Step 10: Transmit the commands in the third column (10 Second TD) of Table 13-75 to the relay.

Step 11: Repeat Steps 2 through 7 with a time delay setting of 10 seconds.

Step 12: (Optional.) Repeat Steps 1 through 11 for Setting Groups 1, 2, and 3.

Breaker Failure (50BF/150BF/250BF/350BF)

Purpose: To verify the operation of the breaker failure (BF) elements.

Reference Commands: SL-x50BF, S<x>-x50BF

The CDS240 has two types of Breaker Failure Initiate, one being contact only, and the other being current supervised relay trip initiate. The following tests are for **Contact Only Initiate**.

Step 1: Prepare the 50BF function block for testing by transmitting the commands in Table 13-76 to the relay.

Table 13-76. 50BF, BFI52 Contact Initiate Test Commands

Command	Purpose
A=	Gain write access
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite
SL-N=50BF-CONTACT	Sets 50BF as custom logic name
SL-50BF=1,0,IN2,/IN1,0	Enables BF CT Input 1, Disable BFI50, IN2 = BFI52 initiate, /IN1 = Breaker Position, No block
SL-VO1=BFT1	Enables OUT1 to close for BF Trip 1
SL-VO2=BFRT1	Enables OUT2 to close for BF Retrip 1
SG-CTP=1,WYE	Input 1 ctr = 1, ct = wye
SG-TRIGGER=BFT1,BFRT1,0	Enable BFT1 to log and trigger fault recording
S0-50BF=0,0,0,100m	Set Control Timer = 0, PFD & GFD = 0, BF time delay at minimum
EXIT	Exit
Y	Save settings

Step 2: IN1 is used to simulate breaker status as supplied by a “b” contact from the circuit breaker. With no wetting voltage applied to relay Input IN1, the relay considers the breaker closed as a result of the /IN1 designation at the breaker status input of the breaker failure element. A switched wetting voltage at IN2 is used to simulate an external BFI52 initiate contact for starting the Breaker Failure Timer. This input is also used to start the test set timer and OUT1 of the relay is used to stop the test set timer. OUT2 should be monitored to verify operation of the re-trip circuit upon breaker failure initiate.

Step 3: With no wetting voltage to relay Input IN1, switch on the wetting voltage to IN2 and measure the operate time. Timer Accuracy = ±0.5% or ±½ cycles), whichever is greater.

Step 4: Apply wetting voltage to IN1 and repeat Step 3. There should be no operation.

Step 5: Repeat Step 3 at 200 ms and 300 ms.

Step 6: Repeat Steps 3, 4, and 5 for 150BF, 250BF, and 350BF. For 150BF use BFT2 and BFRT2. For 250BF use BFT3 and BFRT3 and for 350BF use BFT4 and BFRT4. Make appropriate changes in Table 13-76 for each element tested.

The following tests are for **Current Supervised relay trip initiates**. Any or all relay trips can be used, 87R, 87U, 50T, 51, etc. For ease of testing, the 50TPT variable will be used in the following tests.

Step 7: Prepare the 50BF function block for testing by transmitting the commands in Table 13-77.

Table 13-77. 50BF, BFI50 Current Supervised Relay Trip Initiate Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = none settings.
Y	Confirm overwrite.
SL-N=50BF-CURRENT	Sets 50BF as custom logic name.
SL-50BF=1,50TPT,0,0,0	Enables BF CT Input 1, 50TPT=BFI50 initiate, Disable BFI52 initiate, Disable Breaker Position, No block.
SL-VO1=BFT1	Enables OUT1 to close for BF Trip 1.
SL-VO2=BFRT1	Enables OUT2 to close for BF Retrip 1.
SA-LGC=5	Set Logic Alarm to BF1 Alarm (#5).
SL-VO3=ALMLGC	Enables OUT3 to close for BF1 Alarm.
SG-CTP=1,WYE	Input 1 ctr = 1, ct = wye
SG-TRIGGER=BFT1,BFRT1,0	Enable BFT1 to log and trigger fault recording.
S0-50TP=2.0,0	Set pickup at 2 amps, 0 ms time delay.
S0-50BF=0m,1.0,1.0,50m	Set Control Timer =0 ms, PFD = 1 amp & GFD = 1amp, BF time delay at minimum.
EXIT	Exit.
Y	Save settings

The BF current detector dropout setting (I=0 on BESTCOMS logic diagram) is a fixed value that is determined by the relay current sensing type. Table 13-78 lists the pickup setting for each current sensing type.

Table 13-78. BF Current Detector Dropout Settings

Sensing Type	Dropout Setting
A or B (1 ampere nominal systems)	90 mA
D, E, or F (5 ampere nominal systems)	450 mA

Step 8: In the current supervised Breaker Failure logic, load current must be above current detector dropout settings (Table 13-75), fault current must be above Phase or Ground Fault Detector setting (see Section 4 for range), fault current must be above the 50TP pickup setting to get a BFI 50 initiate and all must occur within the set Control Time including Breaker Failure Time Delay. If the Control Timer expires before BFT1 goes TRUE, BFT is blocked and the Breaker Failure alarm becomes TRUE.

Step 9: Connect a current source to terminals A3 and A4 (A-phase input Current Circuit 1). Apply 50% of nominal current to the relay and note operation of OUT1 and 2. Slowly decrease the current applied until OUT2 (and subsequently OUT1) opens. Slowly increase current until OUT2 operates. Fault Detector Pickup should be ±2% of setting and dropout should be 95% of pickup.

Step 10: Set Phase and Ground Fault Detectors at minimum. Repeat the dropout test in Step 9 to verify current detector dropout. Compare the applied current to the current values listed in Table 13-79. Verify that dropout occurred between the lower and upper limits for your relay.

Table 13-79. BF Dropout Limits

Sensing Type	Lower Dropout Limit	Upper Dropout Limit
A or B (1 ampere nominal systems)	0.09 A	0.11 A
D, E or F (5 ampere nominal systems)	0.45 A	0.55 A

Step 11: Transmit the commands in Table 13-80 to set the BF time delay.

Table 13-80. BF Time Delay Commands

Command	Purpose
A=	Gains write access.
S0-50BF=100m,1.0,1.0,50m	Sets BF time delay at 100 milliseconds.
EXIT	Exit.
Y	Save settings.

Step 12: Verify the BF time delay by applying nominal current for the duration given in the following steps:

1. Apply nominal current to phase A for 4 cycles (67 ms at 60 Hz). No trip should occur.
2. Apply nominal current to phase A for 5 cycles. (83 ms at 60 Hz). No trip should occur.
3. Apply nominal current to phase A for 7 cycles (117 ms at 60 Hz). A BF trip should occur. Use the RS-LGC command to retrieve an SER report and verify that a BF trip was logged 100 milliseconds ±0.5 percent or ±½ cycles; whichever is greater plus 2¼ cycles maximum for currents ≥ 5 times the pickup setting. Three cycles maximum for a current of 1.5 times pickup. Four cycles maximum for a current of 1.05 times the pickup setting.

Step 13: (Optional.) Raise 50TP pickup setting to 10 amps and apply nominal current to the relay. Note that OUT1 and 2 do not operate. No initiate prevents operation of the breaker failure function, blocking the breaker fail logic.

Step 14: Verify Control Time function by first transmitting the settings in Table 13-81.

Table 13-81. Control Time Delay Commands

Command	Purpose
A=	Gain write access
S0-50TP=2.0,0	Set pickup at 2 amps, 0ms time delay
S0-50BF=100m,1.0,1.0,200m	Set Control Timer= 0 ms, PFD = 1amp & GFD = 1amp, BF time delay at 200 ms
EXIT	Exit
Y	Save settings

Step 15: Connect a current source to terminals A3* and A4 (A-phase input Current Circuit 1). Apply nominal current to the relay and note operation of OUT3 and no operation of OUT1 and 2. To verify control time, apply nominal current and start the test set timer. Use OUT3 to stop the timer. Timer Accuracy = ±0.5% or ±½ cycles; whichever is greater.

Step 16: (Optional.) Repeat Steps 3 through 9 for the phase B and phase C elements.

Step 17: Repeat Steps 1 through 10 for the 150BF, 250BF, and 350BF elements.

Virtual Switch Verification (43/143/243/343/443/543/643/743)

To test the virtual switches, we verify each mode of operation but do not verify each of the eight virtual switches. In your testing, you may substitute any or all of the switches as you choose. If you give an invalid command such as CS-243=1/CO-243=1 when Switch 243 is programmed for Mode 3 operation, the relay will not operate on the command and if you were using the ASCII command interface, the monitor would return an `INVALID PARAMETER`. For more information on virtual switch operation, see Section 4, *Protection and Control Functions, Virtual Switches.* You may verify operation of virtual switches by monitoring the programmed output contacts, by monitoring the front panel interface Screen \CTRL\xx or by using the RS-LGC command to retrieve logic variable data from the SER. You may also use the RG-STAT command. See Section 6, *Reporting and Alarms,* for more information on reports.

Virtual Switch Mode 1 Operation (On/Off/Pulse)

Purpose: To verify virtual switch Mode 1 operation.

Reference Commands: SL-43, CS/CO-43.

Step 1: Prepare for Mode 1 testing by transmitting the commands in Table 13-82 to the relay.

Table 13-82. Mode 1 Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=MODE1	Sets MODE1 as custom logic name.
SL-43=1	Sets 43 to Mode 1 operation.
SL-VO1=43	Enables OUT1 to close for 43.
EXIT	Exit.
Y	Save settings.

Step 2: Prepare to monitor the virtual switch operation.

Step 3: Transmit the commands in Table 13-83 to the relay or, navigate to Screen \CTRL\43\43 to set the mode of the 43 Switch to the TRUE state (logic 1).

Result: OUT1 contact closes and remains closed.

Table 13-83. Mode 1 Test Commands

Command	Purpose
A=	Gain write access
CS-43=1	Selects virtual switch 43 for change to closed (True) state
CO-43=1	Executes virtual switch 43 for change to closed (True) state

Step 4: Transmit the commands in Table 13-84 to the relay or, navigate to Screen \CTRL\43\43 to set the mode of the 43 Switch to the FALSE state (logic 0). It is not necessary to gain access for the following steps unless access times out.

Result: OUT1 contact opens and remains open.

Table 13-84. Mode 1 Test Commands

Command	Purpose
CS-43=0	Selects Virtual Switch 43 for change to open (False) state
CO-43=0	Executes Virtual Switch 43 for change to open (False) state

Step 5: Transmit the commands in Table 13-85 to the relay or navigate to Screen \CTRL\43\43 to set the mode of the 43 Switch to the pulse state.

Result: OUT1 contact closes for 200 milliseconds and returns to the open state.

Table 13-85. Mode 1 Test Commands

Command	Purpose
CS-43=P	Selects Virtual Switch 43 for change to closed (True) state and return open.
CO-43=P	Executes Virtual Switch 43 for change to closed (True) state and return open.

Virtual Switch Mode 2 Operation (On/Off)

Purpose: To verify virtual switch Mode 2 operation.

Reference Commands: SL-143, CS/CO-143

Step 1: Prepare for Mode 2 testing by transmitting the commands in Table 13-86 to the relay.

Table 13-86. Mode 2 Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=MODE2	Sets MODE2 as custom logic name.
SL-143=2	Sets 143 to Mode 2 operation.
SL-VO1=143	Enables OUT1 to close for 143.
EXIT	Exit.
Y	Save settings.

Step 2: Prepare to monitor the virtual switch operation.

Step 3: Send the commands in Table 13-87 to the relay or navigate to Screen \CTRL\43\143 to set the mode of the 143 Switch to the TRUE state (logic 1).

Result: OUT1 contact closes and remains closed.

Table 13-87. Mode 2 Test Commands

Command	Purpose
A=	Gains write access.
CS-143=1	Selects Virtual Switch 143 for change to closed (True) state.
CO-143=1	Executes Virtual Switch 143 for change to closed (True) state.

Step 4: Send the commands in Table 13-88 to the relay or navigate to Screen \CTRL\43\143 to set the mode of the 143 Switch to the FALSE state (logic 0). It is not necessary to gain access for the following step unless access times out.

Result: OUT1 contact opens and remains open.

Table 13-88. Mode 2 Test Commands

Command	Purpose
CS-143=0	Selects Virtual Switch 143 for change to open (False) state.
CO-143=0	Executes Virtual Switch 143 for change to open (False) state.

Virtual Switch Mode 3 Operation (Off/Momentary On)

Purpose: To verify virtual switch Mode 3 operation.

Reference Commands: SL-243, CS/CO-243

Step 1: Prepare for Mode 3 testing by transmitting the commands in Table 13-89 to the relay.

Table 13-89. Mode 3 Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=MODE3	Sets MODE3 as custom logic name.
SL-243=3	Sets 243 to Mode 3 operation.
SL-VO1=243	Enables OUT1 to close for 243.
Y	Save settings.

Step 2: Prepare to monitor the virtual switch operation.

Step 3: Send the commands in Table 13-90 to the relay or, navigate to Screen \CTRL\43\243 to set the mode of the 243 Switch to the pulse state.

Result: OUT1 contact closes for 200 milliseconds and returns to the open state.

Table 13-90. Mode 3 Test Commands

Command	Purpose
CS-243=P	Selects Virtual Switch 243 for change to closed (TRUE) state and return open.
CO-243=P	Executes Virtual Switch 243 for change to closed (TRUE) state and return open.

Step 4: Repeat the previous tests for Virtual Switches 343, 443, 543, 643, and 743.

101 Virtual Breaker Control Switch

Purpose: To verify 101 Virtual Breaker Control Switch operation.

Reference Commands: SL-101, CS/CO-101C, CS/CO-101T

Step 1: Prepare for 101 Virtual Breaker Control Switch testing by sending the commands in Table 13-91 to the relay.

Table 13-91. 101 Virtual Breaker Control Switch Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N= S101	Sets S101 as custom logic name.
SL-101=1	Enables 101 Switch.
SL-VO1=101T	Enables OUT1 to close for 101T TRUE.
SL-VO2=101C	Enables OUT2 to close for 101C TRUE.
SL-VO3=101SC	Enables OUT3 to close for 101SC TRUE.
EXIT	Exit.
Y	Save settings.

Step 2: Prepare to monitor the 101 Virtual Breaker Control Switch operation. You may verify operation of the virtual switch by monitoring the programmed output contacts or from the front panel interface Screen \CTRL\BKR or by using the RG-STAT command. See Section 6, *Reporting and Alarms,* for more information.

Step 3: Send the commands in Table 13-92 to the relay or, navigate to Screen \CTRL\BKR to set the mode of the 101 Virtual Breaker Control Switch to the trip state.

Result: OUT1 contact closes for 200 milliseconds and returns to the open state and OUT3 contact opens (trip state) and remains open.

Table 13-92. 101 Virtual Breaker Control Switch Trip Test Commands

Command	Purpose
A=	Gains write access.
CS-101=T	Selects 101T for trip operation.
CO-101=T	Executes 101T for trip operation.

Step 4: Send the commands in Table 13-93 to the relay or, navigate to Screen \CTRL\BKR to set the mode of the 101 Virtual Breaker Control Switch to the close state.

Result: OUT2 contact closes for 200 milliseconds and returns to the open state and OUT3 contact closes (close state) and remains closed.

Table 13-93. 101 Virtual Breaker Control Switch Close Test Commands

Command	Purpose
A=	Gains write access.
CS-101=C	Selects 101C for close operation.
CO-101=C	Executes 101C for close operation.

Repeat tests for additional Virtual Breaker Control Switches (1101, 2101, 3101).

Step 5: Prepare for 101 Virtual Breaker Control Switch testing by sending the commands in Table 13-94 to the relay.

Table 13-94. x101 Virtual Breaker Control Switch Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N= Sx101	Sets Sx101 as custom logic name.
SL-x101=1	Enables x101 Switch.
SL-VO1=x101T	Enables OUT1 to close for x101T TRUE.
SL-VO2=x101C	Enables OUT2 to close for x101C TRUE.
SL-VO3=x101SC	Enables OUT3 to close for x101SC TRUE.
EXIT	Exit.
Y	Save settings.

Note: Replace “x” with 1, 2, or 3 to test each element (1101, 2101, 3101).

Step 6: Prepare to monitor the x101 Virtual Breaker Control Switch operation. You may verify operation of the virtual switch by monitoring the programmed output contacts or from the front panel interface Screen \CTRL\BKR or by using the RG-STAT command. See Section 6, *Reporting and Alarms,* for more information.

Step 7: Send the commands in Table 13-95 to the relay or navigate to Screen \CTRL\BKR to set the mode of the x101 Virtual Breaker Control Switch to the trip state.

Result: OUT1 contact closes for 200 milliseconds and returns to the open state and OUT3 contact opens (trip state) and remains open.

Table 13-95. 101 Virtual Breaker Control Switch Trip Test Commands

Command	Purpose
A=	Gains write access.
CS-x101T=T	Selects x101T for trip operation.
CO-x101T=T	Executes x101T for trip operation.

Step 8: Send the commands in Table 13-96 to the relay or, navigate to Screen \CTRL\BKR to set the mode of the x101 Virtual Breaker Control Switch to the close state.

Result: OUT2 contact closes for 200 milliseconds and returns to the open state and OUT3 contact closes (close state) and remains closed.

Table 13-96. x101 Virtual Breaker Control Switch Close Test Commands

Command	Purpose
A=	Gains write access.
CS-x101C=C	Selects x101C for close operation.
CO-x101C=C	Executes x101C for close operation.

Step 9: Repeat for each of the x101 switches.

Logic Timer Verification (62/162/262/362)

Mode 1 - Pickup/Dropout

Purpose: To verify the operation of the 62 timer elements.

Reference Commands: SL-62/162/262/362, S<g>-62/162/262/362

Step 1: Prepare for Mode 1 logic timer verification testing by sending the commands in Table 13-97 to the relay.

Table 13-97. x62 Mode 1 Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=T62	Sets T62 as custom logic name.
SL-43=2	Enables 43 Switch ON/OFF mode.
SN-43=62_INITIATE,PU,DO	Name switch to make SER easier to read.
SL-62=1,43	Enables 62 PU/DO mode, 43 initiate, no block.
S# -62=400m,2000m	Sets 62 pickup = 400 ms, dropout = 2,000 ms
EXIT	Exit.
Y	Save settings.

Step 2: Send the commands in Table 13-98 to the relay. These commands will initiate the 62 Timer by changing the 43 Switch state to closed (logic 1). Once initiated, the 62 Timer will force an output based on the 400-millisecond pickup time setting.

Table 13-98. x62 Mode 1 Timer Initiate Commands

Command	Purpose
A=	Gains write access.
CS-43=1	Selects 43 for close operation.
CO-43=1	Executes 43 for close operation.

Step 3: Send the commands in Table 13-99 to the relay. These commands will remove the initiate input from the 62 Timer by changing the 43 switch state to open (logic 0). It is not necessary to gain access for the following steps unless access times out.

Table 13-99. x62 Mode 1 Timer Initiate Clear Commands

Command	Purpose
CS-43=0	Selects 43 for open operation.
CO-43=0	Executes 43 for open operation.

Step 4: Use the RS-LGC command to retrieve logic variable data from the SER. Verify that the 43 switch change to a closed state, was logged, and approximately 400 milliseconds later, the 62 Timer picked up. Then, sometime later, the 43 Switch changed to an open state, was logged and the 62 Timer dropped out approximately 2,000 milliseconds later. The state of the 43 switches in the SER report use the programmable name parameters applied to the switch. Figure 13-19 illustrates the timing relationship of the 43 Switch and 62 Timer.

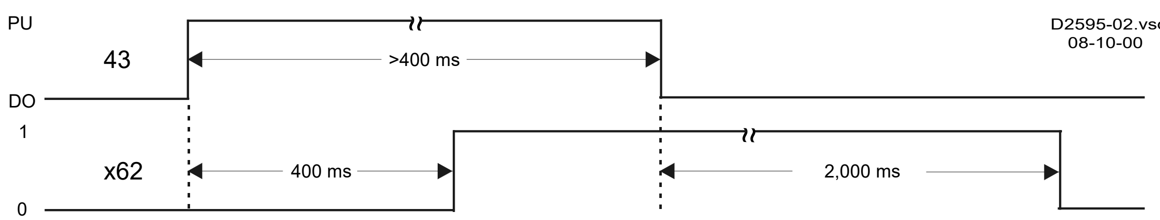


Figure 13-19. x62 Mode 1 (Pickup/Dropout) Timing Example

Mode 2 – One Shot Nonretriggerable

Step 1: Prepare for Mode 2 logic timer verification testing by sending the commands in Table 13-100 to the relay.

Table 13-100. x62 Mode 2 Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=T162	Sets T162 as custom logic name.
SL-143=3	Enables 143 Switch pulse mode.
SN-143=162_INI,INI,NORMAL	Name switch to make SER easier to read.
SL-162=2,143,0	Enables 162 1-shot, nonretriggerable mode, 143 initiate, no blocking.

Command	Purpose
S0-162=400m,20s	Sets 162 delay at 400 milliseconds, 162 dropout at 20 seconds.
EXIT	Exit.
Y	Save settings.

Step 2: Send the commands in Table 13-101 to the relay. These commands supply the 162 Timer with a momentary initiate input by pulsing the 143 Switch from a FALSE state to a TRUE state and then back to a FALSE state. You may view the state changes of the 143 Switch at front panel interface \CTRL\43\143, Screen 2.1.2.

> **NOTE**
>
> The 143 Switch action is performed twice in this test. To illustrate the action of the timer mode, the commands of Table 13-98 should be executed as quickly as possible. Ideally, this test should be repeated within 20 seconds. If this is a problem, try extending the dropout timer setting to 30 seconds.

Table 13-101. x62 Mode 2 Timer Initiate Commands

Command	Purpose
A=	Gains write access.
CS-143=P	Selects 143 for pulse operation.
CO-143=P	Executes 143 for pulse operation.
CS-143=P	Selects 143 for pulse operation.
CO-143=P	Executes 143 for pulse operation.

Step 3: Use the RS-LGC command to retrieve logic variable data from the SER. Verify that a 143 pulse action (FALSE-TRUE-FALSE) was logged and that approximately 400 milliseconds after the initial 143 FALSE-TRUE-FALSE initiate signal action, the 162 Timer output went TRUE. Then, approximately 20 seconds later, duration timer T2 expired and the timer output went FALSE despite a second 143 FALSE to TRUE initiate signal while the duration timer was active. Figure 13-20 illustrates the timing relationship of the 143 Switch and x62 Timer.

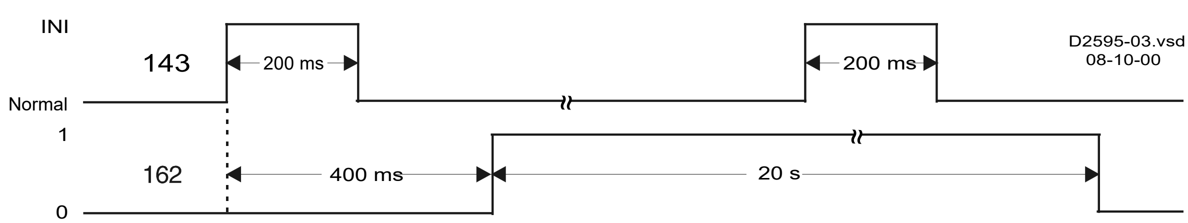


Figure 13-20. x62 Mode 2 (One-Shot Nonretriggerable) Timing Example

Mode 3 – One Shot Retriggerable

Step 1: Prepare for Mode 3 logic timer verification testing by sending the commands in Table 13-102 to the relay.

Table 13-102. x62 Mode 3 Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=T62	Sets T62 as custom logic name.
SL-343=3	Enables 343 Switch pulse mode.
SN-343=62_INI,INI,NORMAL	Name switch to make SER easier to read.
SL-62=3,343,0	Enables 62 1-shot, retriggerable mode, 343 initiate, no blocking.
S0-62=15s,20s	Sets 62 delay at 15 seconds, 62 dropout at 20 seconds.
EXIT	Exit.
Y	Save settings.

Step 2: Send the commands in Table 13-103 to the relay. These commands supply the 62 Timer with a momentary initiate input by pulsing the 343 Switch from a FALSE state to a TRUE state and then back to a FALSE state. You may view the state changes of the 343 Switch at front panel interface \CTRL\43\343, Screen 2.1.4.

NOTE

The 343 Switch action is performed three times in this test. To illustrate the action of the timer mode, the second 343 Switch action should be executed as quickly as possible (within the 15 second duration of the pickup time delay). Perform the third 343 Switch action after at least 15 seconds (the pickup timer setting) have elapsed but before the 20-second dropout time delay expires. This will illustrate the action of the timer mode. The time delay settings may be increased if difficulty is encountered with repeating the 343 Switch actions.

Table 13-103. x62 Mode 3 Timer Initiate Commands

Command	Purpose
A=	Gains write access.
CS-343=P	Selects 343 for pulse operation.
CO-343=P	Executes 343 for pulse operation.
CS-343=P	Selects 343 for pulse operation.
CO-343=P	Executes 343 for pulse operation.
Wait at least 15 seconds (but no longer than 35 seconds) to execute the next commands.	
CS-343=P	Selects 343 Switch for pulse operation.
CO-343=P	Executes 343 Switch for pulse operation.

Step 3: Use the RS-LGC command to obtain an SER report and verify that the following actions were logged. These events are illustrated in the timing diagram of Figure 13-21.

After a 343 pulse action (FALSE-TRUE-FALSE) was logged, the 62 Timer output did not go TRUE because of a second FALSE to TRUE initiate signal action.

Approximately 15 seconds after the second 343 FALSE to TRUE initiate signal, the 62 Timer output went TRUE. The timer output went FALSE when the third FALSE to TRUE initiate signal forced the 62 Timer (T1) to restart.

Fifteen seconds after the third 343 FALSE to TRUE initiate signal, the 62 Timer output went TRUE again and then went FALSE after the duration timer (T2) expired 20 seconds later.

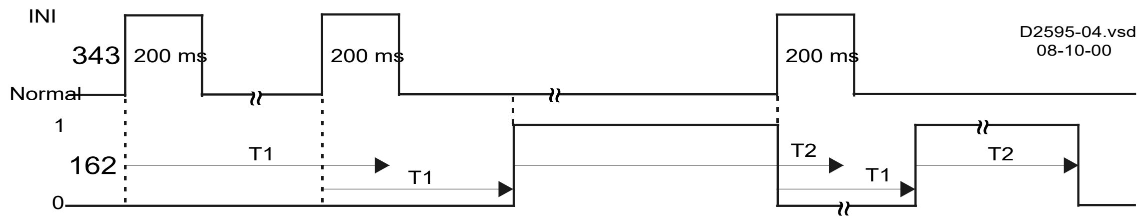


Figure 13-21. x62 Mode 3 (One-Shot Retriggerable) Timing Example

Mode 4 - Oscillator

Because this operating mode is not intended for general use, no testing procedure is provided. Information about Mode 4 is available in Section 4, *Protection and Control, General Purpose Logic Timers.*

Mode 5 – Integrating Timer

Step 1: Prepare for Mode 5 logic timer verification testing by sending the commands in Table 13-104 to the relay.

Table 13-104. x62 Mode 5 Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=T62	Sets T62 as custom logic name.
SL-43=2	Enables 43 Switch ON/OFF mode.
SN-43=62_INI,PU,DO	Name switch to make SER easier to read.
SL-62=5,43,0	Enables 62 integrating mode, 43 initiate, no blocking.
S0-62=15s,5s	Sets T1 at 15 seconds, T2 at 5 seconds.
EXIT	Exit.
Y	Save settings.

NOTE

The CS and CO commands of Table 13-100 are performed three times. Follow the timing sequence to illustrate timer mode action. The time delay settings may be increased if difficulty is encountered with repeating the 43 Switch actions.

Step 2: Send the commands in Table 13-105 to the relay. These commands supply a block input to the 62 Timer by changing the 43 Switch state to TRUE.

Table 13-105. x62 Mode 5 Timer Initiate Commands

Command	Purpose
A=	Gains write access.
CS-43=1	Selects 43 for TRUE operation.
CO-43=1	Executes 43 for TRUE operation.
Wait no longer than 10 seconds to interrupt the T1 Timer.	
CS-43=0	Selects 43 for FALSE operation.
CO-43=0	Executes 43 for FALSE operation.

Command	Purpose
Wait at least 5 seconds for the T2 timer to time out and reset the integration.	
CS-43=1	Selects 43 for TRUE operation.
CO-43=1	Executes 43 for TRUE operation.
Wait at least 20 seconds for the T1 timer to elapse.	
E	Exit.

Step 3: Use the RS-LGC command to obtain an SER report and verify that the following actions were logged. These events are illustrated in the timing diagram of Figure 13-22.

Timer T1 failed to time out in the first 43 Switch action (TRUE).

Timer T2 timed out after the second 43 Switch action (FALSE).

Timer T1 timed out and the 62 Timer output went TRUE.

Timer T2 timed out and the 62 Timer output returned to a FALSE state.

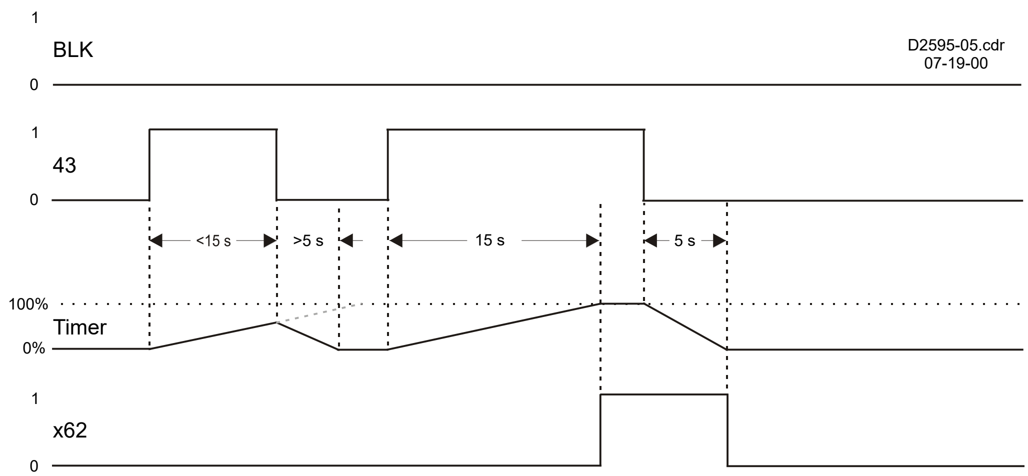


Figure 13-22. x62 Mode 5 (Integrating) Timing Example

Step 4: (Optional.) Repeat the 62 Timer tests for Modes 1, 2, 3, and 5 for Setting Groups 1, 2, and 3.

Mode 6 – Latch Timer

Step 1: Prepare for mode 6 logic timer verification testing by sending the commands in Table 13-106 to the relay.

Table 13-106. x62 Mode 6 Test Commands

Command	Purpose
A=	Gains write access.
SL-N=NONE	Zero out custom logic settings. Overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=T62	Sets T62 as custom logic name.
SL-43=3	Enables 43 Switch pulse mode.
SL-143=3	Enables 143 Switch pulse mode.
SN-43=62_LATCH,INI,NORMAL	Name switch to make SER easier to read.
SN-143=62_RESET,RESET,NORMAL	Name switch to make SER easier to read.

Command	Purpose
SL-62=6,43,143	Enables 62 latch mode, 43 initiate, 143 block (reset latch).
S0-62=30s	Sets T1 at 30 seconds, T2 time not applicable.
EXIT	Exit.
Y	Save settings.

Step 2: Sent the commands in Table 13-107 to the relay. These commands supply a latch input to the 62 Timer by changing the 43 Switch state to TRUE and a reset command by changing the BLK input (143 Switch) to TRUE.

NOTE

The CS and CO commands of Table 13-104 are performed two times. Follow the timing sequence to illustrate timer mode action. The time delay settings may be increased if difficulty is encountered with repeating the 43 and 143 Switch actions.

Table 13-107. x62 Mode 6 Timer Initiate Commands

Command	Purpose
A=	Gains write access.
CS-43=P	Selects 43 for pulse operation.
CO-43=P	Executes 43 for pulse operation (initiates 62 timing).
Execute the following commands in less than 30 seconds.	
CS-43=P	Selects 43 for pulse operation.
CO-43=P	Executes 43 for pulse operation (no effect).
Wait at least 30 seconds (total elapsed time) to initiate the latch reset (block) command (this allows timer T1 to time out (output goes TRUE) and latch until the BLK input goes TRUE).	
CS-143=P	Selects 143 for pulse operation.
CO-143=P	Executes 143 for pulse operation (applies BLK input).
E	Exit.

Step 3: Use the RS-LGC command to obtain an SER report and verify that the following actions were logged. These events are illustrated in the timing diagram of Figure 13-23.

Timer T1 continued to time out after the first 43 Switch action (TRUE).

Timer T1 timed out and the 62 Timer output went TRUE 30 seconds after 43 Switch action (TRUE).

62 Timer output returned to a FALSE state with the 143 Switch action (TRUE).

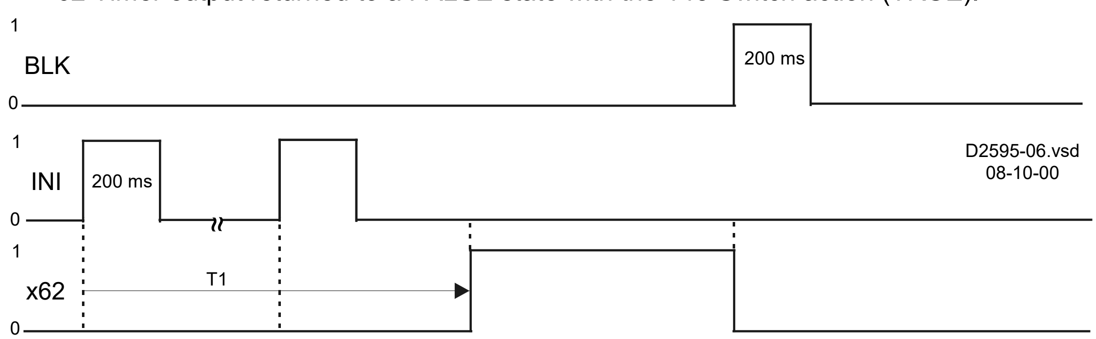


Figure 13-23. x62 Mode 6 (Latch) Timing Example

Step 4: (Optional.) Repeat the 62 Timer tests for Modes 1, 2, 3, and 5 for Setting Groups 1, 2, and 3.

Step 5: Repeat the 62 time tests for each 62 element (62/162/262/362).

Automatic Setting Group Change

Automatic Change

Purpose: To verify the operation of the automatic setting group change function.

Reference Commands: SL-GROUP, SG-SGCON, SP-GROUP, CS/CO-GROUP, SL-51/151/251, S<n>-51.

Step 1: Connect a current source to Terminals A3* and A4 (A-phase Input 1).

Step 2: To initially prepare the automatic setting group change function for testing, transmit the commands in Table 13-108 to the relay.

Table 13-108. Automatic Setting Group Change Function Test Commands

Command	Purpose
A=	Gain access.
SL-N=NONE	Zero out custom logic settings/overwrite with logic = None settings.
Y	Confirm overwrite.
SL-N=ASG	Name custom logic for this test.
SL-GROUP=1,43,143,243,343, 443	Sets logic mode to discrete selection with virtual switches to control.
SL-51P=1,0	Enables 51P CT Input 1.
SG-SGCON=1	Sets SGC alarm = 1 sec, and anti-pump = 2 sec.
SL-VO1=SG1	Enables OUT1 to close when SG1 active.
SL-VO2=SG2	Enables OUT2 to close when SG2 active.
SL-VO3=SG3	Enables OUT3 to close when SG3 active.
SG-CTP1=1,WYE	Input 1 ctr = 1, ct = wye
SG-TRIGGER=51PT,51PPU,0	Enable 51PT to log and trigger fault recording.
SL-43=2	Enables 43 Switch ON /OFF mode.
SL-143=2	Enables 143 Switch ON /OFF mode.
SL-243=2	Enables 243 Switch ON /OFF mode.
SL-343=2	Enables 343 Switch ON /OFF mode.
SL-443=2	Enables 443 Switch ON /OFF mode.
SN-43=GROUP_MAN_SELECT, GROUP0,NORMAL	Set switch names.
SN-143=GROUP_MAN_SELECT, GROUP1,NORMAL	Set switch names.
SN-243=GROUP_MAN_SELECT, GROUP2,NORMAL	Set switch names.
SN-343=GROUP_MAN_SELECT, GROUP3,NORMAL	Set switch names.
SN-443=GROUP_CONTROL, AUTO,MANUAL	Set switch names.
SP-GROUP1=1,75,1,70,51P	SG1 t_s = 1 min @ 75%, t_r = 1 min@70% of SG0 51P.
SP-GROUP2=1,90,1,85,51P	SG2 t_s =1 min @ 90%, t_r = 1 min@85% of SG0 51P.
SP-GROUP3=1,110,1,100,51P	SG3 t_s=1 min @ 110%, t_r= 1 min @ 100% of SG0 51P.
E	Exit.

Command	Purpose
Y	Save settings.

Step 3: Switch group control to automatic using Virtual Switch 443. Use Table 13-109 ASCII commands or front panel interface \CTRL\43\543, Screen 2.1.6.

Table 13-109. Automatic Group Control Selection

Command	Purpose
A=	Gain access.
CS-443=1	Selects 443 for TRUE operation.
CO-443=1	Executes 443 TRUE operation (AUTO).

Step 4: Gain access if access timed out from the previous step. Send to the relay the appropriate setting commands from Table 13-110. With the HMI, you may also go to the front panel interface Screen \PROT\SG0\51\51 and edit the 51P settings. After you send the commands to your relay, EXIT' and (save) 'Y') the changes.

An ohmmeter or continuity tester may be used to monitor the output contacts (OUT1, OUT2, OUT3) status.

Table 13-110. Time Overcurrent 51P Element Pickup Settings

Sensing Input Type	Command	Comments
1 A	S0-51P=1.0,5.0,I2	pu= 1.0, td = 5, curve = I2
	S1-51P=1.5,5.0,I2	pu = 1.5, td = 5, curve = I2
	S2-51P=1.8,5.0,I2	pu = 1.8, td = 5, curve = I2
	S3-51P=2.2,5.0,I2	pu = 2.2, td = 5, curve = I2
5 A	S0-51P=5.0,5.0,I2	pu = 5.0, td = 5, curve = I2
	S1-51P=7.5,5.0,I2	pu = 7.5, td = 5, curve = I2
	S2-51P=9.0,5.0,I2	pu = 9.0, td = 5, curve = I2
	S3-51P=11.0,5.0,I2	pu = 10.5, td = 5, curve = I2

Step 5: Using the values listed in Table 13-111, apply current to the A phase current input, beginning at the starting point, then stepping up to just slightly above the threshold limit for the amount of time listed. If the active setting group does not change, step the current up to just below the next group switch limit for the duration indicated. The setting group change should occur between the low and high limits. Monitor the output contacts to verify that the change occurred within the time limits programmed at an accuracy of ±0.5% of setting or ±2 seconds; whichever is greater. Step the current up to each new level and verify the setting group change and pickup accuracy.

Table 13-111. Automatic Setting Group Change Example Accuracy Limits - Increasing Current

Sensing Type	Current Value		Time	Comments
	Above Switch Threshold	But Below Next Group Switch Threshold and 51P PU		
1 A	0.51 A	0.73 A	-	Starting point 50% of S0-51P pickup
	0.77 A	0.88 A	> 1 min	Switch to SG1 (75% S0 51P pickup)
	0.92 A	1.07 A	> 1 min	Switch to SG2 (90% S0 51P pickup)
	1.13 A	2.1 A	> 1 min	Switch to SG3 (110% S0 51P pickup)
5 A	2.55 A	3.6 A	-	Starting point 50% pickup
	3.83 A	4.4 A	> 1 min	Switch to SG1 (75% S0 51P pickup)
	4.59 A	4.595 A	> 1 min	Switch to SG2 (90% S0 51P pickup)
	5.61 A	10.78 A	> 1 min	Switch to SG3 (110% S0 51P pickup)

Step 6: Verify that SG3 is the active setting group by sending the command RG-GRPACTIVE to the relay. It should echo back that the SG3 is the active group. With the HMI, you may also verify the active setting group at the front panel interface Screen \STAT\OPER\ACTIVEG, 1.4.4.

Step 7: Send to the relay the commands in Table 13-112.

Table 13-112. Automatic Group Control Selection

Command	Purpose
A=	Gain access.
CS-143=1	Selects 143 for TRUE operation.
CO-143=1	Executes 143 TRUE operation (Setting Group 1).
E	Exit.

Step 8: Verify that the relay did not change to Setting Group 1 (SG1) by transmitting the RG-GRPACTIVE to the relay. It should echo back that the SG3 is still the active group. This verifies that the relay will not make any setting group changes from logic inputs while the AUTO input logic is TRUE.

Step 9: Begin stepping down the level of current from one level to the next as shown in Table 13-113. First step the current to just below the threshold limit for the amount of time listed. Monitor the output contacts to verify that the setting group changed. If the active setting group does not change, step the current down to just above the next group switch limit for the duration indicated. This will verify the accuracy of the pickup return threshold. Continue stepping down to each new level.

Table 13-113. Automatic Setting Group Change Example Accuracy Limits - Decreasing Current

Sensing Type	Current Value		Time	Comments
	Below Switch Timing Threshold	But Above Next Group Switch Threshold		
1 A	2.1 A	1.13 A	> 1 min	SG3 (110% SG0 51P).
	0.98 A	0.86 A	> 1 min	Switch to SG2 (100% SG0 51P).
	0.83 A	0.71 A	> 1 min	Switch to SG1 (85% S0 51P pickup).
	1.13	2.1	> 1 min	Switch to SG0 (70% S0 51P pickup).
5 A	10.78 A	5.61 A	> 1 min	SG3 (110% SG0 51P).
	4.9 A	4.4 A	> 1 min	Switch to SG2 (100% SG0 51P).
	4.16 A	3.57 A	> 1 min	Switch to SG1 (85% S0 51P pickup).
	3.43 A	2.55 A	> 1 min	Switch to SG0 (70% S0 51P pickup).

Step 10: Remove the current from A-phase, Input 1.

Step 11: Using the RS-LGC command to retrieve logic variable data from the SER, verify that the following actions were logged:

- Verify that all setting group changes were logged.
- Verify that VO1 went TRUE and closed relay output OUT1 when SG1 became the active setting group.
- Verify that VO2 went TRUE and closed relay output OUT2 when SG2 became the active setting group and that relay output OUT1 opened.
- Verify that VO3 went TRUE and closed relay output OUT3 when SG3 became the active setting group and that relay output OUT2 opened.
- Verify that when the Virtual Switch 143 went TRUE (as a discrete input to the SG1 input of the setting group logic block) that the active setting group remained SG3.
- Verify the events that occurred in reverse order when the current was being stepped down.

Manual Change Mode 1

Manual Change Mode 1 test procedures are a continuation of the automatic test procedures. Do not change the logic or settings except for those in Step 1 and subsequent.

Step 1: Transmit to the relay the commands in Table 13-114.

Table 13-114. Manual Group Control Selection

Command	Purpose
A=	Gain access.
CS-443=0	Selects 443 for FALSE operation to enable logic control (manual mode).
CO-443=0	Executes 443 for FALSE operation to enable logic control (manual mode).
E	Exit.

Step 2: Verify that VO1 went TRUE and closed relay output OUT1 when SG1 became the active setting group (remember in Step 6, Switch 143 was made TRUE).

Step 3: Send to the relay the commands in Table 13-115. Monitor the output contacts to verify the setting group changes. After all commands have been sent, verify that SG3 is the active setting group by sending the command RG-GRPACTIVE to the relay. It should echo back that the SG3 is the active group. Using the HMI, you may also verify the active setting group at the front panel interface Screen \STAT\OPER\ACTIVEG, 1.4.4.

Table 13-115. Manual Group Control Selection

Command	Purpose
A=	Gain access.
CS-143=0	Deselects Setting Group 1 for operation.
CO-143=0	Executes Deselecting Setting Group 1 for operation.
CS-43=1	Selects Setting Group 0 for operation.
CO-43=1	Executes Setting Group 0 for operation.
CS-43=0	Deselects Setting Group 0 for operation.
CO-43=0	Executes Deselecting Setting Group 0 for operation.
CS-243=1	Selects Setting Group 2 for operation.
CO-243=1	Executes Setting Group 2 for operation.
CS-243=0	Deselects Setting Group 2 for operation.
CO-243=0	Executes Deselecting Setting Group 2 for operation.
CS-343=1	Selects Setting Group 3 for operation.
CO-343=1	Executes Setting Group 3 for operation.
E	Exit.
Y	Save settings

Step 4: Using the RS-LGC command to retrieve logic variable data from the SER, verify that the setting group change actions were logged.

Manual Change Mode 2

Manual Change Mode 2 test procedures are a continuation of the Mode 1 test procedures. Do not change the logic or settings except for those in Step 1 and subsequent.

Step 1: Send to the relay the commands in Table 13-116.

Table 13-116. Binary Group Control Selection Setup

Command	Purpose
A=	Gain access.
SL-GROUP=2	Sets setting group control function to binary coded selection (AUTO logic is unchanged from Table 13-80).
E	Exit.
Y	Save settings.

Step 2: Verify that relay Outputs OUT3 opened when the commands in Table 13-113 were completed and OUT1 and OUT2 remained open. With the existing logic and discrete select enabled, D0 and D1 inputs are FALSE, and D2 and D3 inputs have no effect on setting group selection. For more information on setting group selection, see Section 4, *Protection and Control Functions, Setting Groups.*

Step 3: Verify that SG0 is the active setting group by sending the command RG-GRPACTIVE to the relay. It should echo back that the SG0 is the active group. Using the HMI, you may also verify the active setting group at the front panel interface Screen \STAT\OPER\ACTIVEG, 1.4.4.

Step 4: Send to the relay the commands in Table 13-117.

Table 13-117. Binary Group Control Selection Test Commands

Command	Purpose
A=	Gain access.
CS-43=1	Selects Setting Group 1 for operation.
CO-43=1	Executes Setting Group 1 for operation (D0=1).
CS-43=0	Deselects Setting Group 1 for operation.
CO-43=0	Executes Deselecting Setting Group 1 for operation.
CS-143=1	Selects Setting Group 2 for operation.
CO-143=1	Executes Setting Group 2 for operation (D1=1).
CS-43=1	Selects Setting Group 3 for operation.
CO-43=1	Executes Setting Group 3 for operation (D0=1 and D1=1).
E	Exit.

Step 5: Verify that the appropriate setting groups became active and relay outputs OUT1 through OUT3 closed in accordance with the discrete inputs of Table 13-114. Refer to Step 3 for more information on verifying active setting groups.

SECTION 14 • BESTCOMS™ SOFTWARE

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SECTION 14 • BESTCOMS™ SOFTWARE

Description

BESTCOMS™ is a Windows® based program that runs on an IBM compatible computer and provides a user friendly, graphical user interface (GUI) for use with Basler Electric communicating products. BESTCOMS is an acronym that stands for **B**asler **E**lectric **S**oftware **T**ool for **C**ommunications, **O**perations, **M**aintenance, and **S**ettings.

BESTCOMS provides the user with a point and click means for setting and monitoring the in-service relay or relays under test. The point and click method provides an efficient, fast setup for configuring one or several relays. This software is provided free with every BE1-CDS240 Current Differential System.

Introduction

A primary advantage of the 32-bit BESTCOMS is that an actual unit (i.e., operating transmission protection system) is not required to perform any or all settings and adjustments for any preprogrammed scheme. Nor is it needed to create a custom scheme complete with settings and adjustments. Also, BESTCOMS is identical within all of the Basler Electric Numerical Systems except for differences inherit in the individual systems. This means that once you become familiar with a BESTCOMS for one system, you are also familiar with BESTCOMS for all of the systems.

Using the BESTCOMS GUI, you may prepare setting files off-line (without being connected to the relay) and then upload the settings to the relay at your convenience. These settings include protection and control, operating and logic, breaker monitoring, metering, and fault recording. Engineering personnel can develop, test, and replicate the settings before exporting them to a file and transmitting the file to technical personnel in the field. In the field, the technician simply imports the file into the BESTCOMS database and uploads the file to the relay where it is stored in nonvolatile memory. (See the paragraphs on *File Management* later in this manual for more information on saving, uploading, and downloading files.)

The BESTCOMS GUI also has the same preprogrammed logic schemes that are stored in the relay. This gives the engineer the option (off-line) of developing his/her setting file using a preprogrammed logic scheme, customizing a preprogrammed logic scheme, or building a unique scheme from scratch. Files may be exported from the GUI to a text editor where they can be reviewed or modified. The modified text file may then be uploaded to the relay. After it is uploaded to the relay, it can be brought into the GUI but it cannot be brought directly into the GUI from the text file. The GUI logic builder uses basic AND/OR gate logic combined with point and click variables to build the logic expressions. This reduces the design time and increases dependability.

The BESTCOMS GUI also allows for downloading industry-standard COMTRADE files for analysis of stored oscillography data. Detailed analysis of the oscillography files may be accomplished using BESTWAVE software.

This section provides an introduction to all of the screens in the BE1-CDS240 Current Differential System with their field layouts and typical entries. Common program activities such as applying settings, modifying logic, and setting up password security are discussed. These discussions are application oriented. We explore how the activity or task can be performed using an appropriate BE1-CDS240 BESTCOMS screen.

BESTCOMS screens are similar to most Windows based GUI screens. You may immediately notice common features such as the pull-down menu, toolbar, icons, and help prompts when the mouse pointer is paused over an icon. Some of these features are shown in Figure 14-1. If the Navigation Bar has a right and left arrow at the extreme right hand side of the screen, clicking on these arrows will shift the Navigation Bar to allow access to all of the icons on the bar. Like most computer programs, there is often more than one way to perform an activity or task. These various methods are discussed in the following paragraphs in conjunction with the appropriate BESTCOMS screen.

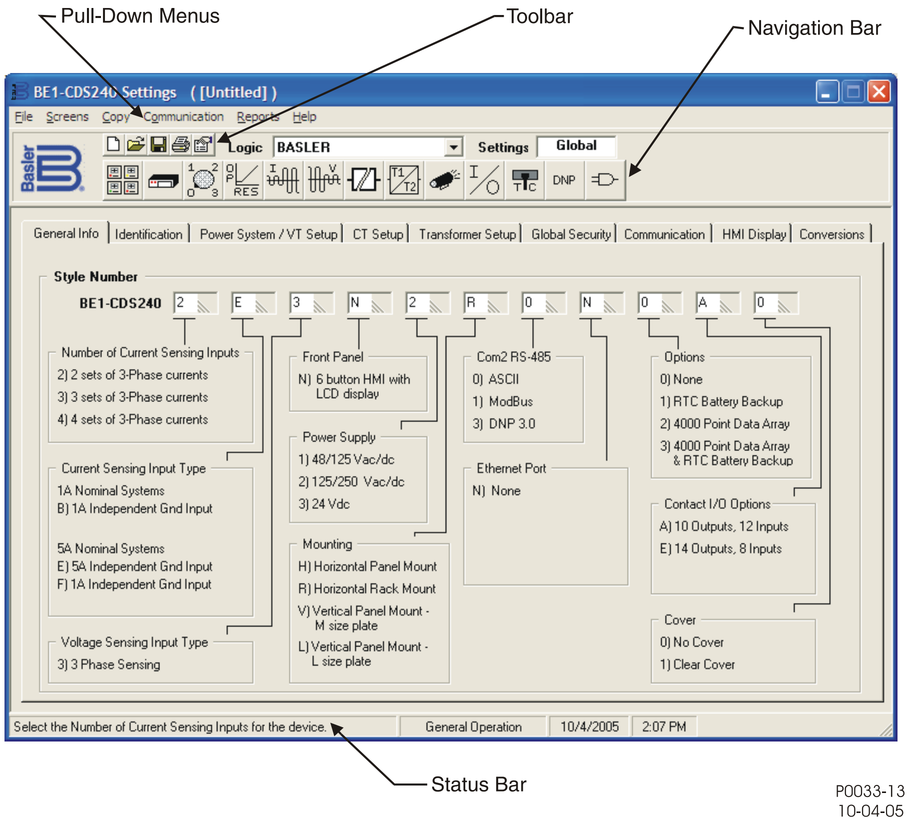


Figure 14-1. Typical User Interface Components

Installation

BESTCOMS for BE1-CDS240 software contains a setup utility that installs the program on your PC. (This is typical for all of the BE1 numerical systems.) When it installs the program, an uninstall icon (in the Control Panel, Add/Remove Programs feature) is created that you may use to uninstall (remove) the program from your PC. The minimum recommended operating requirements are listed in the following paragraph.

PC Requirements

- Pentium 233 MHz or faster processor (300 MHz is recommended)
- 64 megabytes (MB) of RAM (128 MB is recommended)
- Windows® XP (32-bit), Windows® Vista (32-bit all editions), Windows® 7 (32/64-bit all editions), and Windows® 8
- 7 MB of hard disk space
- CD-ROM drive for installation
- One available serial port

Installing the Program on Your PC Using Microsoft® Windows®

1. Insert the CD in the PC CD-ROM drive.
2. When the *Setup and Documentation CD* menu appears, click the install button for the BESTCOMS PC Program. The setup utility automatically installs "BESTCOMS for BE1-CDS240" on your PC.

When BESTCOMS installation is complete, a Basler Electric folder is added to the Windows program menu. This folder is accessed by clicking the Start button and Programs and then Basler Electric. The *Basler Electric* folder contains an icon for the "BESTCOMS for BE1-CDS240" program.

Connecting the PC to the Relay

Remember, you do not have to have a unit connected to the PC to operate BESTCOMS and program settings. If you have an actual unit, connect a communication cable between the front RS-232 communication port on the BE1-CDS240 front panel and an appropriate communication port on the PC.

Updating BESTCOMS™ Software

Future enhancements to relay functionality may make firmware update desirable. Enhancements to relay firmware typically coincide with enhancements to BESTCOMS software for that relay. When a relay is updated with the latest version of firmware, the latest version of BESTCOMS should also be obtained.

If you obtained a CD-ROM containing firmware from Basler Electric, then that CD-ROM will also contain the corresponding version of BESTCOMS software. BESTCOMS can also be downloaded from the Basler Electric web site (http://www.basler.com) after creating an account.

Starting BESTCOMS™

Start BESTCOMS™

Start BESTCOMS by clicking the *Start* button, *Programs*, *Basler Electric*, and then the *BESTCOMS for BE1-CDS240* icon. At startup, a splash screen with the program title and version number is displayed for a brief time (Figure 14-2). After the splash screen clears, you can see the initial screen - the *System Setup Summary* screen. (This is the same process if you do or do not have a unit connected to your PC.)

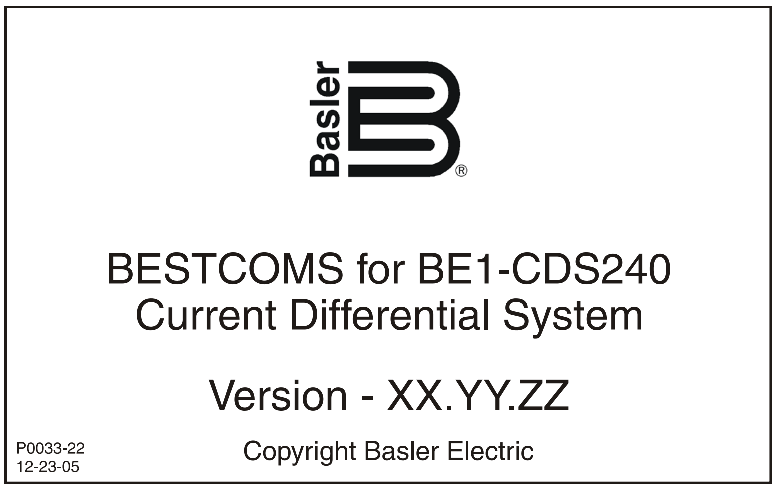
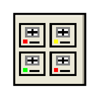


Figure 14-2. BESTCOMS™ Splash Screen

System Setup Summary Screen



If you are at another BESTCOMS screen such as *Overcurrent* and want to go to this screen, you may use the *Screens* pull-down menu or click on the *System Setup Summary* icon as is shown at the right margin of this paragraph. This screen has two areas or folder tabs (like paper file folder tabs) to the screen (see Figure 14-3). The first tab is *Protection and Control* and the second tab is *Reporting and Alarms*.

This screen gives you an overview of the system setup. When the screen is first displayed, the *Protection and Control* tab is in the foreground and the *Reporting and Alarms* tab is in the background. You may select either of these tabs and bring that tab and information into the foreground.

Protection and Control

Look in the lower, right-hand corner for the legend. This legend provides interpretation for the various indicated colors. Any protection and control function or element may be enabled or disabled and the current state is indicated by the associated color. If the function is enabled, the color is green. If the function is **only** disabled by a setting (such as zero), the color is yellow. If the function is **only** disabled by logic, the color is blue. If the function is disabled by **both** a setting and logic, the color is gray.

If a function has variations such as 51P, which has six modes (Circuit 1, Circuit 2, Circuit 3, Circuit 4, Circuit 5, and Circuit 6) and none of these modes are enabled, a tilde (~) is displayed.

In addition to the functional status, *Group Selection* is displayed and the names are shown for the displayed and active logic and the virtual switches.

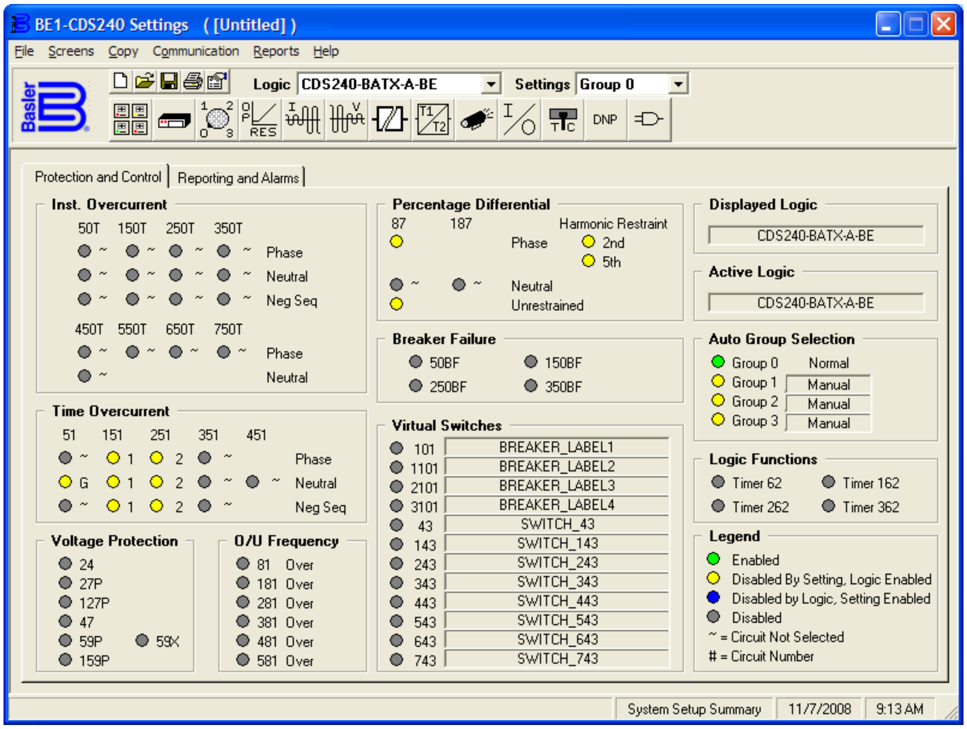


Figure 14-3. System Setup Summary Screen, Protection and Control Tab

Reporting and Alarms

This second tab of the *System Setup Summary* screen (Figure 14-4) provides the remaining summary information for the relay in regard to monitoring, metering, and alarms. Again, a legend for the color-coding of relay status is provided in the lower right side of the screen.

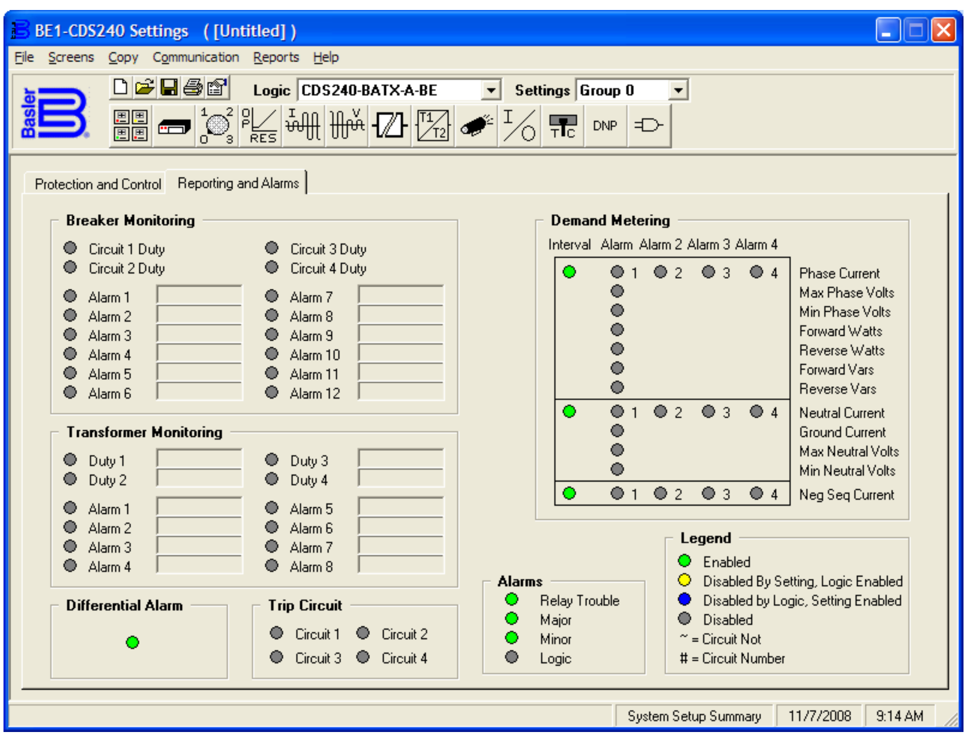


Figure 14-4. System Setup Summary Screen, Reporting and Alarms Tab

Configuring the PC

If you have an actual BE1-CDS240 relay, configure your PC to match the BE1-CDS240 configuration. To do this, pull down the *Communication* menu in the pull-down menu and select *Configure*. Now, match the communication configuration in the BE1-CDS240 relay. You may select *Terminal (VT100 Emulation)* and go directly to that communication protocol. You must close *Terminal Mode* before you can use BESTCOMS again. If you are comfortable using ASCII commands, the *Terminal Mode* is an easy method for checking the actual settings or status of the relay when you are in doubt about an action to take in BESTCOMS. ASCII commands are available in Section 11, *ASCII Command Interface*.

Setting the Relay

To set the relay, we will discuss the contents of each of the screens for BESTCOMS for the BE1-CDS240. The *System Setup Summary* screen was discussed in previous paragraphs. We begin with the assumption that you have started BESTCOMS, connected the PC to the relay, and configured your PC to the relay. If the default settings are active in your relay, you will have to change the logic to clear the Major alarm or disable the Logic = None Alarm under *Alarm Priority* in *Reporting and Alarms, Alarms*. This section describes BESTCOMS features as they occur and not on a priority (perform this setting first) basis. For information on how to select or name the active logic, see the paragraphs on *BESTlogic.*

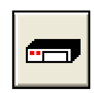
Select Logic Scheme for Display

In Figure 14-4, below the pull-down Menu bar, there is a pull-down arrow for the *Logic* window in the Toolbar row. To select a preprogrammed scheme, pull down this menu and click on the desired scheme. When you do, the selected logic name is displayed in the *Logic* window and the *System Setup Summary* screen displays what results would be if that scheme were active. It does not make it the active screen. You select custom and preprogrammed logic schemes using the *BESTlogic* screen. (See additional paragraphs in this section.)

Settings Display and Selection

Immediately to the right of the *Logic* window is a *Settings* window. A pull-down menu is shown and provides for Group 0, 1, 2, or 3 selection. An example of this is the *Overcurrent Protection* screen. Pull down the *Screens* menu and select *Overcurrent*. When you do, the *Settings* window display changes to the *Group* pull-down menu. If you wanted the specific setting change that you were about to make to affect the Group 1 settings, select Group 1.

General Operation Screen



Pull-down the *Screens* menu and select *General Operation* or click on the General Operation icon that is shown at the right margin of this paragraph. This screen has nine folder tabs and the first tab is General Info.

General Info

Pull-down the *Screens* menu and select *General Operation* or click on the General Operation icon, which is shown at the right margin of this paragraph. This screen has nine folder tabs. The first tab is *General Info* (Figure 14-5).

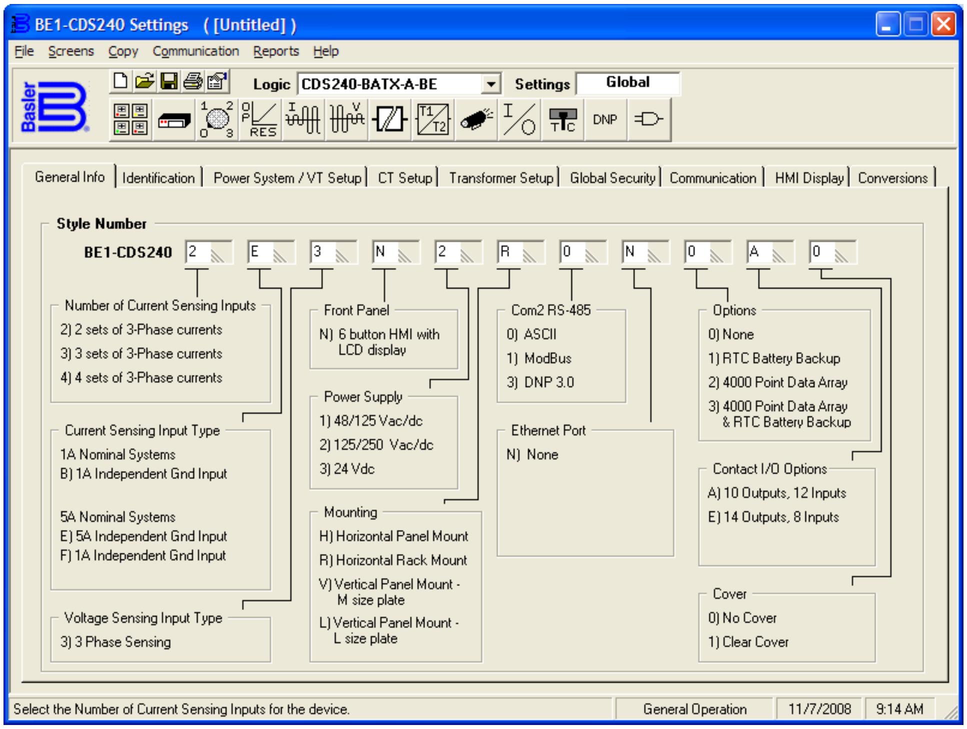


Figure 14-5. General Operation Screen, General Info Tab

Identification

This screen (Figure 14-6) allows you to fill in the serial number of the relay and the various software and firmware application version information. Additionally, you may enter the name of the relay, substation identification, and other installation-specific identification. This information will become useful when reports are generated.

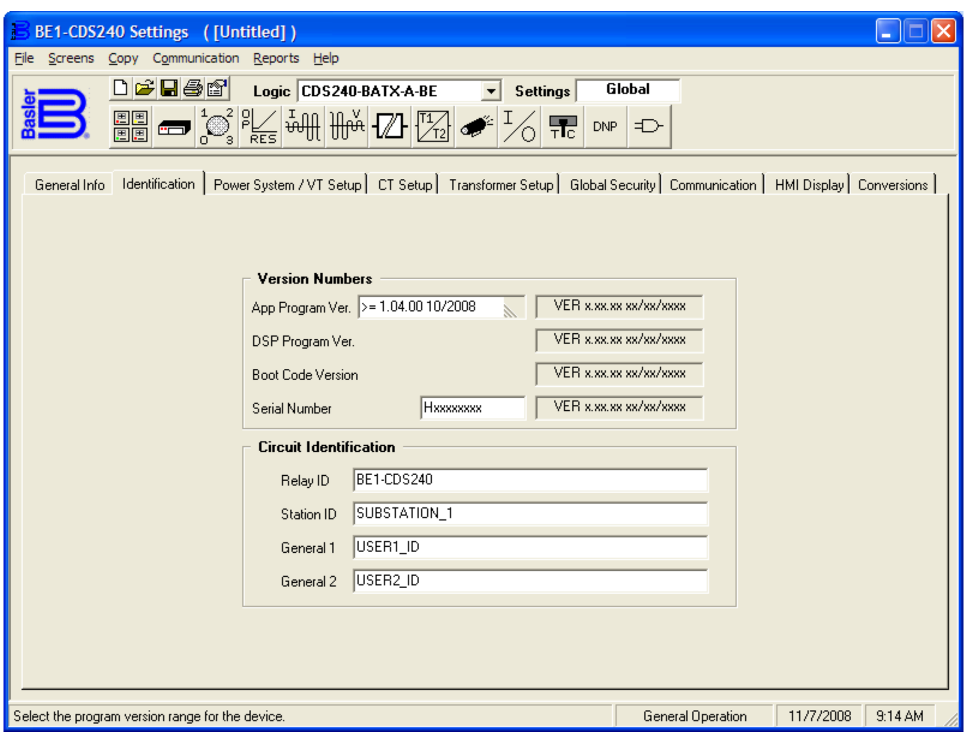


Figure 14-6. General Operation Screen, Identification Tab

Power System/VT Setup

This screen (Figure 14-7) allows you to enter the nominal frequency, normal phase rotation, nominal secondary voltage and current, and VTP parameters. If the phase rotation entry is not correct, it will cause problems in several areas including metering values and targets. In other words, you must make entries in these fields in order for the BE1-CDS240 protection elements to function.

VTP Setup allows a person to set the *VT Ratio - Turns*. Enter the *Turns* value and the primary voltage value is entered for you. Overvoltage and undervoltage modes can be set to operate on either the phase-to-phase (PP) or phase-to-neutral (PN) quantities. Click on the appropriate button to select the quantity required. Pull down the *Connection* menu and select the appropriate connection for phase voltage input. Click the pull-down menu for *Circuit* and select Circuit 1 through 6 to establish the effected circuit number. To ensure correct power metering, the Power Flow Polarity setting should be set to *Reverse* when the input voltage polarity is reversed. Set Power Flow Polarity to *Normal* when the input voltage is correct.

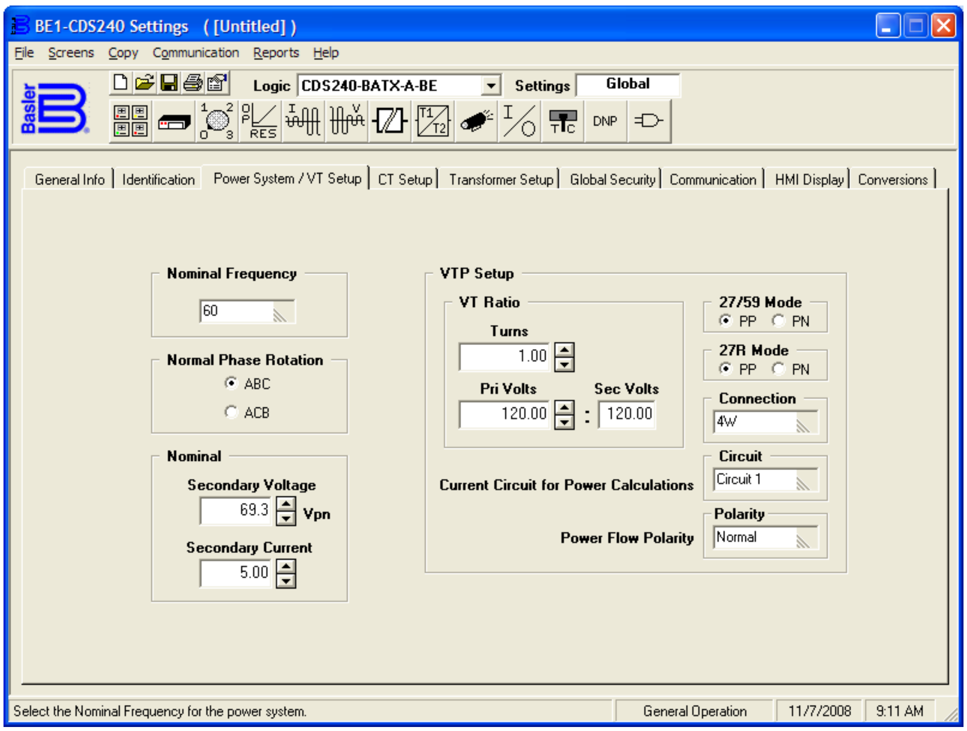


Figure 14-7. General Operation Screen, Power System / VT Setup Tab

CT Setup

This screen (Figure 14-8) allows you to enter the CT ratios and setup the CT parameters. These entries affect every function that relies on current measurements and calculations derived from those measurements. Pull down the *CT Ratio, Pri Amps, Sec Amps* menu and select the appropriate nominal current input. Enter the *CT Ratio Turns* value and the primary amperes value is entered for you. For example, if you entered 240 for the *Turns* value and the secondary nominal current input is 1, the primary amperes value is 240. If you change the secondary nominal current input to 5, the primary amperes value becomes 1,200. Select the correct *CT Connection* type. As appropriate, enter the values for CT Input 2, 3 and 4. If the ground current input is valid for your relay, enter the appropriate values for *Ground Input 1* (I_g) and *Ground Input 2* (I_{g2}).

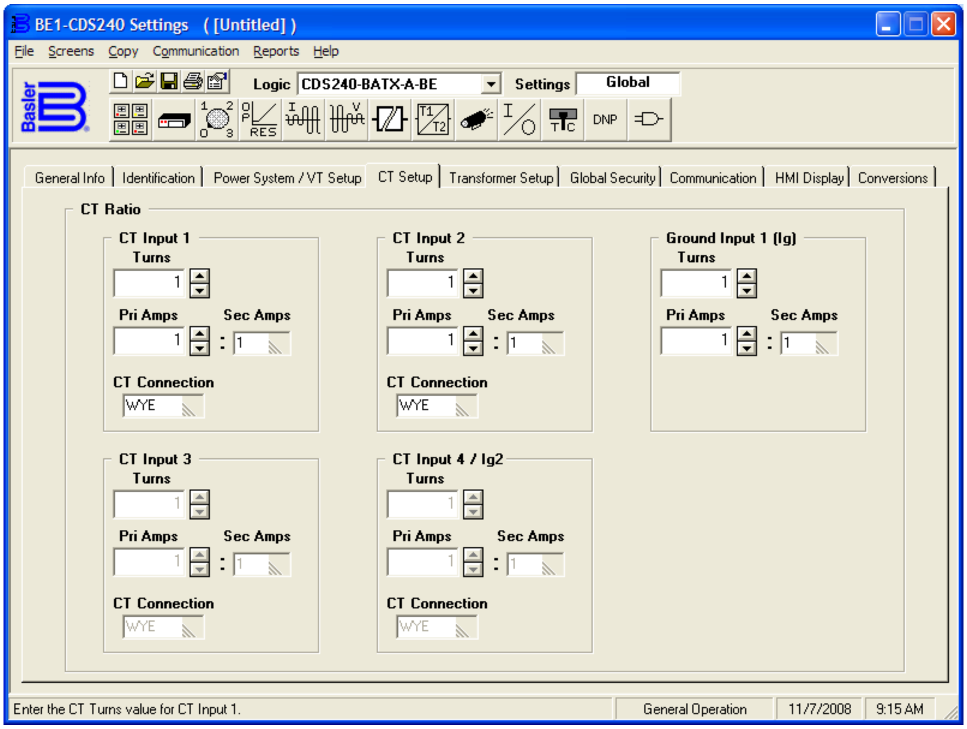


Figure 14-8. General Operation Screen, CT Setup Tab

Transformer Setup

This screen (Figure 14-9) allows you to set up the circuit configurations for four transformers circuits and two virtual circuits. Connection types, differential circuit, and transformer phase relationships can be set using pull-down menus. IEC transformer setup can be accessed by clicking the *IEC Setup* button. For more information on IEC Setup, refer to Section 3, *Input and Output Functions, Power System Inputs, Measurement Functions Setup, IEC Transformer Setup*.

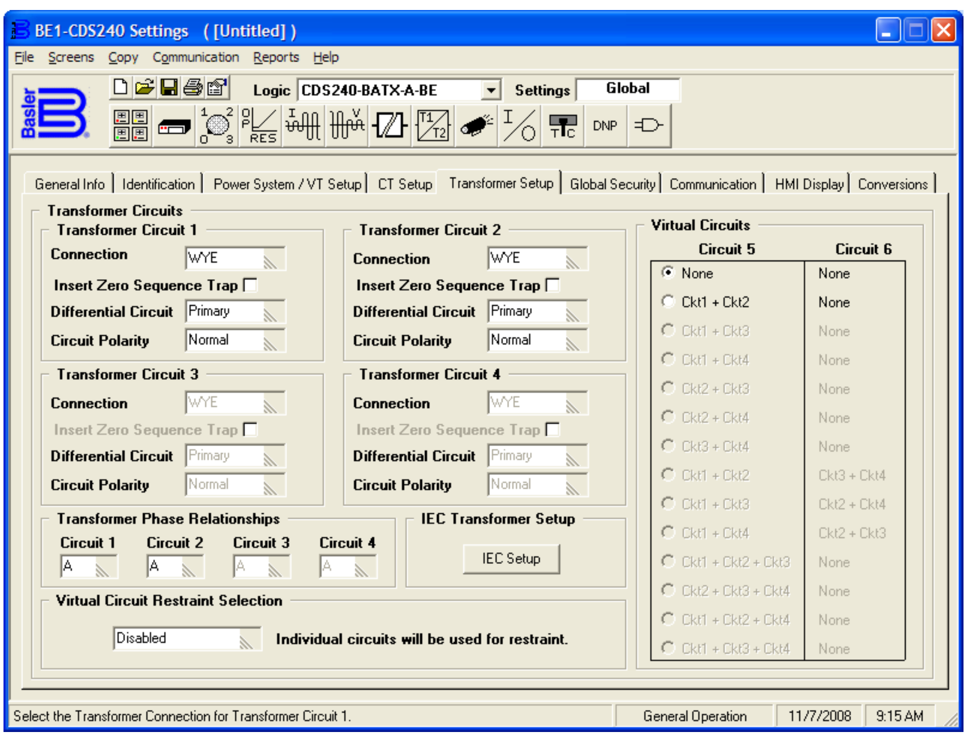


Figure 14-9. General Operation Screen, Transformer Setup Tab

Global Security

This screen (Figure 14-10) allows you to set up password security. Each of three communication ports and the four functional areas (Global, Settings, Reports, and Control) are protected with password security. This allows the user to customize password protection for any or all ports. For example, you could allow technicians to have global access (sometimes called a fourth level of access) to all three functional areas via the front port. You could also restrict the rear port, which is connected to a modem to read-only access.

If you select show passwords and notice that the default passwords have not been changed, then you may change all four passwords. If the global password has been changed, a dialog box appears explaining that you must enter the global password to enable viewing and editing the existing passwords. After entering the global password, the passwords and enable boxes appear. You may then make changes in any or all areas. Clicking a box for a specific communication port toggles the functional area for that port either ON or OFF. Notice that the front panel human-machine interface (HMI) and communications port zero are combined and considered as one.

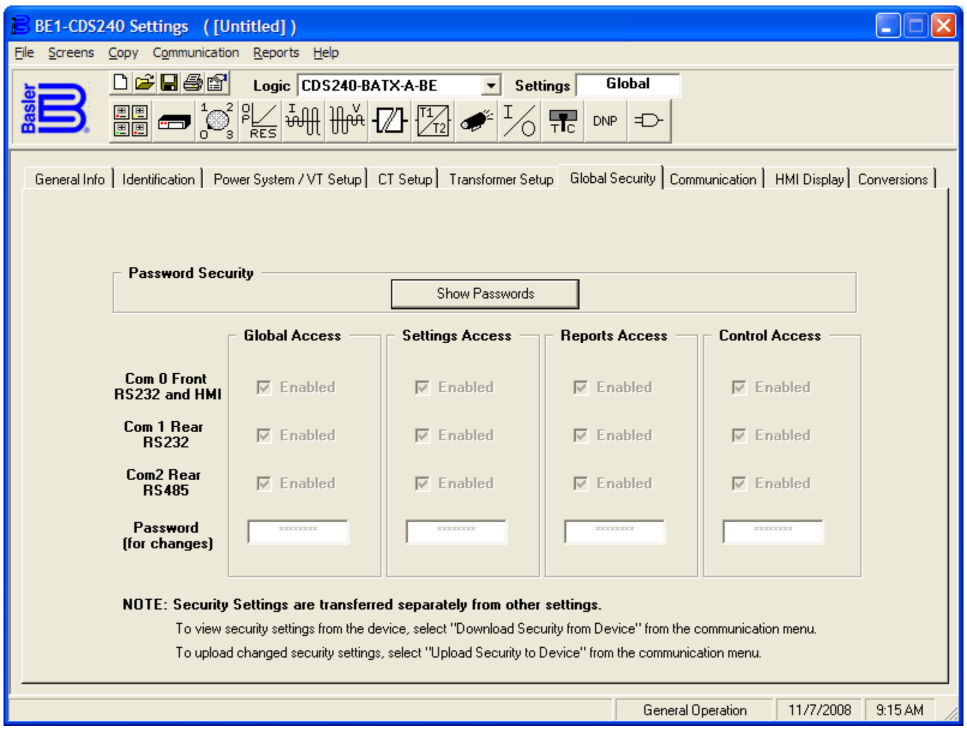


Figure 14-10. General Operation Screen, Global Security Tab

Communication

This screen (Figure 14-11) allows the user to set or change additional communication parameters that cannot be set with the toolbar *Communication, Configure* screen. *Baud Rate* has the pull-down menu while *Reply* and *Handshaking* are either enabled or disabled. *Page Length* can be stepped up or down one page at a time using the *Up* or *Down* arrow buttons. *Address* can be stepped up or down to change the address except for Com Port 0 Front. This address is always A0 and cannot be changed. If the relay has Modbus®, the *Com Port 2, Modbus Settings* panel appears on the *General Operation* screen, *Communication* tab. This panel allows the user to select the *Precision Format, Parity, Remote Delay Time*, *Stop Bits,* and *Password*. For more information on these parameters, see the Modbus Instruction Manual (Basler Electric part number 9365200992).

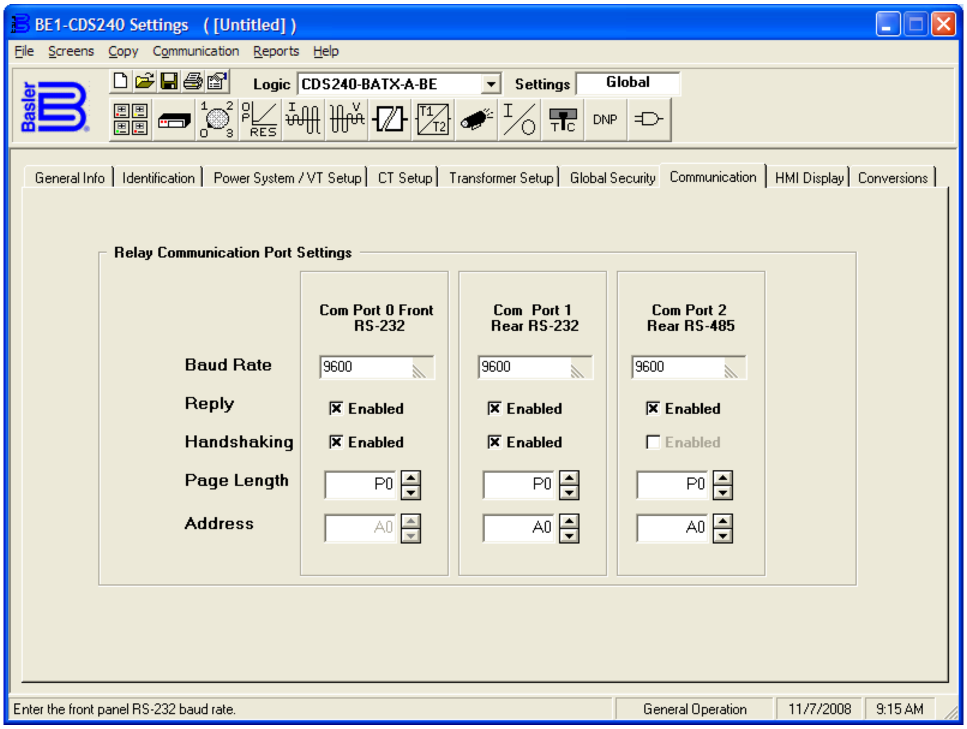


Figure 14-11. General Operation Screen, Communication Tab

HMI Display

The human-machine interface (HMI) screen (Figure 14-12) allows the user to change the screen scroll list. Only the code for the latest version of BESTCOMS is contained within BESTCOMS. If you have an earlier version of the embedded firmware in your relay and selected that information on the *General Info* tab under *General Operation* screen, you can select a screen scroll item in BESTCOMS that is not available in the relay. If you do, you will get an error code immediately.

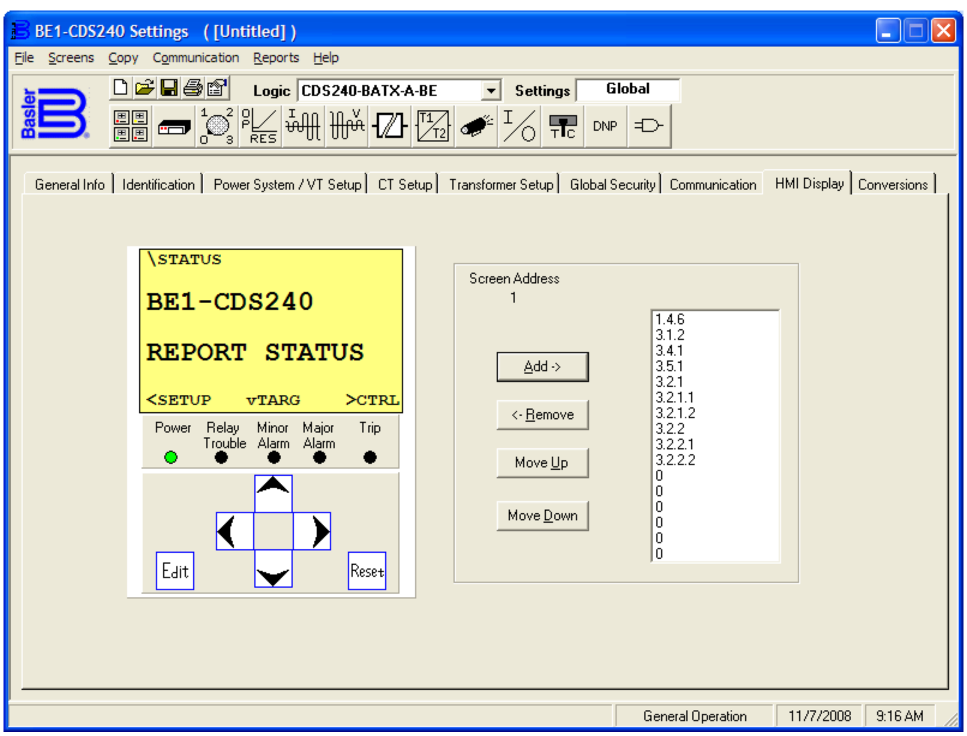


Figure 14-12. General Operation Screen, HMI Display Tab

Conversions

The *Conversions* tab (Figure 14-13) brings up the screen that allows entries in per unit. The per unit conversion for the settings involves entries for the base quantities. When you are entering settings later on, you can select primary current values, secondary current values, percent, or per unit. If you are using percent or per unit, then you have to enter the *Conversion* screen field values regarding three-phase, phase-to-phase, and phase-to-neutral base quantities. If the settings are entered in terms of primary or secondary current values, you do not need to enter this information.

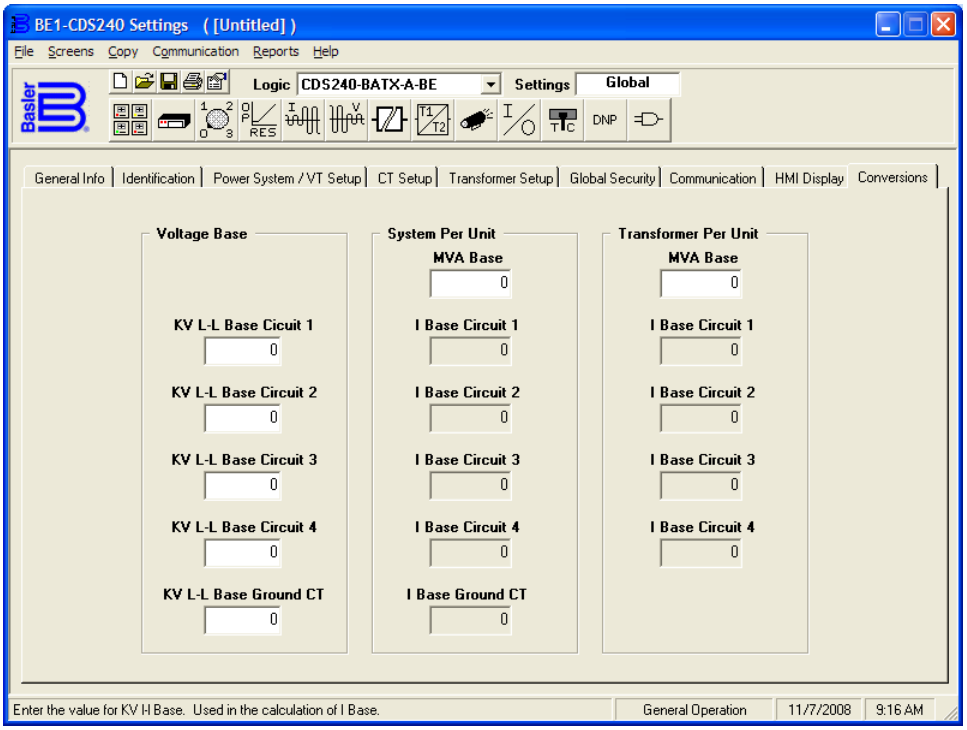
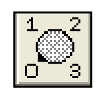


Figure 14-13. General Operation Screen, Conversions Tab

Setting Group Selection

Pull down the *Screens* menu and select *Setting Group Selection* or click on the Setting Group Selection icon that is shown at the right margin of this paragraph. This screen (Figure 14-14) does not have folder tabs and it is labeled *Setting Group Selection*.



Setting group selection involves programming the relay to automatically select one group out of four protective element setting groups in response to system conditions. When the system is normal, the default or normal group is 0. Auxiliary setting groups allow adapting the coordination settings to optimize them for a predictable situation. Sensitivity and time coordination settings can be adjusted to optimize sensitivity or clearing time based upon source conditions or to improve security during overload conditions. Near the bottom of Figure 14-14, there is a *Monitor Setting* window for Groups 1, 2, and 3. This field in each group allows you to select which element controls that specific group selection. The *Switch Threshold* sets the level for the monitored element and the *Switch Time* sets the time delay to prevent the group change from changing the instant that the monitored element exceeds the *Switch Threshold* setting. Return *Threshold* and *Time* does the same thing for changing back to the previous group.

You do not have to depend only on monitored conditions to change group selection. The active Setting Group can be controlled at any point in time by the setting group control logic. (Refer to Section 4, *Protection and Control*, for more information on Setting Groups.) The setting group control also has an alarm output variable SGC (Setting Group Changed). This output is asserted whenever the BE1-CDS240 switches from one setting group to another. The alarm bit is asserted for the SGCON time setting. You can click in the *Setting Group Change (SGC) Alarm Timer (Sec)* field and set the SGCON time setting.

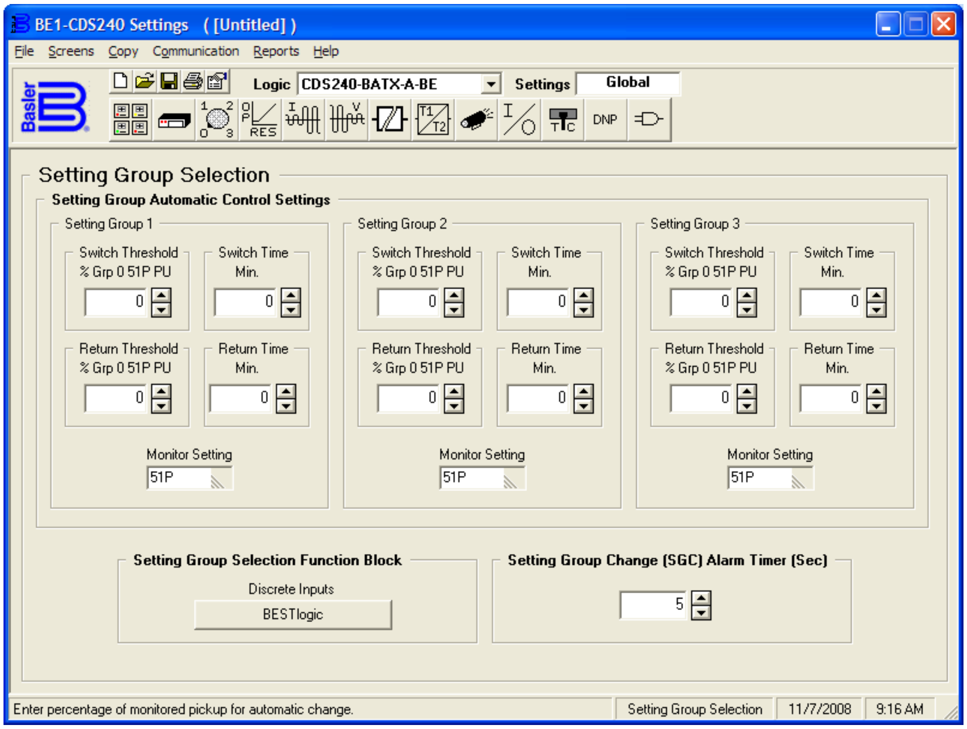
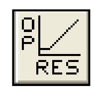


Figure 14-14. Setting Group Selection Screen

Percentage Differential



Pull down the *Screens* menu and select *Percentage Differential* or click on the Percentage Differential icon that is shown at the right margin of this paragraph. This screen has three folder tabs and the first tab is *87 Phase*.

87 Phase

The 87 Phase tab (Figure 14-15) brings up the screen that allows setting the 87 Tap. In the *MANUAL* mode, Tap, CT amps can be set for Circuit 1 and Circuit 2, only, through a range of 2 to 20. By selecting the box, "*Select to Enter Data for Auto Tap Calculation*," the *MANUAL* display changes to *AUTO*. In this mode, the transformer MVA can be set in the range of .5 to 9,999 and kv, CT can be set in the range of .01 to 1,000.

The *Restrained Pickup* can be set using the drop down menu. The 87 Phase can be adjusted from 0.10 times tap to 1.00 times tap using the *Up/Down* arrows. Restraint Slope % is, likewise, adjustable from 15 to 60% with 45% being the default. The 2nd *Harmonic Restraint % Iop* can be set from 5 to 75 with 18.0 being the default. The 5th *Harmonic Restraint % Iop* has the same range with 35.0 being the default.

Unrestrained Pickup is set using the drop down menu arrow next to the selection box. To the right, *Up/Down* arrows are used to select any value between 1 times tap to 21 times tap with zero as the default.

Refer to Section 4, *Protection and Control, Differential Protection,* for more information on the 87 function.

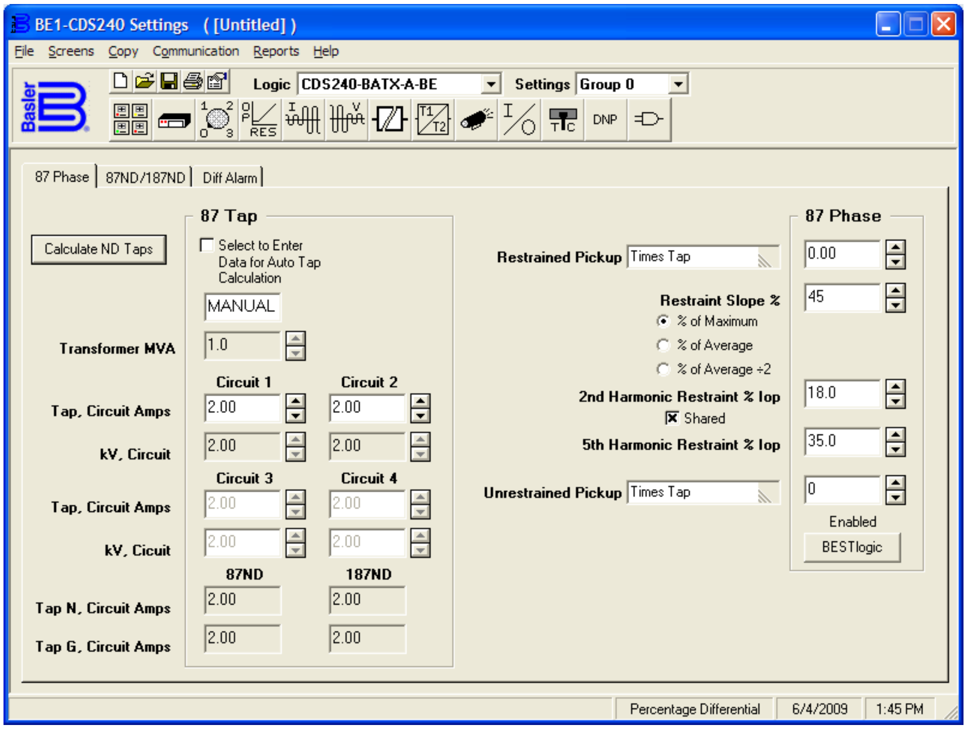


Figure 14-15. Percentage Differential Screen, 87 Phase Tab

87ND/187ND

The 87ND/187ND tab (Figure 14-16) brings up the screen that allows setting the 87 Neutral Differential. *Restrained Pickup* is adjusted using the pull-down menu with *Times Tap* as the default. Other options include *Input 1-4 amps* and *Input 1% to 3% Full Load*. The allowed range for *Times Tap* is 0.010 times tap to 1.000 times tap using the *Up/Down* arrows. *Restraint Slope %* can be set for 15 to 60 degrees. *Time* can be set for milliseconds, minutes, or cycles using the drop down menu.

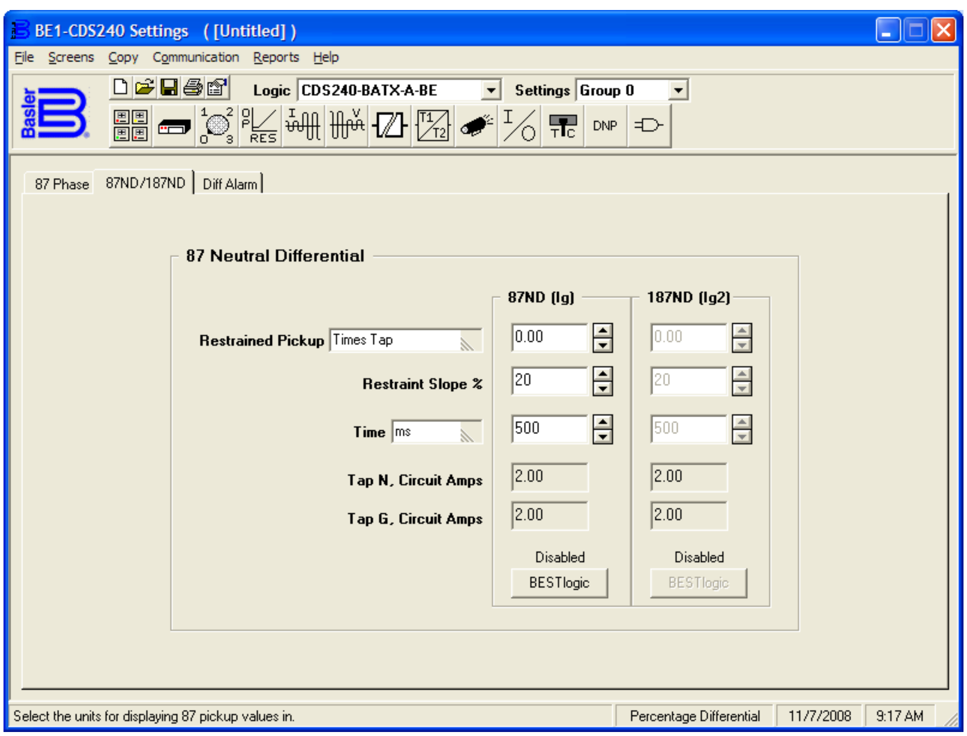


Figure 14-16. Percentage Differential Screen, 87ND/187ND Tab

Diff Alarm

The Diff Alarm tab (Figure 14-17) brings up a screen that allows setting the percentage of differential characteristic. The default value is 67% but the permissible range is 50 to 100.

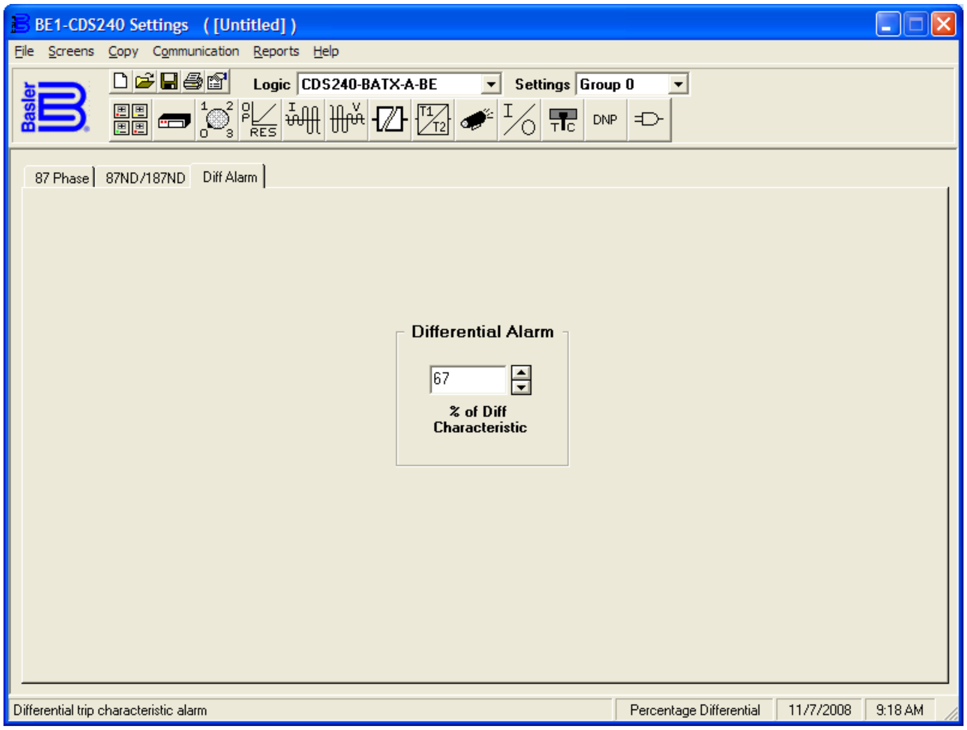
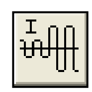


Figure 14-17. Percentage Differential Screen, Diff Alarm Tab

Overcurrent Protection

Pull down the *Screens* menu and select *Overcurrent* or click on the Overcurrent Protection icon that is shown at the right margin of this paragraph. This screen has seven folder tabs and the first tab is *51*.



51

This screen (Figure 14-18) allows you to enter the settings for the 51 time overcurrent elements. BE1-CDS240 relays have four phase time overcurrent elements, five neutral time overcurrent elements, and four negative-sequence time overcurrent elements. They are divided up into three tabs, (*51, 151/251,* and *351/451*). The pull down *Pickup* menu allows you to select the relative pickup quantity. BE1-CDS240 relays measure the current input in secondary amperes. If you want to use per unit, percent amperes, or primary current, you must coordinate the settings in *CT & VT Setup* and *Conversions*. Do this also for the *27R Threshold* setting. If you want to use the voltage control mode instead of voltage restraint, pull down the menu for *Restraint* (default setting) and select *Control*. Settings for *Time Dial, Curve* (time characteristic curve), and *Direction Control* are conventional settings. If you want to change the characteristic curve constants, select the *Curve Coefficients* and a dialog box opens for those entries. Select the *BESTlogic* button at the bottom of the *Phase (51P)* panel. The status of the logic is shown above the *BESTlogic* button. A dialog box (*BESTlogic Function Element*) opens showing the status of the element logic and the logic scheme name. If you have a custom logic scheme active, you may change the status of the element logic by pulling down the menu and selecting from the available choices.

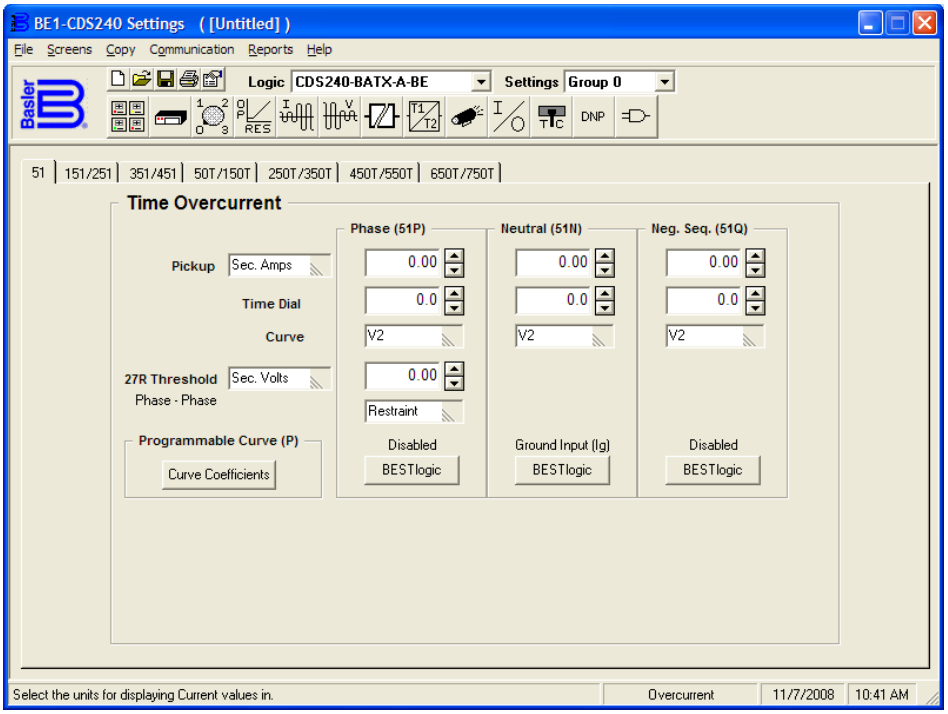


Figure 14-18. Overcurrent Screen, 51 Tab

151/251 and 351/451 Tabs

These two screen tabs allow you to enter the settings for the 151/251 and 351/451 time overcurrent elements. They are configured the same as on the *51* tab.

50T/150T

BE1-CDS240 relays have eight instantaneous overcurrent elements with settable time delay. The screens for the instantaneous elements are almost identical to the *51* screen. The settable time delay is the primary difference. See Figure 14-19. To change the time delay, pull down the *Time* menu, select your preferred unit of measure, and then change the time for the appropriate phase, neutral, or negative sequence element.

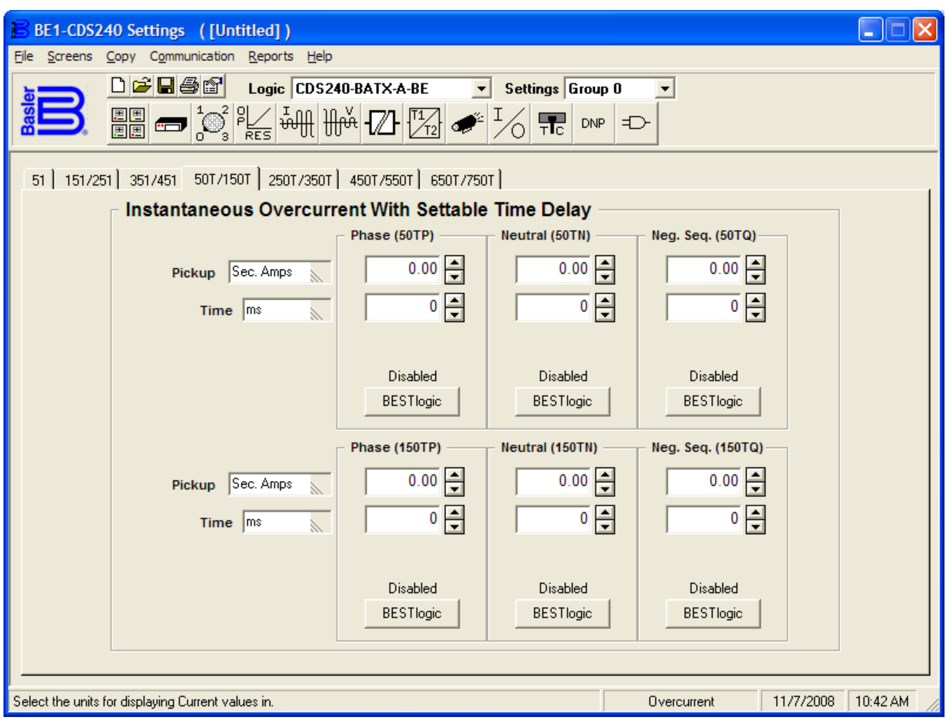
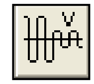


Figure 14-19. Overcurrent Screen, 50T/150T Tab

250T/350T, 450T/550T and *650/750T Tabs*

These three screen tabs allow you to enter the settings for the 250T, 350T, 450T, 550T, 650T, and 750T time overcurrent elements with settable time delay elements. They are configured as explained above.

Voltage Protection



Pull down the *Screens* menu and select *Voltage Protection* or click on the Voltage Protection icon that is shown at the right margin of this paragraph. The screen (Figure 14-20) has six tabs and the first tab is *24*. Many of the settings for voltage protection are identical or similar to those settings in overcurrent protection, so the explanations will not be repeated.

24

This tab (Figure 14-20) allows you to make the settings for the overexcitation (volts/hertz) element. The pull down pickup menu allows you to select the relative pickup quantity. The BE1-CDS240 relay measures the voltage input in secondary voltage. If you want to use primary volts, per unit volts, or percent volts, you must coordinate the settings in *CT & VT Setup* and *Conversions*. Whatever the measurement, the method is displayed beside the settings - e.g., V_{PP} (voltage, phase-to-phase). Settings for *Time Dial* and *Reset Dial* can be adjusted in the range of 0 to 9.9 in .1 increments. The *Alarm Threshold* (percent of pickup) can be adjusted from 0 to 120.

Select the *BESTlogic* button at the bottom of the 24 column. The status of the logic is shown above the *BESTlogic* button. A dialog box (*BESTlogic Function Element*) opens showing the status of the element logic and the logic scheme name. If you have a custom logic scheme active, you may change the status of the element logic by pulling down the menu and selecting from the available choices.

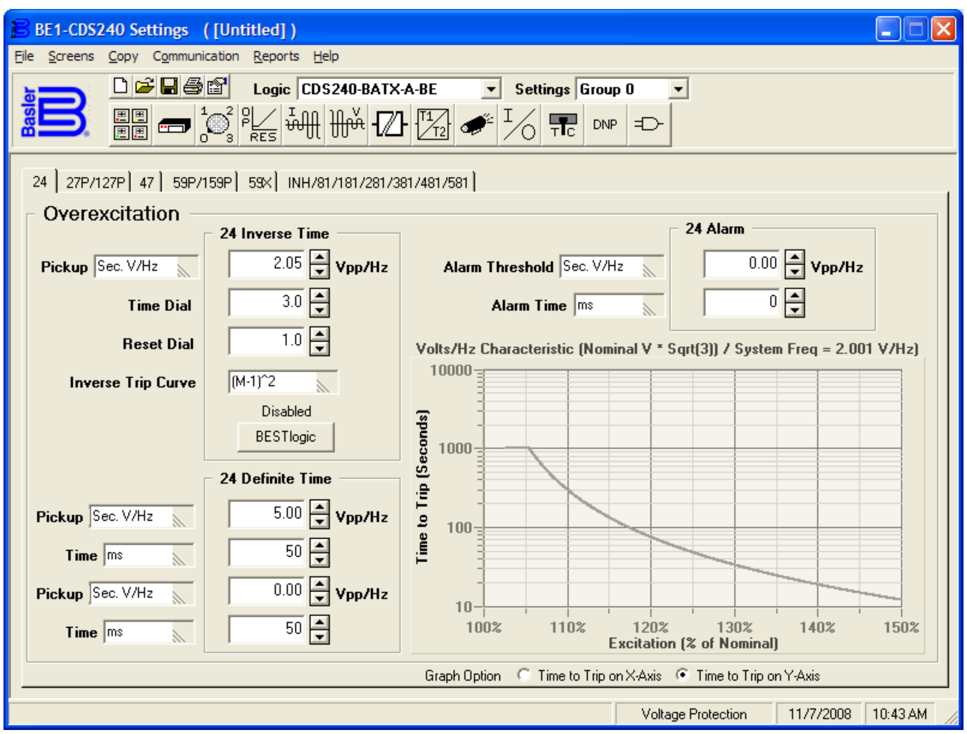


Figure 14-20. Voltage Protection Screen, 24 Tab

27P/127P

This tab (Figure 14-21) allows you to configure the phase undervoltage with settable time delay elements. The pull down *Pickup* menu allows you to select the relative pickup quantity and inhibit quantity. The BE1-CDS240 relay measures the voltage input in secondary voltage. If you want to use primary volts, per unit volts, or percent volts, you must coordinate the settings in *CT & VT Setup* and *Conversions*. Whatever the measurement, the method is displayed beside the settings - e.g., V_{PP} (voltage, phase-to-phase). Select the *Time* delay unit of measure and the value for the 27P and 127P elements in the range of 0.50 to 600 seconds. Select the *BESTlogic* button at the bottom of the *Phase (27P)* or *Phase (127P)* columns. The status of the logic is shown above the *BESTlogic* button. A dialog box (*BESTlogic Function Element*) opens showing the status of the element logic and the logic scheme name. If you have a custom logic scheme active, you may change the status of the element logic by pulling down the menu and selecting from the available choices.

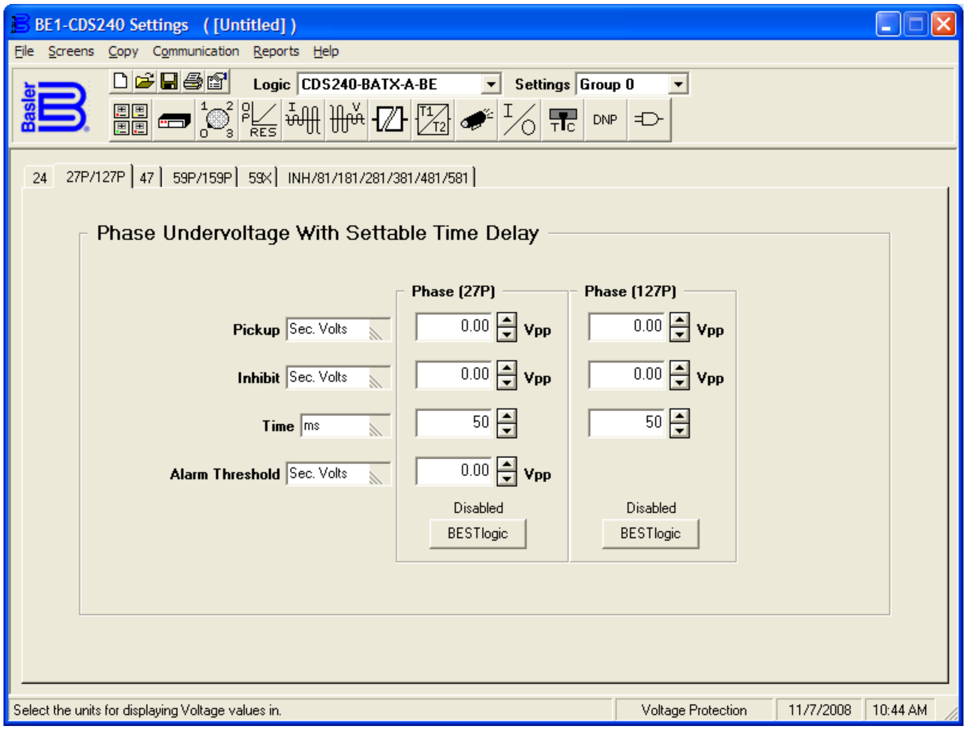


Figure 14-21. Voltage Protection Screen, 27P/127P Tab

47

This tab (Figure 14-22) is the *Negative Sequence Overvoltage With Settable Time Delay*. Changing the settings for this element is similar to those of the 27P/127P elements above.

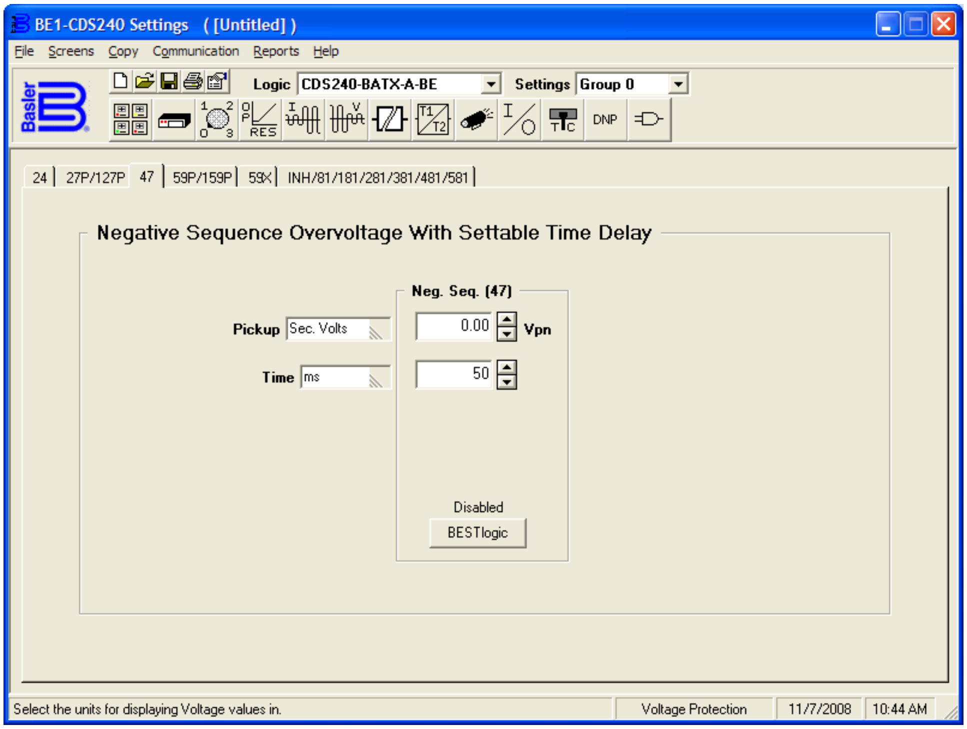


Figure 14-22. Voltage Protection Screen, 47 Tab

59P/159P

This tab (Figure 14-23) is the *Phase Overvoltage With Settable Time Delay*. Changing the settings for this element is similar to those settings of the 27P/127P elements above.

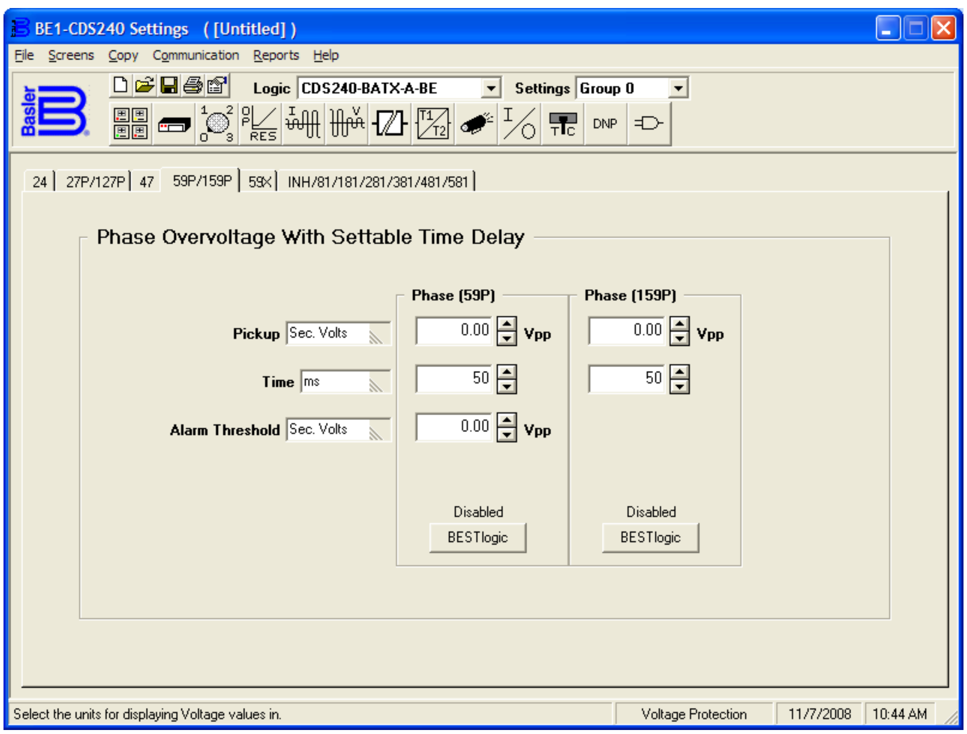


Figure 14-23. Voltage Protection Screen, 59P/159P Tab

59X

This tab (Figure 14-24) is the *Auxiliary Overvoltage Protection With Settable Time Delay*. Changing the settings for this element is similar to those settings of the 27P/127P elements above.

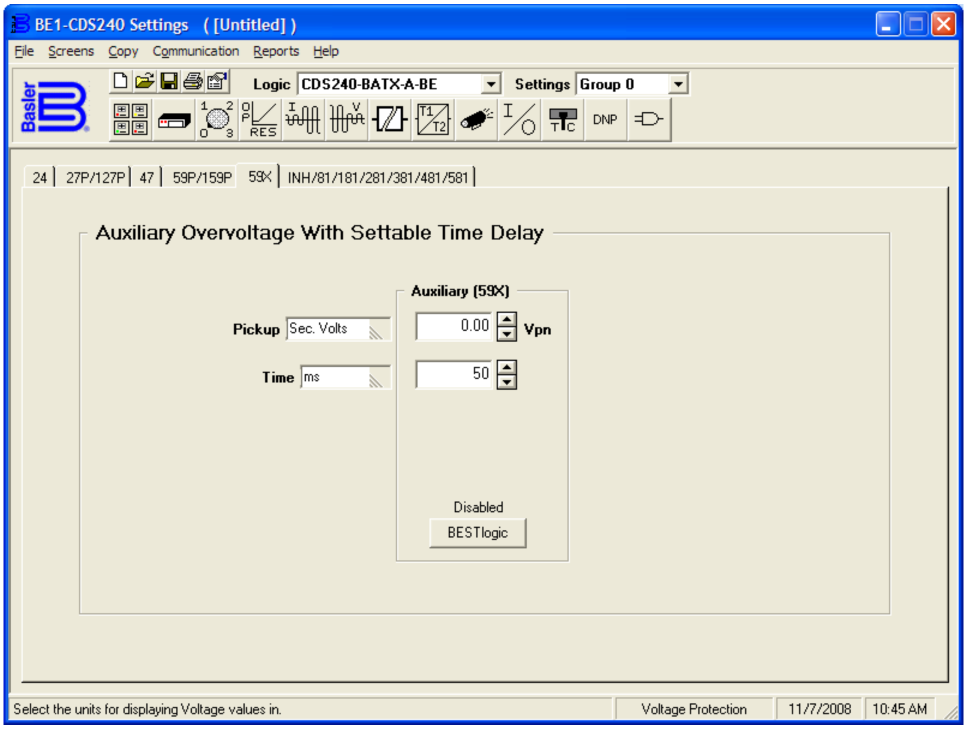


Figure 14-24. Voltage Protection Screen, 59X Tab

INH/81/181/281/381/481/581

This tab (Figure 14-25) is the *O/U Frequency With Settable Time Delay*. Changing the settings for these elements are similar to those settings of the 27P/127P elements above.

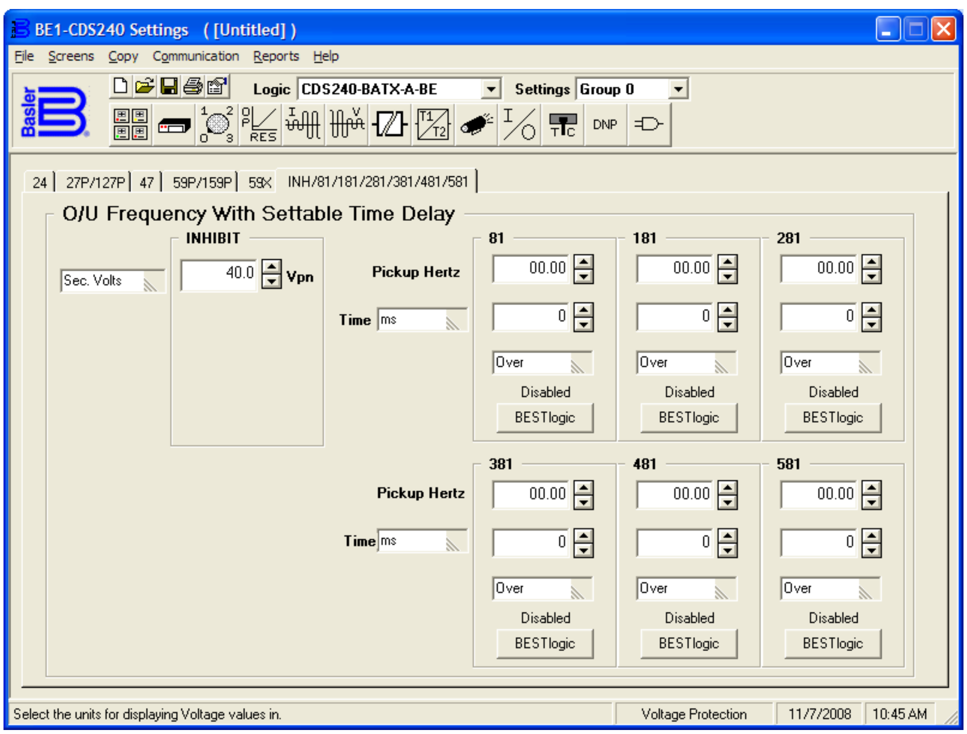
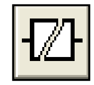


Figure 14-25. Voltage Protection Screen, INH/81/181/281/381/481/581

Breaker Failure



Pull down the *Screens* menu and select *Breaker Failure* or click on the Breaker Failure icon that is shown at the right margin of this paragraph. This screen has four folder tabs and the first is *50BF*.

50BF

To set the time delay from when the breaker failure initiate is received and the trip output is asserted, first pull down the *Time* menu and set the units for time measurement i.e., milliseconds, seconds, minutes, or cycle). See Figure 14-26. Then set the *Pickup* secondary amps, primary amps, per unit amps, or percent amps. *Phase* and *Neutral Fault Detector Pickup (PU)* can then be set in the range of .25 to 10.0. The BF150 *Control Timer* can be set using the *Up/Down* arrows within a range of 50 to 999 milliseconds.

Logic settings for the breaker failure function can be made by clicking on the *BESTlogic* button and with your custom logic selected. Select the mode and other input logic by using the *Mode* pull-down menu and clicking on the logic inputs to set the logic.

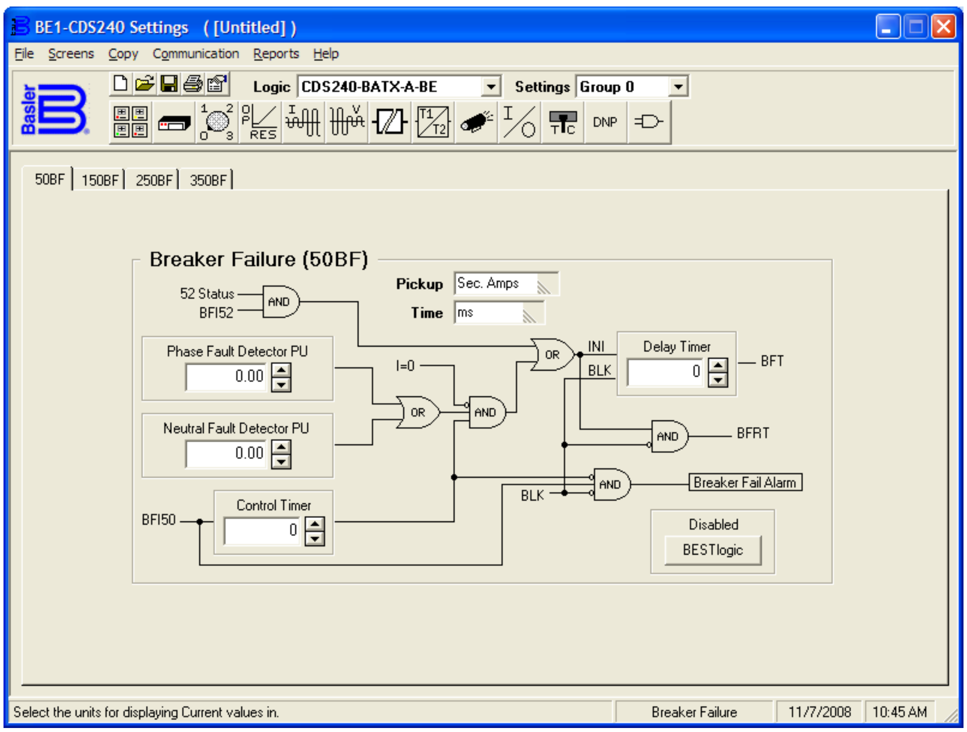
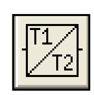


Figure 14-26. Breaker Failure Screen, 50BF Tab

150BF, 250BF, 350BF Tabs

These three tabs are for setting the 150 Breaker Failure, 250 Breaker Failure, and 350 Breaker Failure elements. Changing the settings for these elements are identical to those of the 50BF element above.

Logic Timers



Pull down the *Screens* menu and select *Logic Timers* or click on the Logic Timers icon that is shown at the right margin of this paragraph. This screen (see Figure 14-27) configures four logic timers and has no folder tabs.

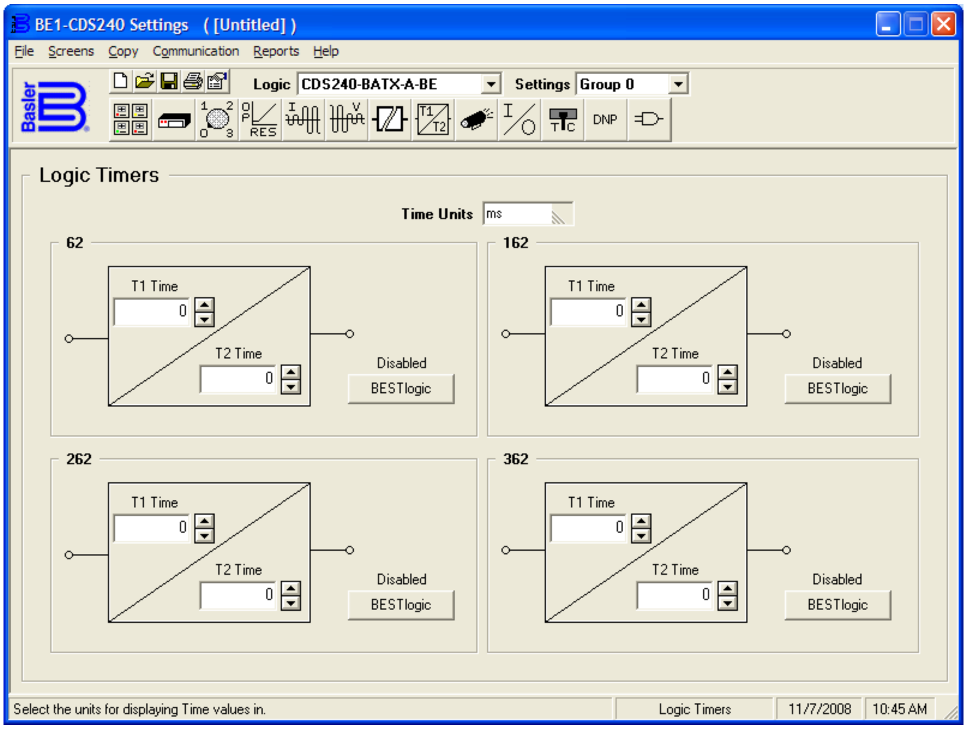


Figure 14-27. Logic Timers Screen

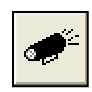
62/162/262/362

Logic timers, 62, 162, 262, and 362 are general-purpose timers with six operating modes. Each operating mode has a T1 and T2 setting. The function of these settings depends on the type of timer (mode) selected. For a description of the setting functions, see Section 4, *Protection and Control*.

Logic settings for the logic timers can be made by clicking on the *BESTlogic* button and with your custom logic selected. Use the *Mode* pull-down menu and select one of the six timer modes or disable the logic timers. Select other input logic by clicking on the logic inputs to set the logic.

Reporting and Alarms

Pull down the *Screens* menu and select *Reporting and Alarms* or click on the Reporting and Alarms icon that is shown at the right margin of this paragraph. This screen has ten folder tabs and the first tab is *Clock Display Mode*.



Clock Display Mode

Use the Time Format and Date Format pull-down menus to set the current time and date in the preferred format.

Recording of time or date changes made via Modbus® or DNP is optional and is disabled by default. Recording of time or date changes made via the HMI or the SG-CLK ASCII command is automatic and cannot be disabled. See Figure 14-28.

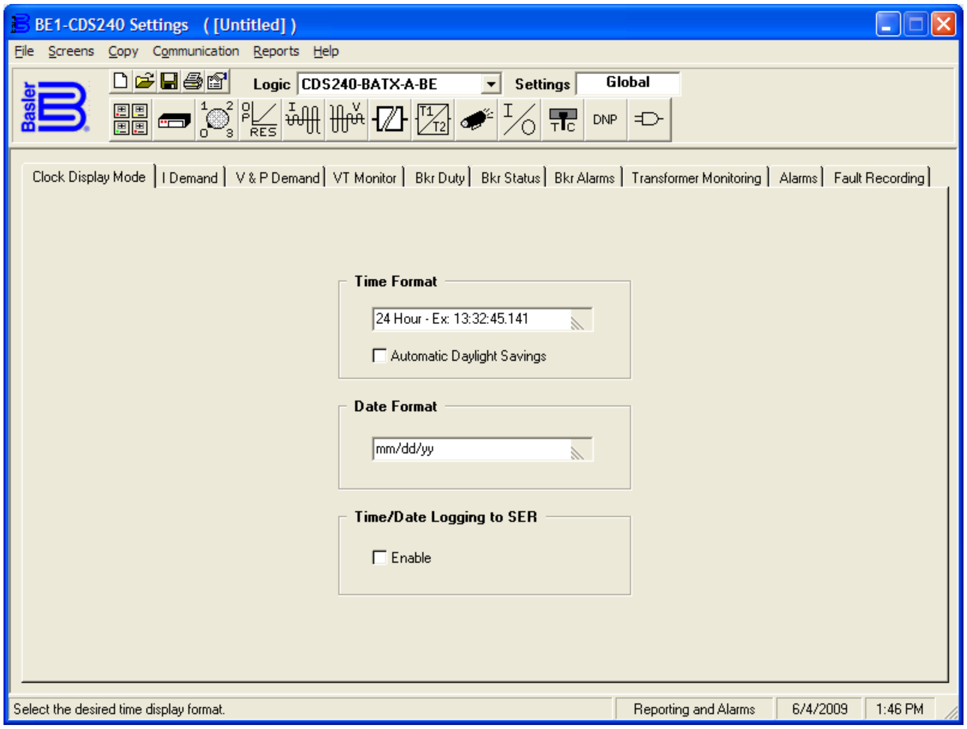


Figure 14-28. Reporting and Alarms Screen, Clock Display Mode Tab

I Demand

The long title for this screen is *Current Demand Metering and Alarms* (Figure 14-29). Demand intervals can be set independently for the phase, neutral, and negative-sequence demand calculations. Click in the *Phase, Neutral,* or *Neg. Sequence* fields and enter the time in minutes or adjust the time by using the appropriate (*Up* or *Down*) arrow buttons. Use the pull-down menus to set the unit of measure for each threshold setting. The demand value is shown in each field as the data is metered.

Load Profile is an optional function and is not available on some units. This option uses a 4,000-point data array for data storage. At the load profile logging interval, the data in the demand calculation registers is copied and stored in the data array. The period required to generate 4,000 entries is shown in the *Logging Period (Days)* field. To set the *Logging Interval (Minutes)*, click in the field and enter the time or adjust the time by using the appropriate (*Up* or *Down*) arrow buttons in the range of 1 to 60 minutes.

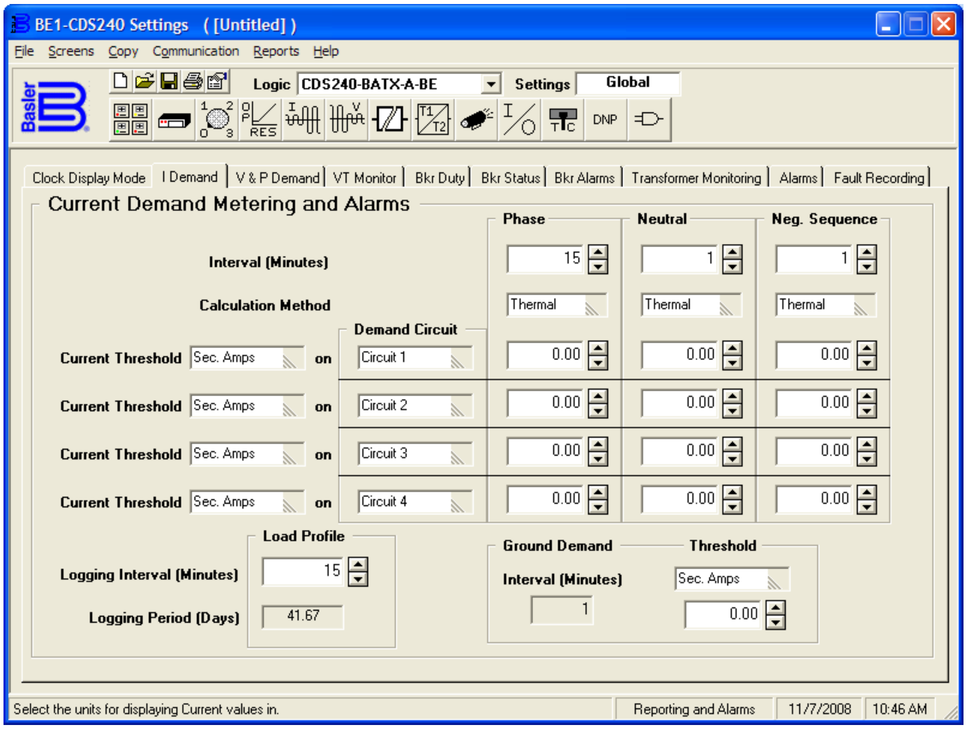


Figure 14-29. Reporting and Alarms Screen, I Demand Tab

V & P Demand

The long title for this screen is *Voltage and Power Demand Metering and Alarms* (Figure 14-30). Using the pull-down menu, select *Sec. Volts, Per U Volts,* or *% Volts* as the *Phase & Average Voltage Threshold* unit of measure. Then by using the *Up/Down* arrows, set the *Max* and *Min Phase* values in the range of 10.0 to 300 secondary volts. Likewise, *Max Neutral* and *Min Neutral* can be set in the range of 10.0 to 150 secondary volts.

Watt Demands and *Var Demands* can be set in a similar fashion after establishing the unit of measure. The permissible range is 0.0 to 8,500 secondary watts, or vars, as appropriate.

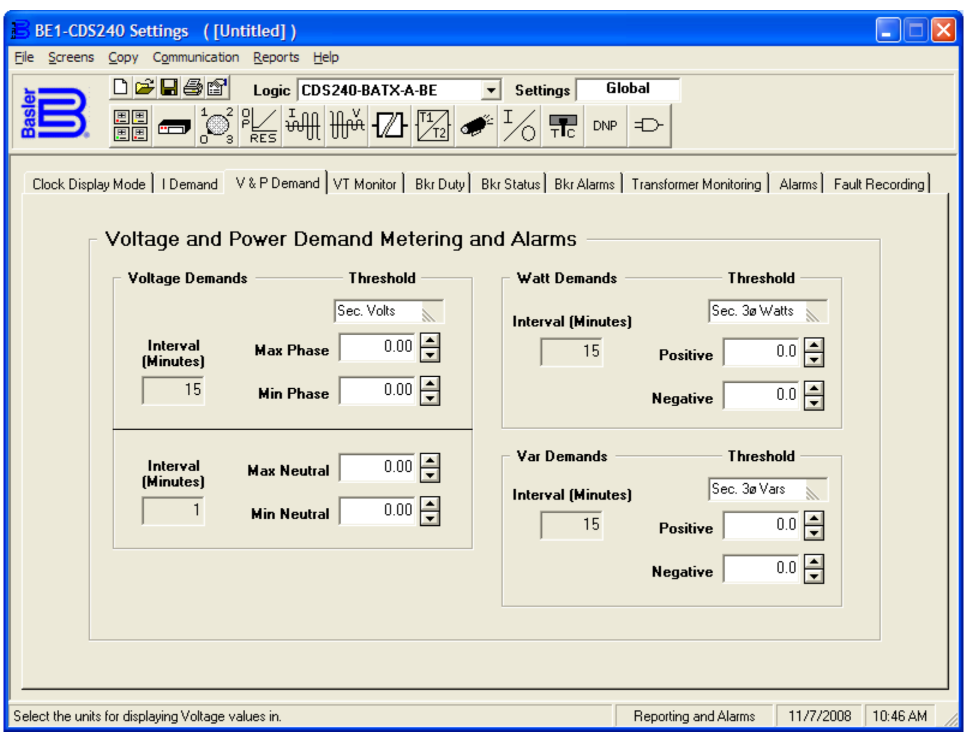


Figure 14-30. Reporting and Alarms Screen, V & P Demand Tab

VT Monitor

The long title for this screen is *Fuse Loss Block Logic* (Figure 14-31). Fuse loss block logic can prevent misoperation on loss of sensing voltage. This can be applied on both the 51/27 (voltage control) and 27/59 functions.

When the 51/27 function is set for control and a 60FL condition is detected, the phase overcurrent elements will be disabled if you place an **x** in the *51/27 Block Voltage Control* field by clicking in the field.

If the *27/59, Block Phase* is enabled with a check mark in the field and a 60FL condition is detected, all functions that use the phase voltage are blocked. If the *27/59, Block 3V0* is enabled with a check mark in the field and a 60FL condition is detected, all functions that use the auxiliary over/undervoltage (27x/59x) functions with Mode 2 selected are blocked. If the *27/59, Block V2* is enabled with a check mark in the field and a 60FL condition is detected, all functions that use the negative sequence voltage are blocked.

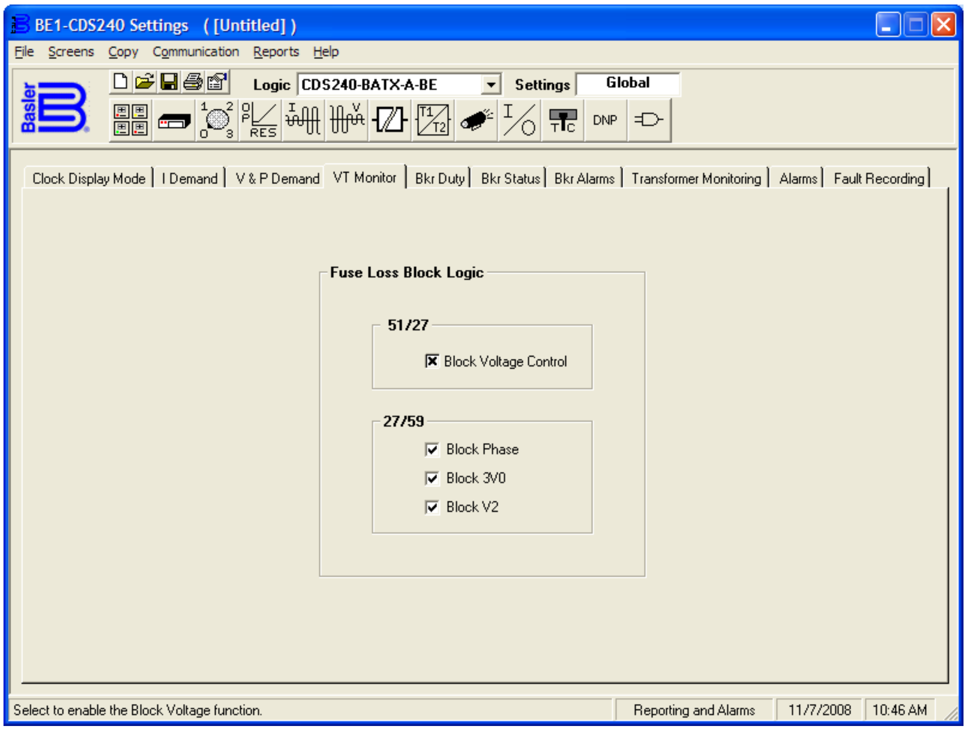


Figure 14-31. Reporting and Alarms Screen, VT Monitor Tab

Bkr Duty

The long title for this screen is *Circuit x Breaker Duty Monitoring* (Figure 14-32) where x equals Circuits 1 through 4. Every time the breaker trips, the breaker duty monitor updates two sets of registers for each pole of the breaker. This function selects which of the two sets of duty registers are reported and monitored, sets the existing values, and programs the function logic.

Click in the field for *100% Duty Maximum* and set the value. Logic settings for the *Block Accumulation Logic* can be made by clicking on the *Logic* button. With your custom logic selected, select the block accumulation logic.

Because the relay is completely programmable, it is necessary to program which logic variable monitors breaker status (how the relay knows when the breaker is closed). Set the *Breaker Status Logic* by clicking on the *Logic* button. With your custom logic selected, select the control logic.

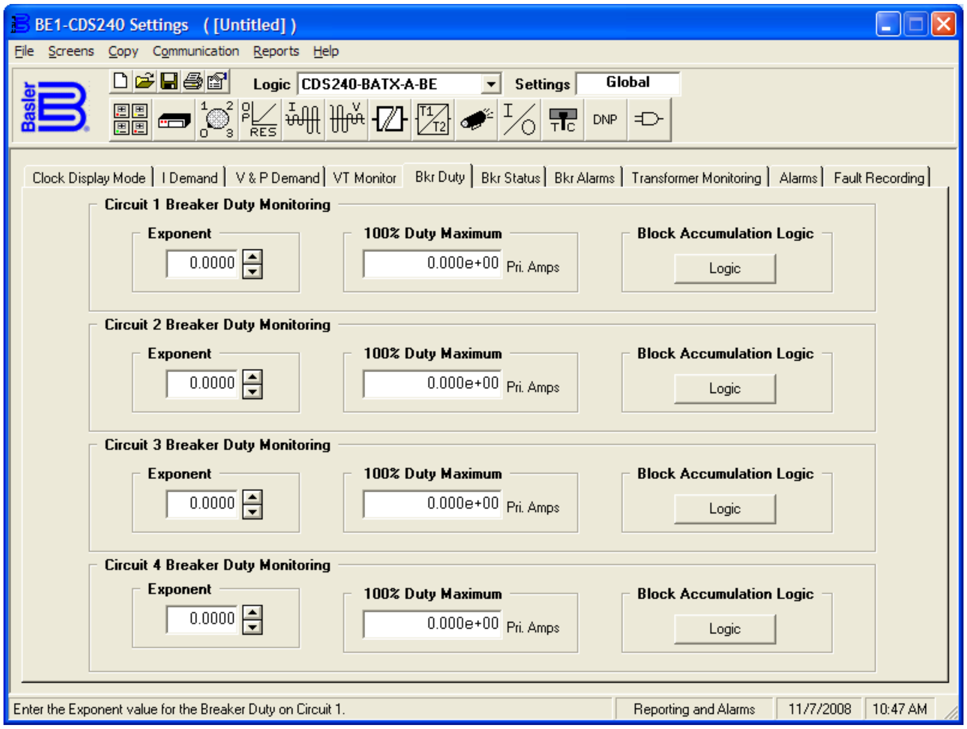


Figure 14-32. Reporting and Alarms Screen, Bkr Duty Tab

Bkr Status

The long title for this screen is *Circuit x Breaker Status* (Figure 14-33) where x equals Circuit 1, 2, 3, or 4. Circuit breaker labels can be tailored to meet user-defined needs by entering the new label in the *Breaker Name* box. If desired, the *Enable Trip Coil Monitor* may be enabled by selecting the appropriate box for each of the four possible circuits being monitored. Breaker status logic is TRUE when the breaker is closed.

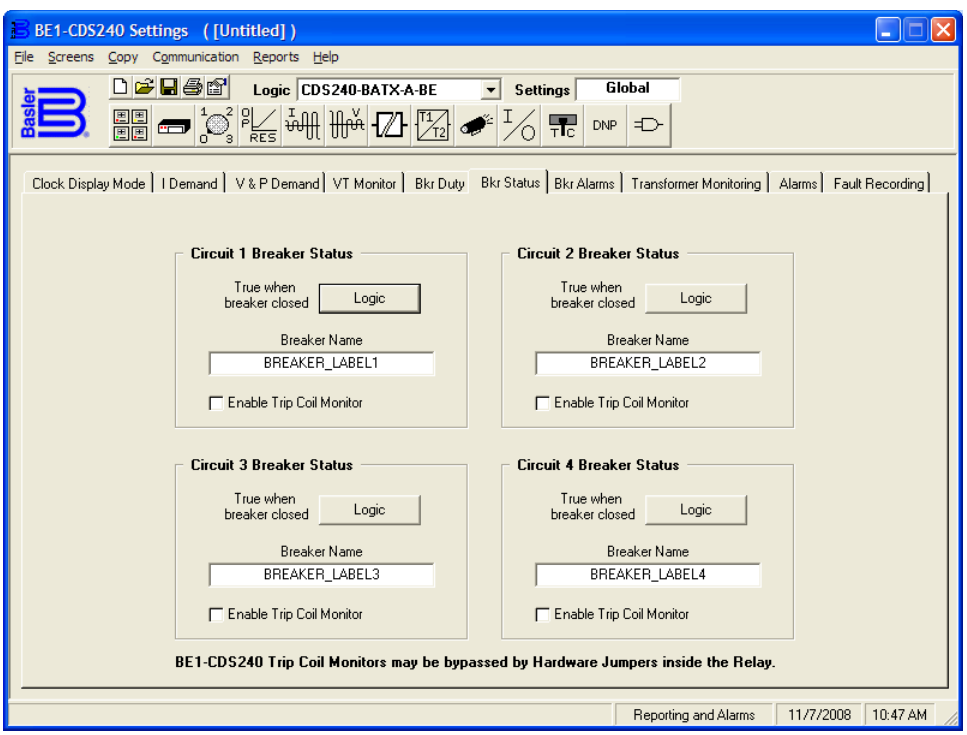


Figure 14-33. Reporting and Alarms Screen, Bkr Status Tab

Bkr Alarms

The long title for this screen is *Breaker Alarms* (Figure 14-34). Twelve alarms can annunciate events involving up to four circuits (Circuit 1-4). For each alarm (Alarm 1 -12), the mode, circuit number, and threshold can be set. The pull down arrows will allow the *Mode* to be selected as *Disabled* (default), *Duty*, *Operations*, or *Clearing Time*. The Threshold (range) is set using *Up/Down* arrows and is dependent on the mode setting: *Duty:* 0-100; *Operations:* 0-99,999; and *Clearing Time:* 20 - 1,000 ms.

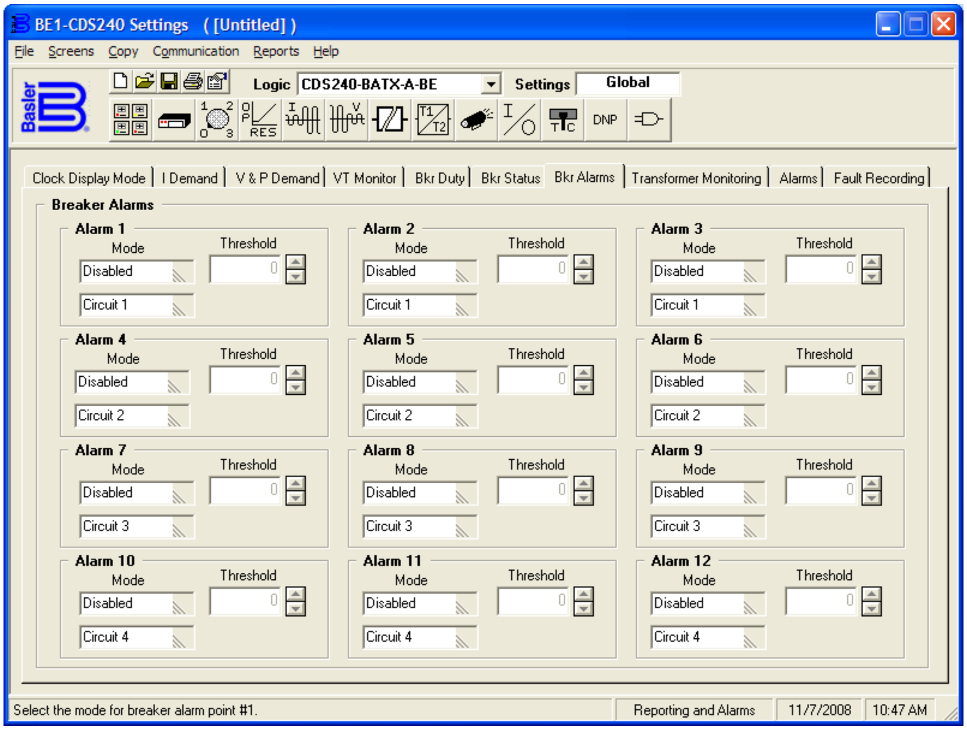


Figure 14-34. Reporting and Alarms Screen, Bkr Alarms Tab

Transformer Monitoring

The long title for this screen is *Transformer Duty Monitoring - Transformer Alarms* (Figure 14-35). Four transformer duty monitors are provided with the BE1-CDS240 (Monitor 1-4). Each one has settings for *Mode* (*Disabled, Enabled I,* and *Enabled I2*), circuit number (*Circuit 1-6*), and *100% Duty Maximum* in primary amps.

In addition, eight transformer alarms are provided (Alarm 1-8). The pull down arrows will allow the *Mode* to be selected as *Disabled* (default), *Duty*, or *Thru Faults*. The *Threshold* (range) is set using *Up/Down* arrows and is dependent on the mode setting: *Duty:* 0-100 and *Thru Faults:* 0 - 99,999. *Duty* is selectable using a pull-down arrow with options for *Duty 1* (default) thru *Duty 4*.

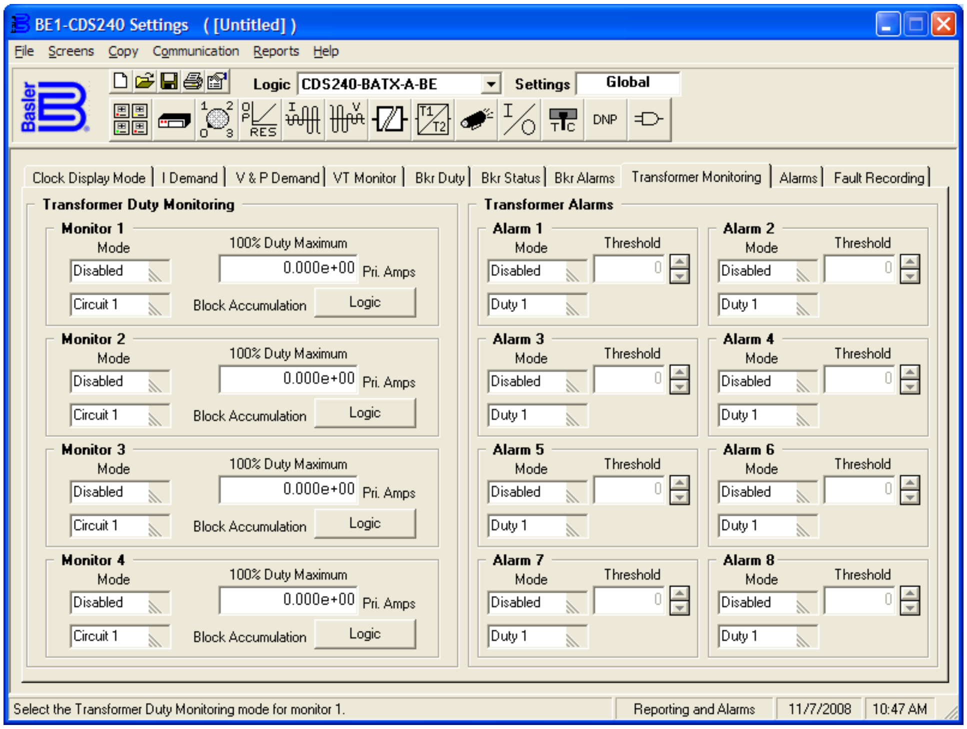


Figure 14-35. Reporting and Alarms Screen, Transformer Monitoring Tab

Alarms

BE1-CDS240 relays have 71 programmable alarm points (Figure 14-36). These points are for the monitored power system, associated equipment, and non-core circuits and functions in the relay. Each of these alarm points can be programmed to assert the Major, Minor, or Logic Alarm when an alarm point is activated. To program an alarm point, find the point in the *Alarm Priority* list and then click on the appropriate field under *the Major, Minor,* or *Logic Alarm*.

Logic settings for the *Alarm Reset Logic* can be made by clicking on the *Logic* button and then clicking on the *Reset* input. Other logic blocks shown under the BESTlogic panel are shown for reference only. There is no interaction available.

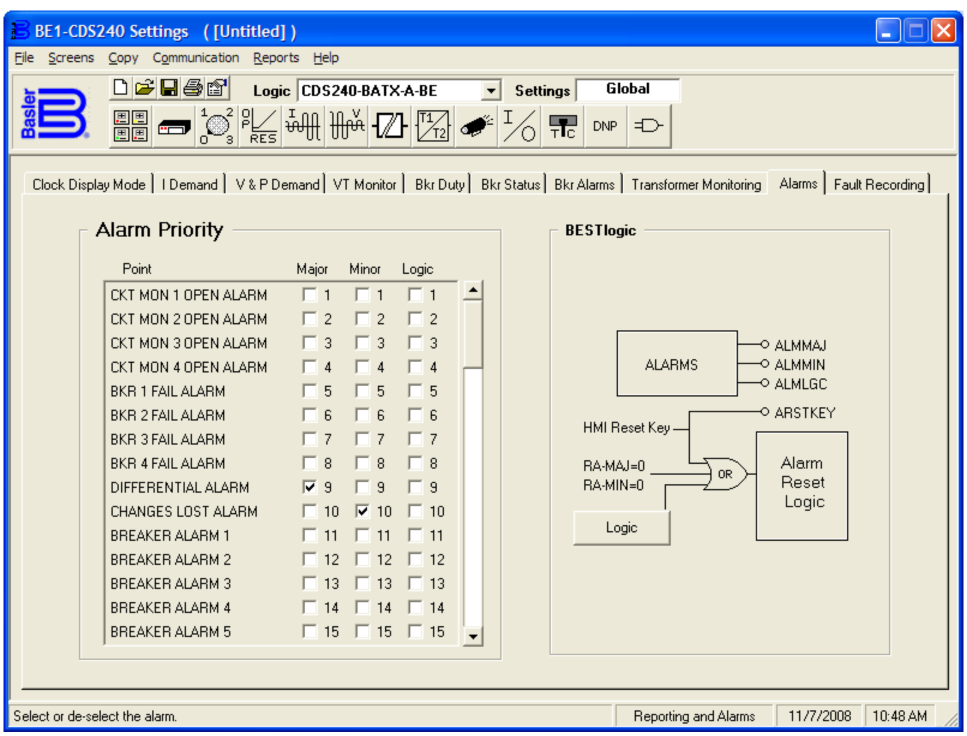


Figure 14-36. Reporting and Alarms Screen, Alarms Tab

Fault Recording

Logic expressions define the three conditions that determine when a fault has occurred. If a fault is detected by the relay, the relay records (stores in memory) data about the fault. The three conditions that determine a fault are *Trip*, *Pick Up*, and *Logic* trigger. To define these conditions, click on *Fault Recording, Logic*, and then click on *Tripped, Pickup*, and *Logic* in turn and program the inputs that define each condition. (See Figure 14-37.) You may clear the existing programming by clicking on the *Clear* button or clicking on each individual variable.

The fault recording function can record up to 32 oscillographic records in non-volatile memory. Because there is only a specific amount of memory available, as additional faults are recorded, the oldest records are overwritten. Each record can record only a limited number of data cycles. If you have less than 32 records, you can have more than 15 cycles of data per record (total of 480 cycles). To select the number of cycles of data and number of records, click on the Oscillographic Records, *Select* button, and click on the number of records that you want to record.

Logic settings for the Target Reset Logic can be made by clicking on the *Target Reset Logic* button and then clicking on the *Reset* input. Other logic blocks shown under BESTlogic on the panel are shown for reference only. There is no interaction available.
Any protective function, except 62, 162, and 60FL that has a trip, will set a target because these functions have the targets enabled on the *Fault Recording* tab. If you are using a protective function in a supervisory capacity and do not want to set a target when the protective function trips, disable that target by clicking on the specific target. If you want to disable all of the targets for a function such as the frequency protection function, click on the *No 81's* button on the left side of the *Enabled Targets*.

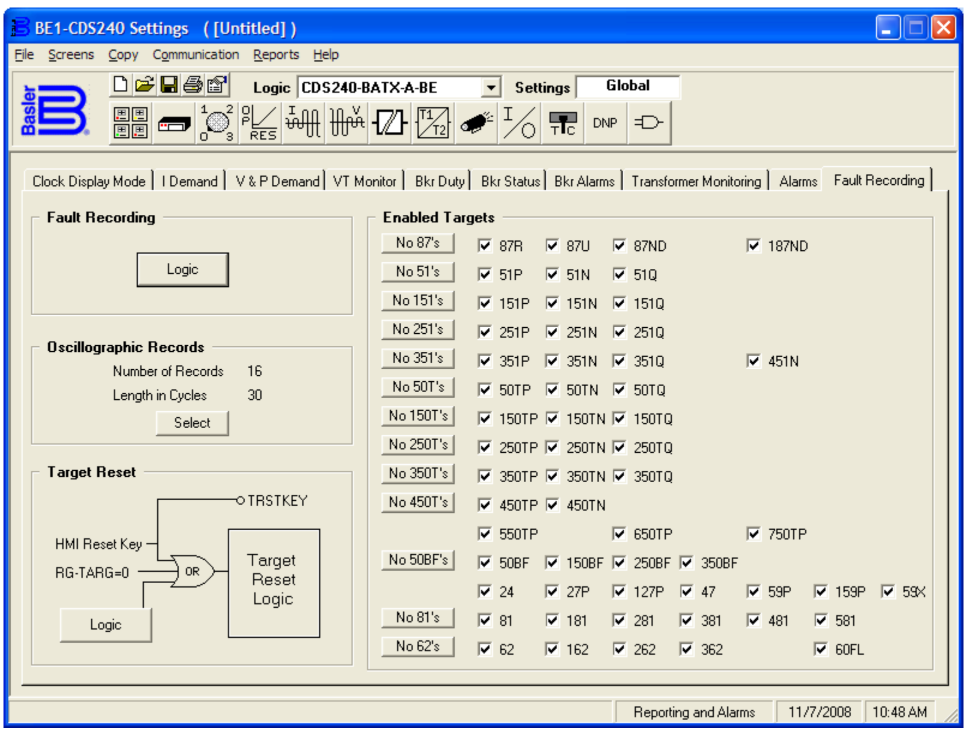
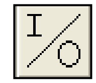


Figure 14-37. Reporting and Alarms Screen, Fault Recording Tab

Inputs and Outputs



Pull down the *Screens* menu and select *Inputs and Outputs* or click on the Inputs and Outputs icon that is shown at the right margin of this paragraph. This screen has three folder tabs and the first tab is *Inputs 1 - 6.*

Inputs 1 - 6

Six programmable inputs in the BE1-CDS240 relay are set by this tab. See Figure 14-38.

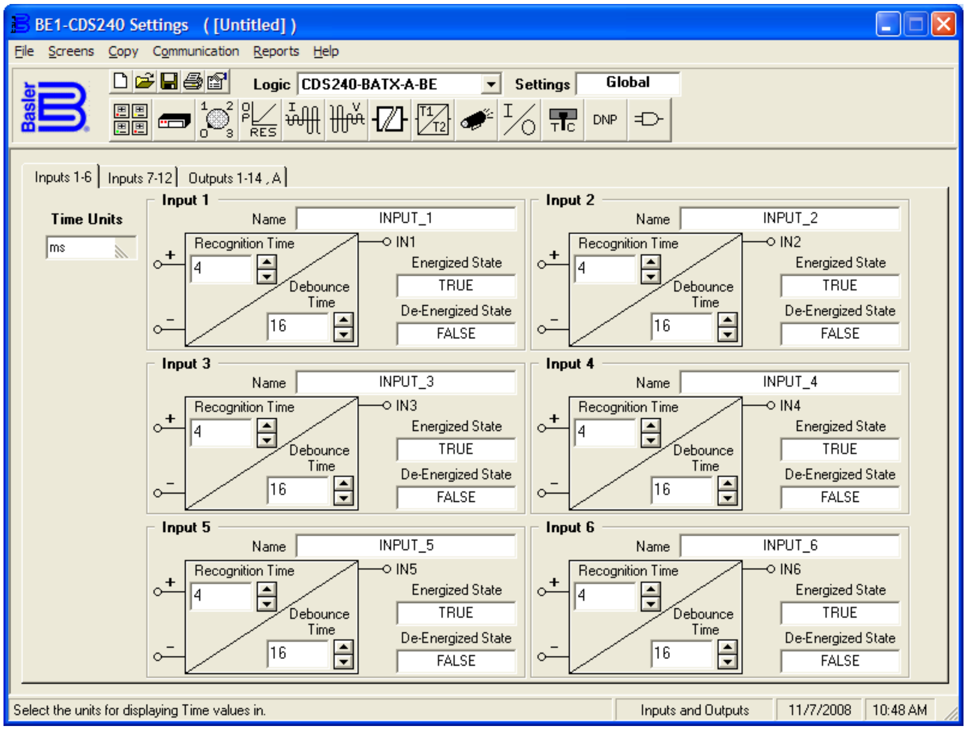


Figure 14-38. Inputs and Outputs Screen, Inputs 1 - 6 Tab

To program how long the Input 1 contact must be closed for it to be recognized as closed, first pull down the *Time Units* menu and set the units for the appropriate time measurement (i.e., ms (default), seconds minutes, or cycles). Then, click on the *Input 1, Recognition Time* and enter the new value or use the appropriate (*Up* or *Down*) arrow buttons to set the new value. To program how long the Input 1 contact must be open to be recognized as open, click on the *Input 1, Debounce Time* and enter the new value or use the appropriate (*Up* or *Down*) arrow buttons to set the new value.

You can assign a meaningful name to each input. This makes sequential events reports easier to analyze. To assign a meaningful name to Input 1, click in the *Name* field and enter the new name. To change the label for the *Energized State*, click on the *Energized State* field and enter the new name. To change the label for the *De-Energized State*, click on the *De-Energized State* field and enter the new name. The remaining five inputs have the same functions.

Inputs 7 - 12

There are six programmable inputs in the BE1-CDS240 relay that are set by this tab. Functionality is the same as described for Inputs 1 - 6.

Outputs 1 - 14, A

On this tab (Figure 14-39), the only feature that you may change is to select the programmable hold attribute. To select the hold attribute (contacts remain closed for 200 milliseconds) for any output, click on the *Hold Attribute* field for that output. To change the label for any of the virtual outputs, see the paragraphs on *BESTlogic, Virtual Outputs,* later in this section.

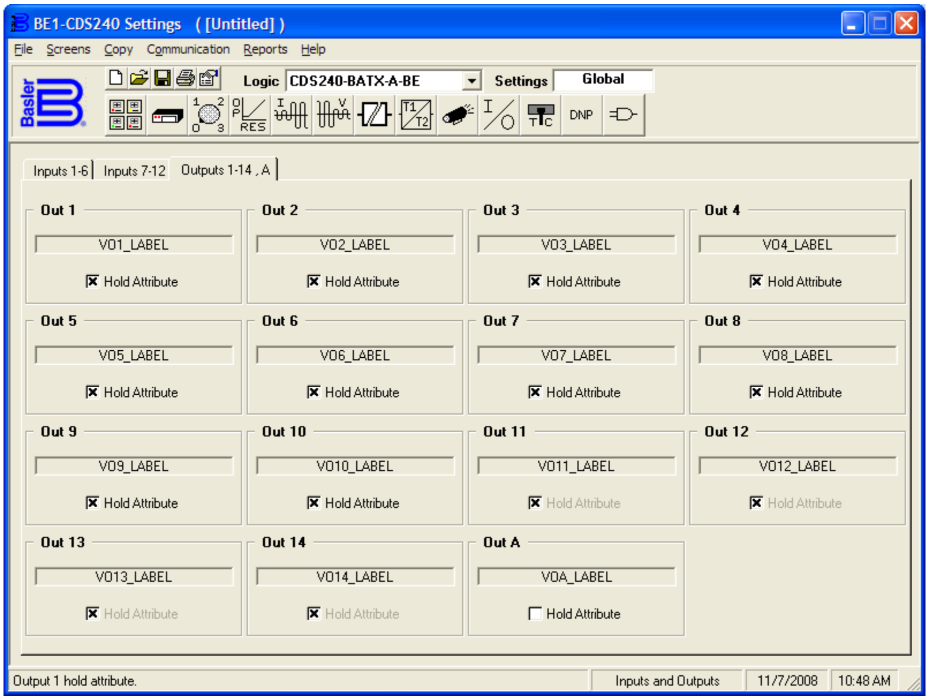
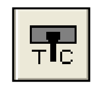


Figure 14-39. Inputs and Outputs Screen, Outputs 1 - 14, A Tab

Virtual Switches

Pull down the *Screens* menu and select *Virtual Switches* or click on the Virtual Switches icon that is shown at the right margin of this paragraph. This screen has three folder tabs and the first is *43-143-243-343.*



43-143-243-343

You can assign a meaningful name or label to each virtual switch (Figure 14-40). This makes sequential events reports easier to analyze. To assign a meaningful label to Virtual Switch 43, click in the *Label* field and enter the new name. To change the label for the *True State*, click on the *True State* field and enter the new name. To change the label for the *False State,* click on the *False State* field and enter the new name. The 143, 243, and 343 switches can be changed in the same manner.

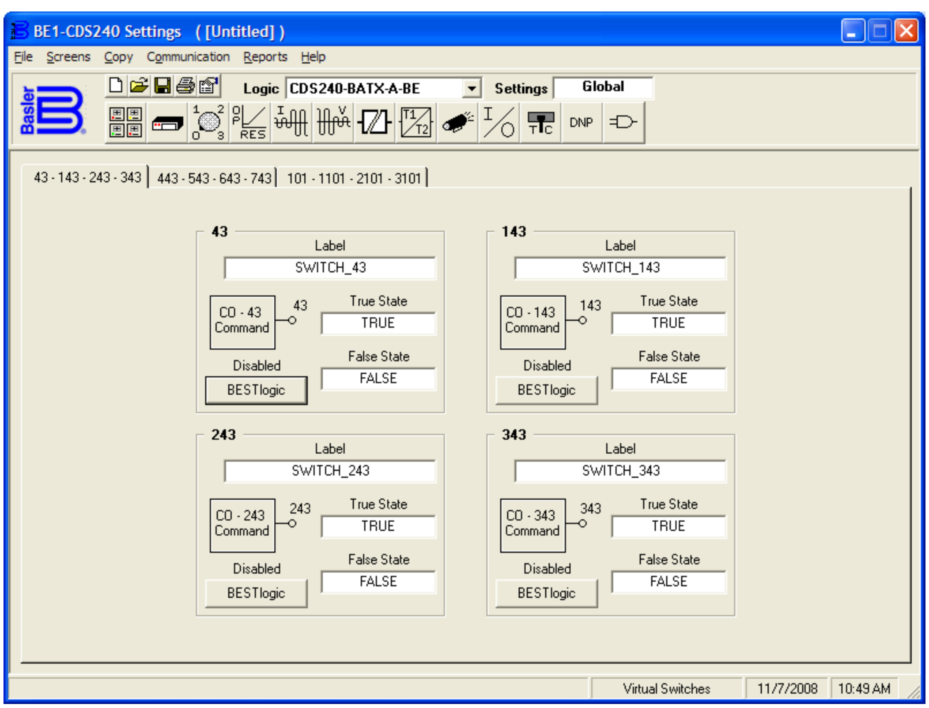


Figure 14-40. Virtual Switches Screen, 43-143-243-343 Tab

The virtual breaker control switch provides manual control of a circuit breaker or switch without using physical switches and/or interposing relays. The mode logic setting for Virtual Switch 43 can be made by clicking on the *BESTlogic* button. With your custom logic selected, select the mode logic by using the *Mode* pull-down menu. The 143, 243, and 343 switches can be changed in the same manner.

443-543-643-743

These virtual switches have the same functionality as the 43 virtual switch explained above.

101-1101-2101-3101

Four virtual breaker control switches are available with the BE1-CDS240 (Figure 14-41). The mode logic setting for Virtual Breaker Control Switch 101 can be made by clicking on the *BESTlogic* button. With your custom logic selected, select the mode logic by using the *Mode* pull-down menu. Trip outputs include *Trip, Close,* and *Slip Contact.* The other three virtual breaker control switches are configured in the same manner.

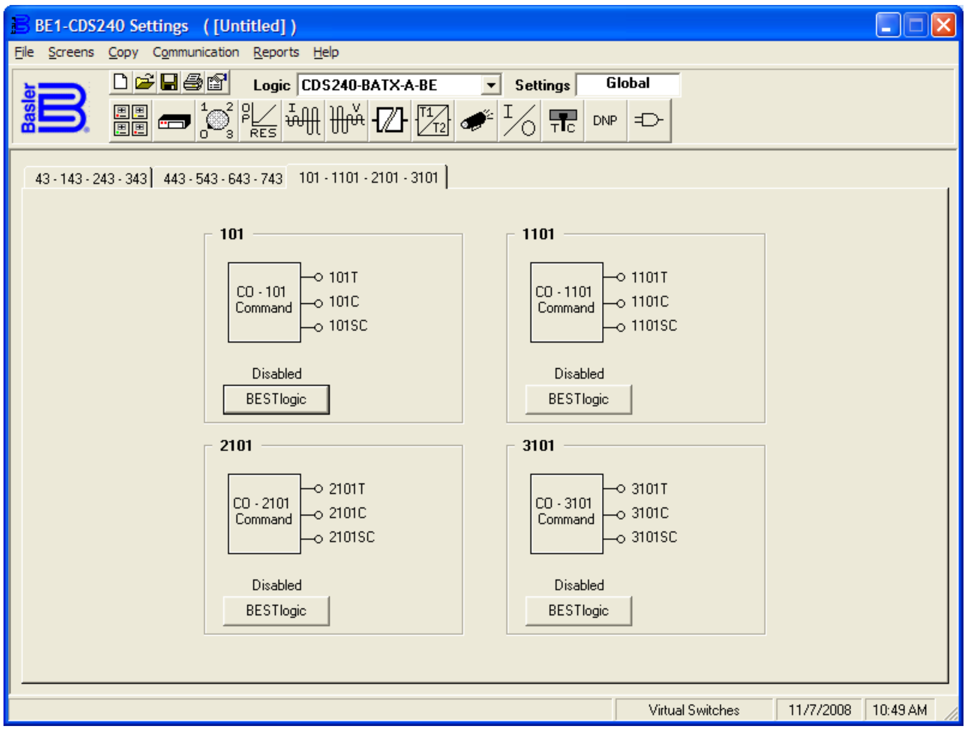
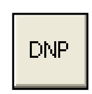


Figure 14-41. Virtual Switches Screen, 101-1101-2101-3101 Tab

DNP



If the CDS-240 is DNP equipped, you can pull down the *Screens* menu and select *DNP Settings* or click on the *DNP Settings* icon, which is shown at the right margin of this paragraph. This screen has three folder tabs and the first tab (Figure 14-42) is labeled *DNP Settings*.

For additional information, refer to Basler Electric Instruction Manual 9365200991, *Distributed Network Protocol (DNP3).*

DNP Settings

This tab is used to setup the *DNP Analog User Map, DNP Binary User Map,* and *Misc DNP Settings.*

DNP Analog User Map. In the left pane, use the *DNP Map Selection* pull-down menu to select the type of map (*DEFAULT* or *USER*). Use the *Edit User Map* button to add or remove Analog DNP Input Points to or from the Analog DNP User Map. The *View User Map* button can be used to view the current Analog DNP User Map.

DNP Binary User Map. In the middle pane, use the *DNP Map Selection* pull-down menu to select the type of map (*DEFAULT* or *USER*). Use the *Edit User Map* button to add or remove Binary DNP Input Points to or from the Binary DNP User Map. The *View User Map* button can be used to view the current Binary DNP User Map.

Misc DNP Settings. The right pane is used to set the *Pre Transfer Delay* time and the *Synchronization Period* time.

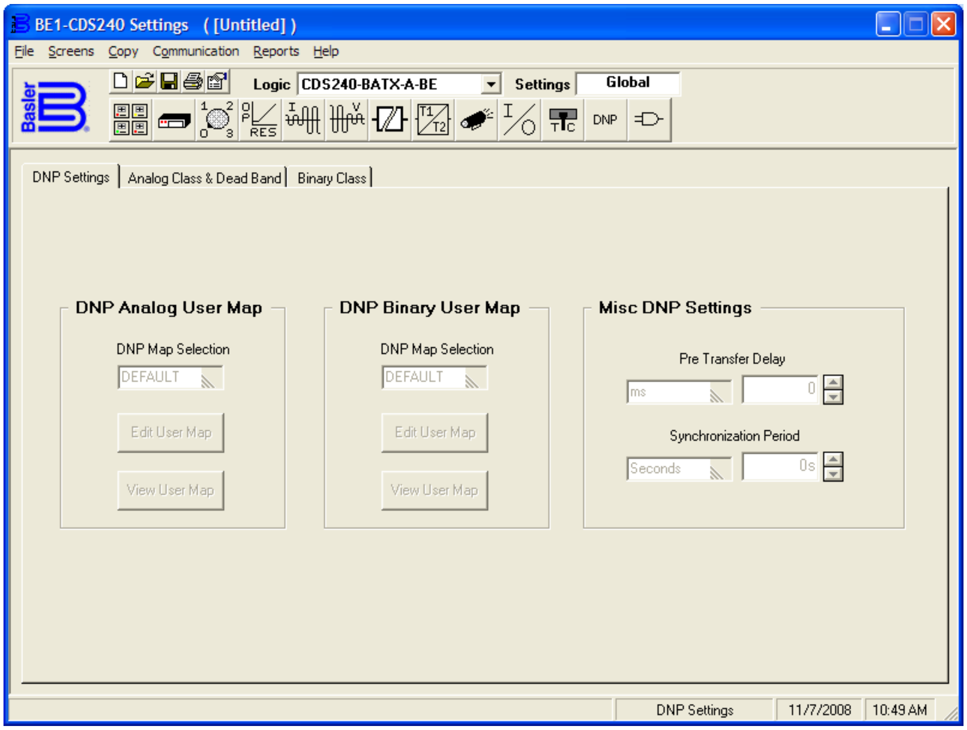


Figure 14-42. DNP Settings Screen, DNP Settings Tab

Analog Class & Dead Band

This tab (Figure 14-43) allows the user to edit Analog DNP Points. Using normal Windows techniques, place a bullet next to the *Point Range* you wish to edit. Now, using the pull-down menus for *Class,* select 0, 1, 2, or 3. Finally, enter a value in the *Dead – Band* box from 0 to 4294967295.

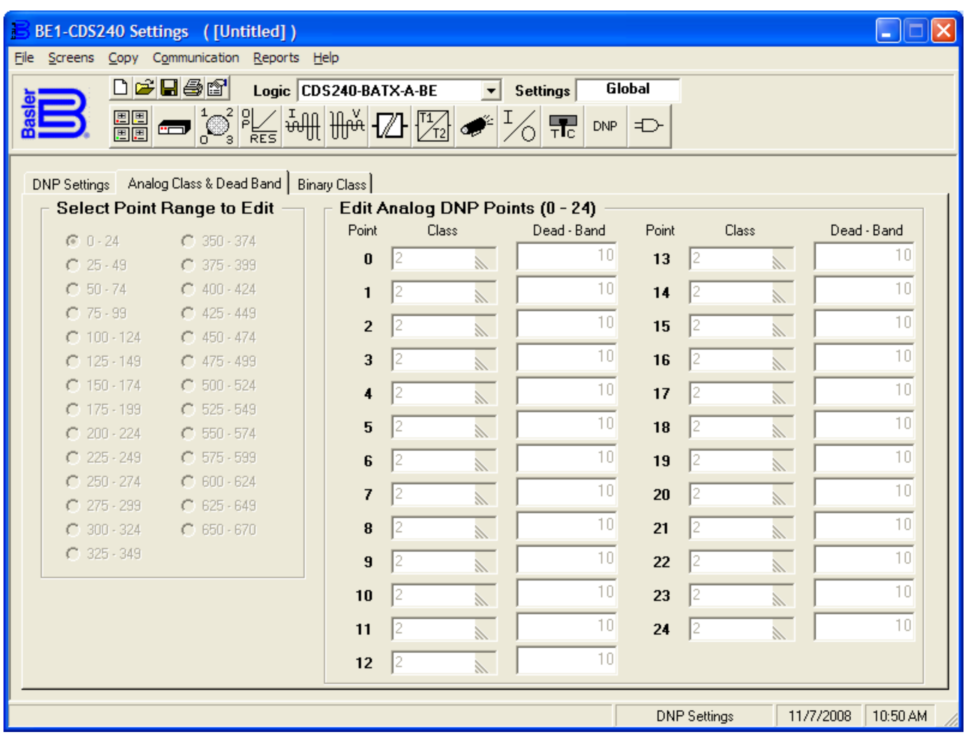


Figure 14-43. DNP Settings Screen, Analog Class & Dead Band Tab

Binary Class

This tab (Figure 14-44) allows the user to edit Binary DNP Points. Using normal Windows techniques, place a bullet next to the *Point Range* you wish to edit. Using the pull-down menus for *Class,* select 0, 1, 2, or 3.

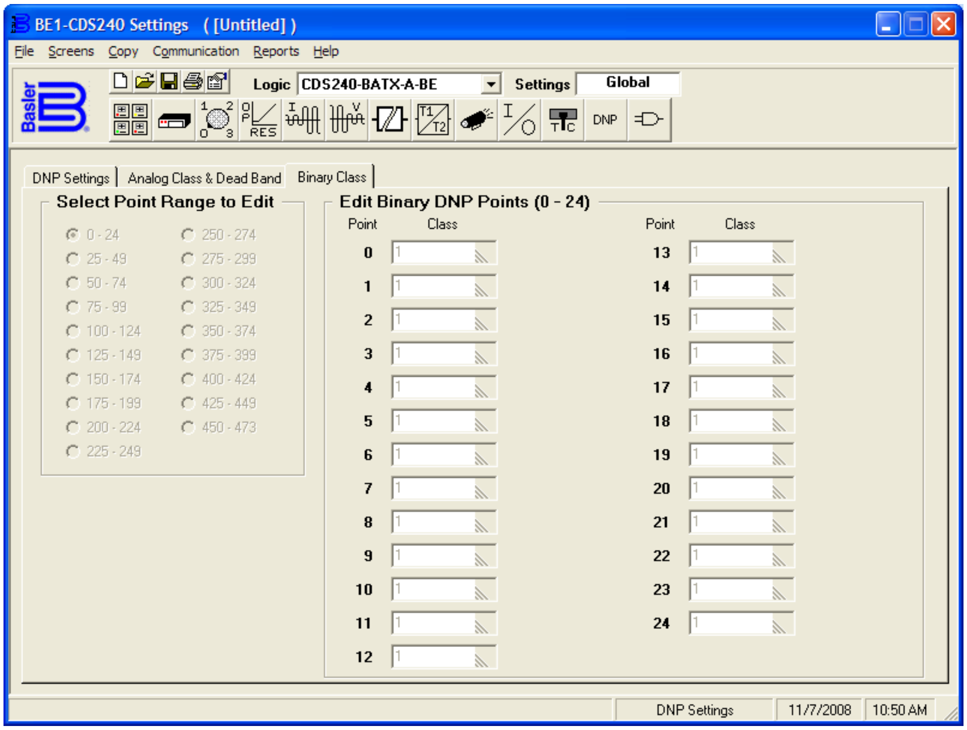
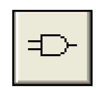


Figure 14-44. DNP Settings Screen, Binary Class Tab

BESTlogic



Pull down the *Screens* menu and select *BESTlogic* or click on the BESTlogic icon, which is shown at the right margin of this paragraph. This screen has four folder tabs and the first tab is *Logic Select.*

Logic Select

This screen (Figure 14-45) allows you to select one of the preprogrammed logic schemes and copy that nothing in the scheme. You must rename that logic to a custom name and then make changes as you desire. Click on the logic to be copied to the active logic and a dialog box appears requiring that you okay the replacement of all settings. Execute the *OK* and then type in the custom name.

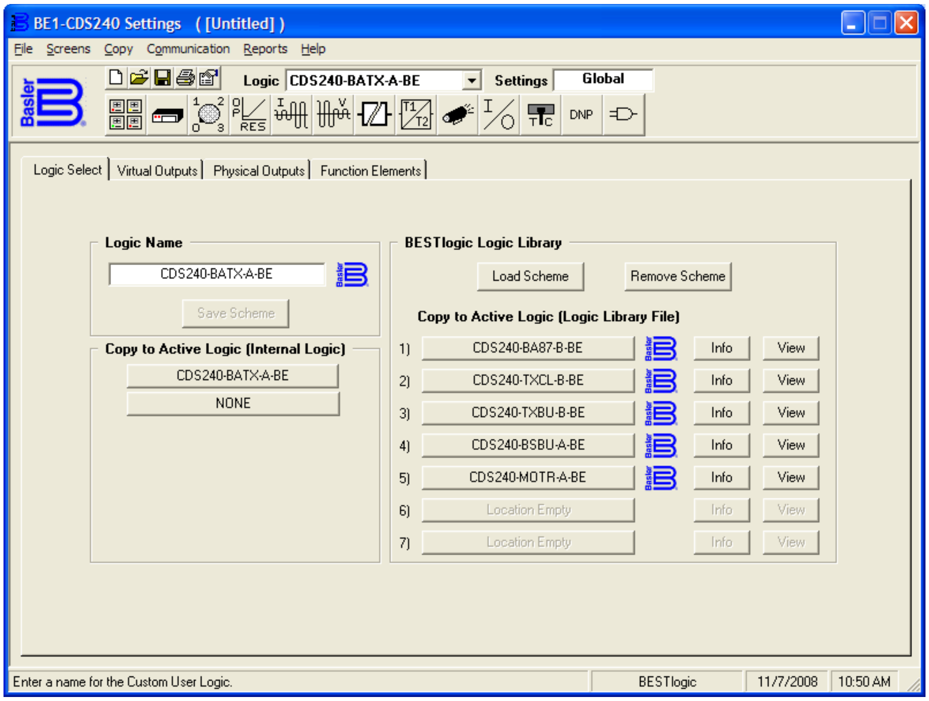


Figure 14-45. BESTlogic Screen, Logic Select Tab

Virtual Outputs

You can assign a meaningful name or label to each virtual output. This makes sequential events reports easier to analyze. To assign a meaningful label to a virtual output (Figure 14-46), click in the *Label* field and enter the new name. Any virtual output can be assigned to any physical output. Only VOA and VO1 through VO10 (or VO14 depending on style number) have hardware output contacts. To change the label for the *True State,* click on the *True State* field and enter the new name. To change the label for the *False State,* click on the *False State* field and enter the new name. To change the logic associated with VO6, click on the *BESTlogic* button associated with VO6. Click on the logic input and program the logic variables that define VO6. You may clear the existing programming by clicking on the *Clear* button or clicking on each individual variable. All 16 virtual outputs have the same function.

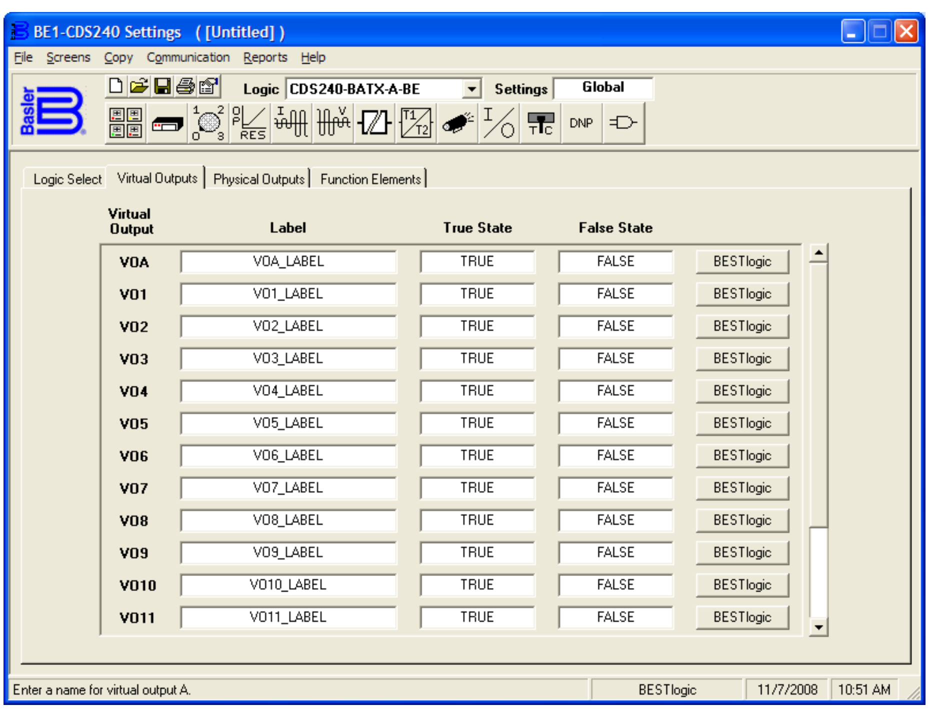


Figure 14-46. BESTlogic Screen, Virtual Outputs Tab

Physical Outputs

To change the logic on a physical output (Figure 14-47), click on the *BESTlogic* button associated with OUTx. Click on the logic input and program the logic variables that define OUTA and OUT1 through OUT14.

Note: The CDS-240 relay can have either 10 or 14 hardware output contacts depending on the *Contact I/O Options* in the style number.

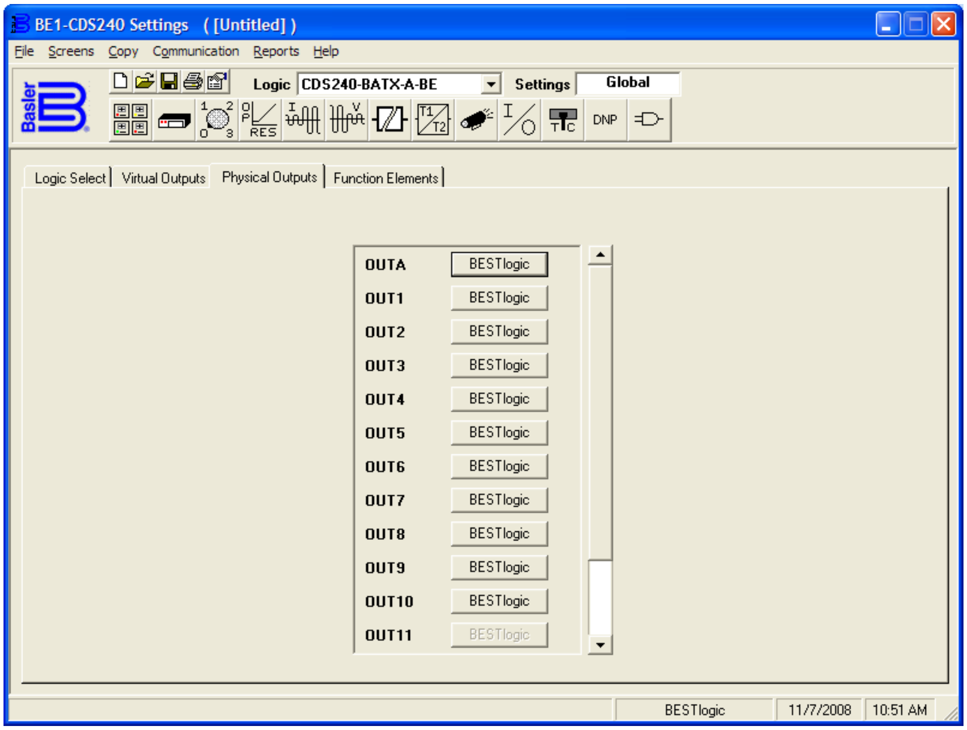


Figure 14-47. BESTlogic Screen, Physical Outputs Tab

Function Elements

Not all of the logic functions have *BESTlogic* labeled on the button (Figure 14-48). If the logic function is labeled *Logic* and not *BESTlogic,* the ASCII command for the function is not prefixed with SL-. For example: *Breaker Status* is a function of breaker monitoring and the ASCII command is SB-LOGIC for Setting, Breaker-Logic. To program a logic function, find the logic function in the list and click on the associated *BESTlogic* or *Logic* button. The *BESTlogic Function Element* dialog box opens (see Figure 14-49) with the available programming. If the *Mode* pull-down menu is available, select the appropriate mode. Click on the logic inputs and program the appropriate logic.

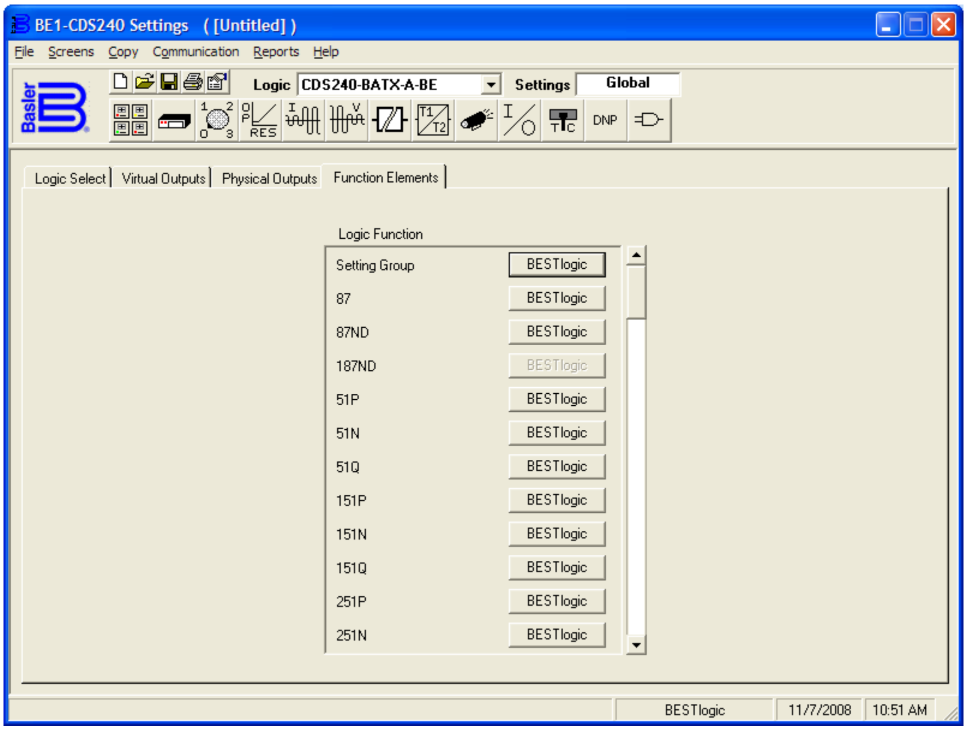


Figure 14-48. BESTlogic Screen, Function Elements Tab

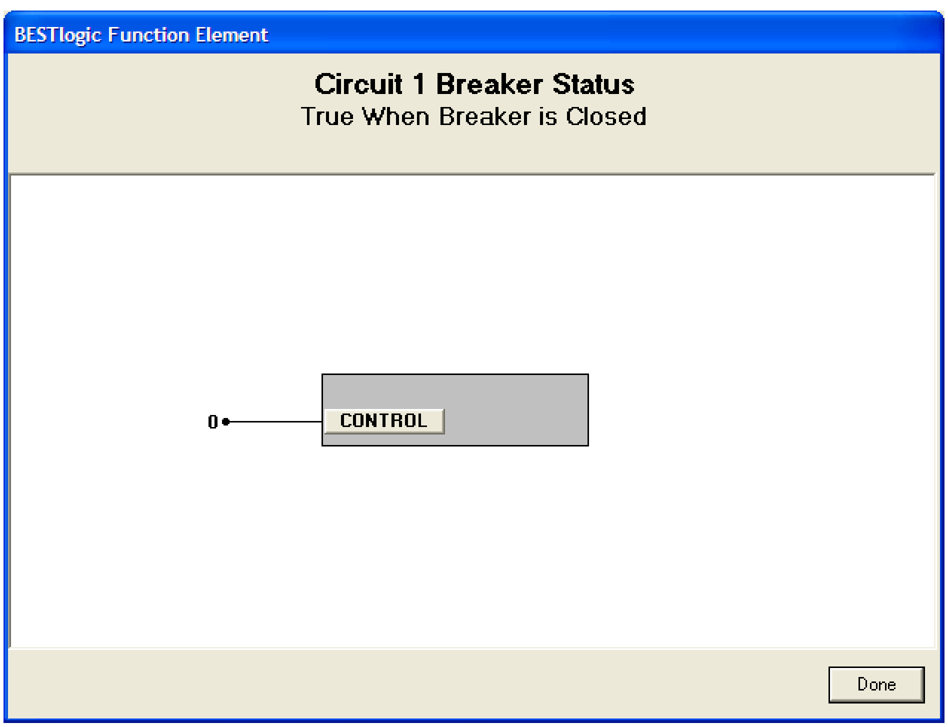


Figure 14-49. BESTlogic Function Element Screen, Circuit 1 Breaker Status

Copying Settings from Group to Group

There are a lot of settings in any BE1-numerical systems product and the differences between Group 0 and any other group settings may be minimal. It would be convenient if there were a way to copy settings from Group 0 to another group and then just change only those settings that are different. With BESTCOMS, there is an easy way to do that. Pull down the *Copy* menu from the pull-down menu as shown in Figure 14-50. There is only one choice, *Copy From Group to Group*. When you select this choice, a dialog box opens (Figure 14-51) allowing you to select the *Copy to Group*. After you *OK* the copy routine, another dialog box opens to inform you that the copy routine is complete.

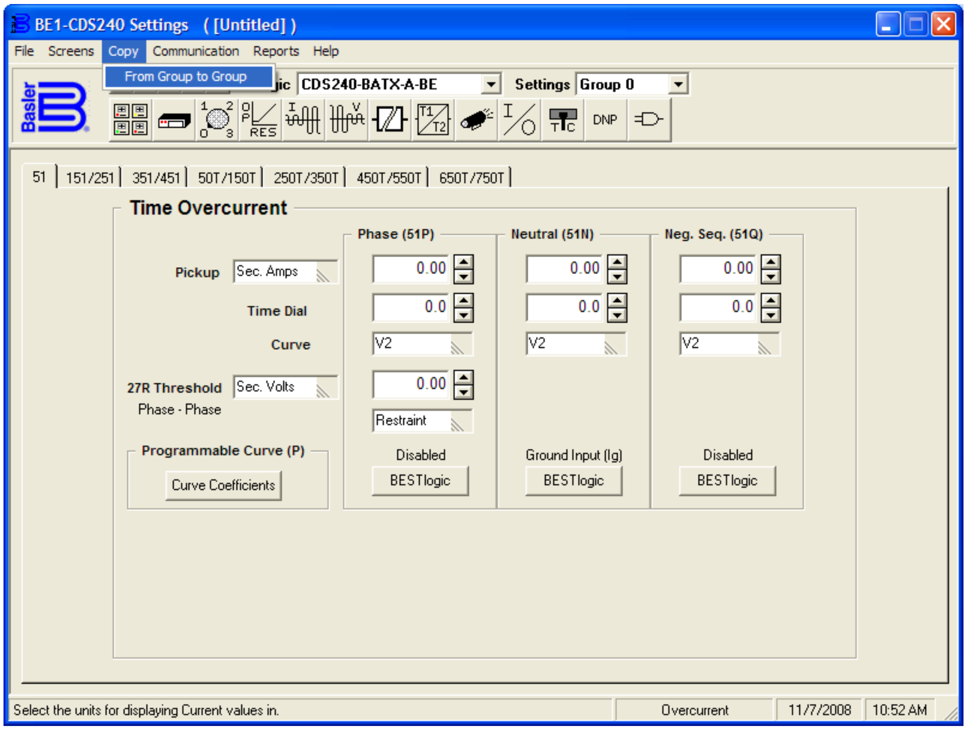


Figure 14-50. From Group to Group from Copy Pull-down Menu

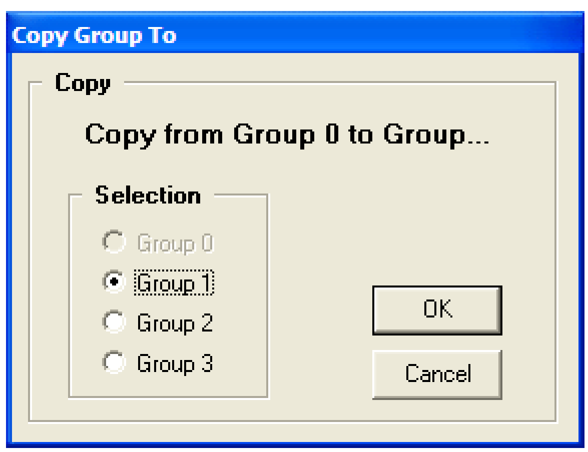


Figure 14-51. Copy Group To Dialog Box

Downloading Oscillography Files

To download an oscillography file, pull down the *Reports* menu from the pull-down menu as shown in Figure 14-52 and select *Oscillography Download*. When you select this choice, you may get a communication error if you are not configured to an actual relay. If you have communication with the relay, a dialog box opens (Figure 14-53) allowing you to *View/Download Relay Fault Files*. If there have been no fault events triggered, you may create one by clicking on the *Trigger* button in the *View/Download Relay Fault Files* dialog box.

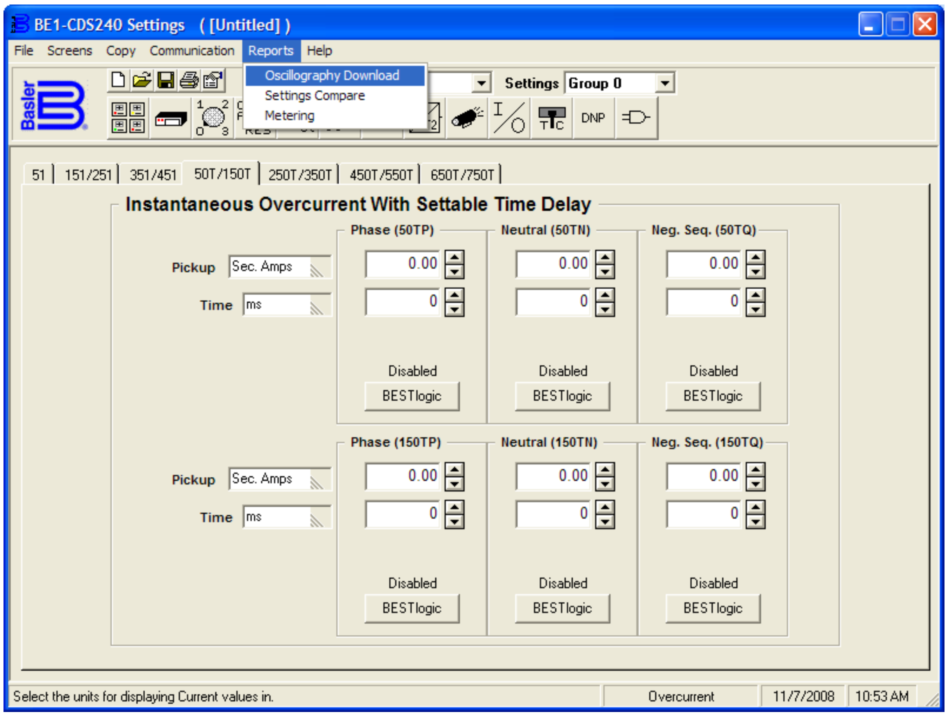


Figure 14-52. Oscillography Download from Reports Pull-down Menu

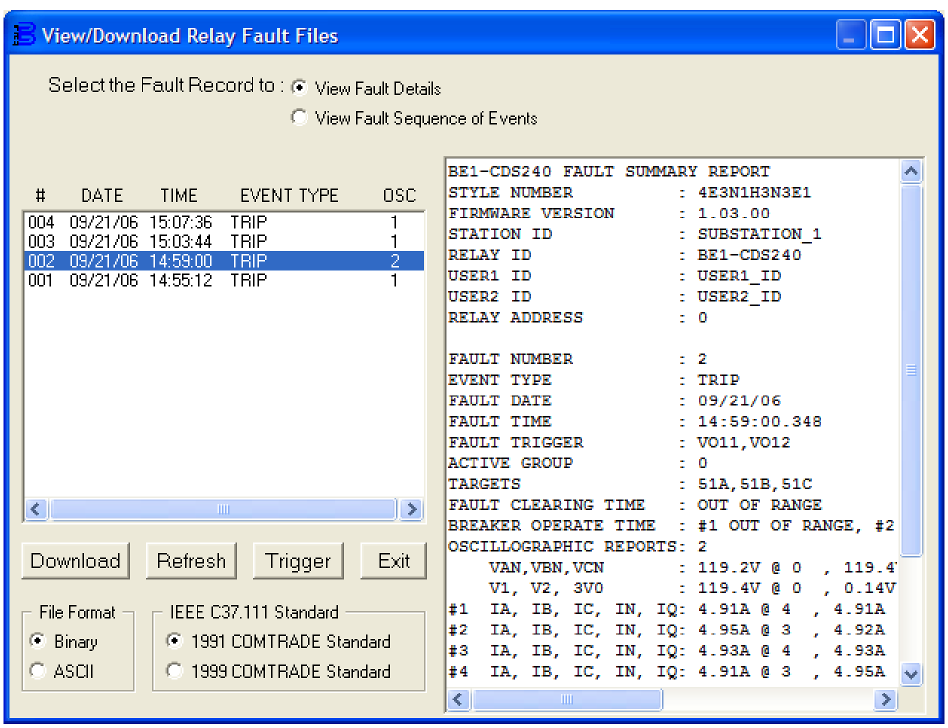


Figure 14-53. View/Download Relay Fault Files Screen

View Fault Details

To view the fault record details, select an event by clicking on the event number or anywhere on the event line. The event grays-out while the information is being retrieved from the relay. View the fault details in the associated window.

View Fault Sequence of Events

To view the fault record sequence of events, click on the radio button by the *View Fault Sequence of Events*. View the fault sequence of events in the associated window.

Download Oscillography File

To download an oscillography file, select the type of file to download: *Binary* or *ASCII* and *1991* or *1999 Comtrade Format*. Click on the *Download* button in the *View/Download Relay Fault Files* dialog box. Use normal Windows techniques to select the computer folder that is to receive the download file. You may create a new folder at this time by clicking on the *New Folder* button. Okay the file save and the *Fault Record Filenames* dialog box opens. Use the default *Base Filename* or enter a new file name. As you change the file name, the names for the *Header File, Fault Sequence*, and *Fault Summary* also change automatically. *OK* the file names and then exit the dialog box. You have now downloaded the oscillography file. You may view this oscillography file using BESTWAVE software.

Metering

To observe the system metering, pull down the *Reports* menu from the pull-down menu and select *Metering*. When the *Metering* dialog box (Figure 14-54) opens, click on the *Start Polling* button. If BESTCOMS is not configured to the relay communication settings, you will receive a Communications Error. The *Metering* dialog box has two pull-down menus: *File* and *Communication*. To configure communication with the relay, pull down the *Communication* menu and select *Configure*. Choose the *Com Port* and *Baud Rate*, as required. If you have communication with the relay, click on the *Start Polling Button*. Metering values are displayed in the various screen windows. If you select *Configure* with polling in progress, you will get the *Polling Active* dialog box. You must stop polling before you can change configuration. To stop polling, click on the *Stop Polling* button. To exit, pull down the *File* menu and select *Exit*. You may also use the Windows techniques and click on the close icon (X) in the upper right-hand corner of the *Metering* dialog box.

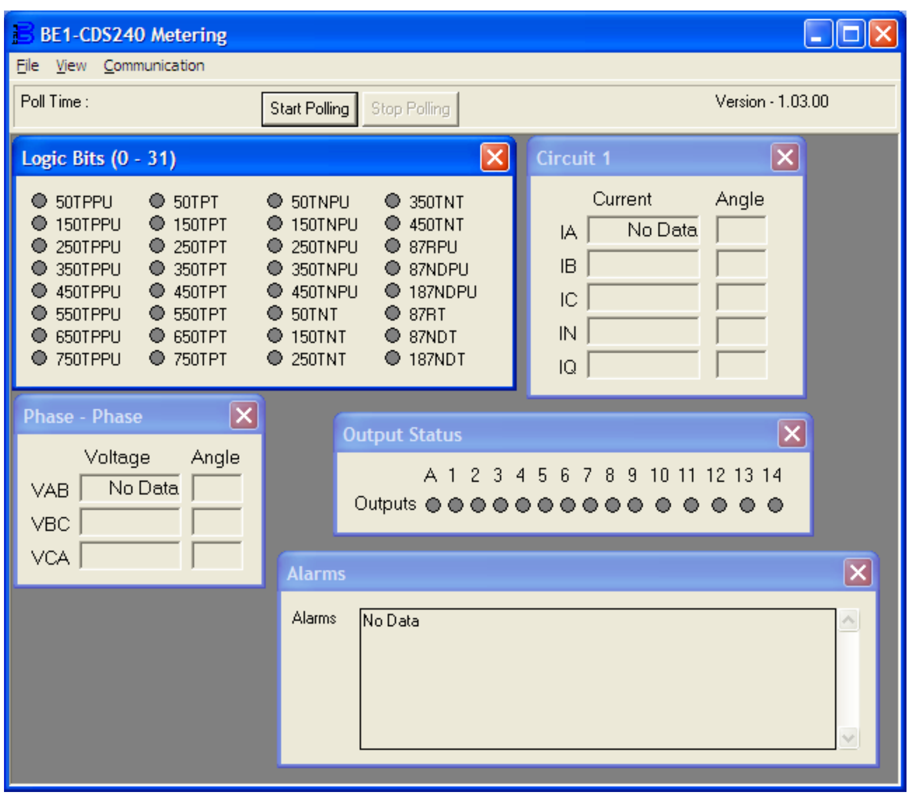


Figure 14-54. Metering from Reports Pull-Down Menu

File Management

In these paragraphs, file management describes saving, opening, uploading, downloading, printing, and comparing settings files.

Saving a Settings File

If you change any settings in the active custom logic scheme and try to exit BESTCOMS, the dialog box shown in Figure 14-55 appears. If you choose *Yes*, a file properties dialog box appears. The file properties dialog box also appears if you pull down the file menu and choose *Save* or *Save As*. The lines of information that are grayed-out are automatically entered based on the file name and relay identifier information command (SG-ID). You may enter up to 50 characters in the *Additional Info:* field and 2,500 characters in the *File Comments* field. When you okay the dialog box, you are given an opportunity to name the file and select the path. Clicking on *Save* completes the saving of a settings file.

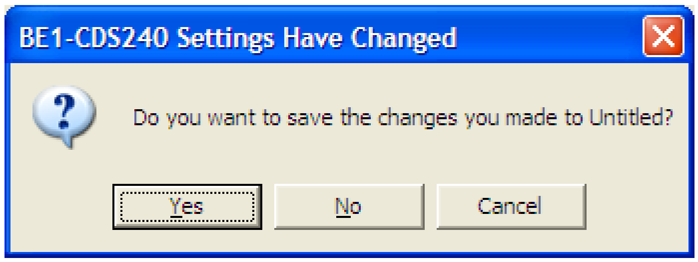


Figure 14-55. Settings Have Changed Dialog Box

Opening a Settings File

To open a settings file into BESTCOMS, pull down the *File* menu and choose *Open*. If the settings in your BESTCOMS have changed, a dialog box will open asking you if want to save the current settings changes. You may choose *Yes* or *No*. After you have taken the required action to save or not save the current settings, the *Open* dialog box appears. This dialog box allows you to use normal Windows techniques to select the file that you want to open. Select the file and open it and the file settings have been brought into BESTCOMS.

Uploading a Settings File

To upload a settings file to the BE1-CDS240 relay, you must first open the file through BESTCOMS or create the file using BESTCOMS. Then pull down the *Communication* menu and select *Upload Settings to Device.* You are prompted to enter the password. If the password is correct, the upload begins and the percent complete loading bar is shown. At upload completion, you are asked if you want to save the settings and make them active. After replying, you are informed of the status: Yes - settings are saved or No - settings are discarded. If you would like to view the file names as they are uploaded, pull down the *Communication* menu and select *Configure*. When the *Configure Communication Port* dialog box opens, click the *On* button for *Show Commands During Data Transfer* and then click *OK*. Now, during data transfer, you will see two screens (*Sending* and *Status*) and the percent complete loading bar. If a data transfer error occurs, you can briefly see the error notification in the *Status* window. The file settings will not be uploaded and the changes discarded. You may then scroll through the *Status* window until you find the error notification. Click on the error notification and the data file that transferred in error is shown in the *Sending* window.

Downloading a Settings File

To download a settings file from a BE1-CDS240 relay, you must pull down the *Communication* menu and select *Download Settings from Device*. If the settings in your BESTCOMS have changed, a dialog box will open asking you if want to save the current settings changes. You may choose *Yes* or *No*. After you have taken the required action to save or not save the current settings, the downloading is executed.

Printing a Settings File

To print a settings file, pull down the *File* menu and select *Print*. A dialog box, *Print BE1-CDS240 Settings File* opens with the settings file shown and typical Windows choices to setup the page and the printer. Execute these commands, as necessary, and then select *Print*.

You may also export the settings file to a text file. Pull down the *File* menu and select *Export to Text*. A dialog box, *Export to Text File* opens with the settings file shown. Execute the *OK* command and then use normal Windows techniques to select the path. Execute the *Save* command and you now have a text file of your BESTCOMS settings.

Settings Compare

BESTCOMS has the ability to compare two different settings files. To use this feature, pull down the *Reports* menu and select *Settings Compare*. The *BESTCOMS Settings Compare Setup* dialog box appears. See Figure 14-56. Select the location of the first file to compare under *Left Settings Source* and select the location of the second file to compare under *Right Settings Source*. If you are comparing a *Settings file on disk*, click on the folder button and browse for the file. If you wish to *Download settings from unit* to compare, click on the RS-232 button to setup the *Com Port* and *Baud Rate*. Click on the *Compare* button to compare the settings files that you have selected.

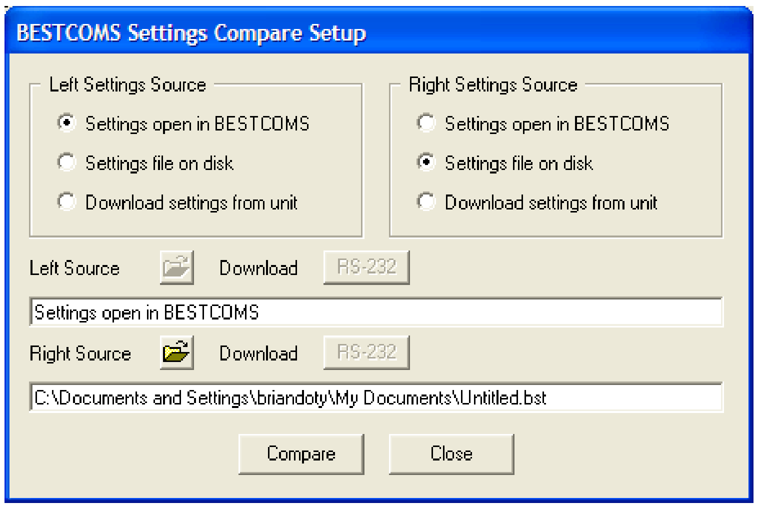


Figure 14-56. BESTCOMS™ Settings Compare Setup Dialog Box

If there are any differences in the two files, a dialog box will pop up notifying you that *Differences Are Found*. The *BESTCOMS Settings Compare* dialog box pops up (Figure 14-57) where you can select to *Show All* or *Show Diffs*.

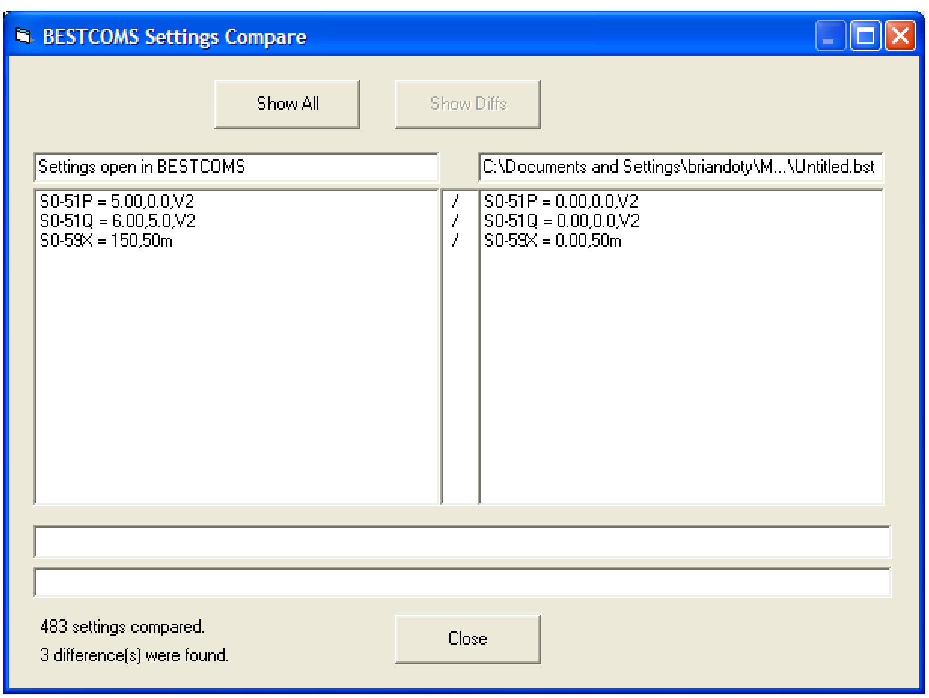


Figure 14-57. BESTCOMS™ Settings Compare Dialog Box

BESTprint™

BESTprint, which is found on the CD included with the BE1-CDS240 relay, will preview and print Basler Electric relay settings files. This is via graphic representations similar to what is seen in the BESTCOMS software application. BESTprint will only read the settings files and document the information. It will not write or change any settings in the settings file (*.bst) at this time.

Profile files for each device are needed to print documentation for that particular device. New and updated profiles will be available from Basler Electric. One new set of profiles and their support files will be the optimum way to acquire additional printing of more devices or updated settings files.

For additional information, see the *Help* files in the BESTprint application.

APPENDIX A • TIME OVERCURRENT CHARACTERISTIC CURVES

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APPENDIX A • TIME OVERCURRENT CHARACTERISTIC CURVES

General

Basler Electric inverse time overcurrent systems (ANSI Device 51) provide time/current characteristic curves that very closely emulate most of the common electro-mechanical, induction disk relays that were manufactured in North America. To further improve proper relay coordination, selection of integrated reset or instantaneous reset characteristics is also provided.

Curve Specifications

Timing Accuracy (All 51 Functions): Within ±5% or ±1½ cycles, whichever is greater, with time dial settings greater than 0.1, and multiples of 2 to 40 times the pickup setting but not over 150 A for 5 A CT units or 30 A for 1 A CT units.

Sixteen inverse time functions, one fixed time function, and one programmable time function can be selected. Characteristic curves for the inverse and definite time functions are defined by the following equations and comply with IEEE Std C37.112 - 1996 - *IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays*.

$$T_T = \frac{A \cdot D}{M^N - C} + B \cdot D + K$$ *Equation A-1*

$$T_R = \frac{R \cdot D}{\left| M^2 - 1 \right|}$$ *Equation A-2*

T_T = Time to trip when $M \geq 1$

T_R = Time to reset if relay is set for integrating reset when $M < 1$. Otherwise, reset is 50 milliseconds or less

D = TIME DIAL setting (0.0 to 9.9)

M = Multiple of PICKUP setting (0 to 40)

A, B, C, N, K = Constants for the particular curve

R = Constant defining the reset time.

Table A-1 lists time characteristic curve constants. See Figures A-1 through A-17 for graphs of the characteristics.

Table A-1. 51P, 51N, and 51Q Time Characteristic Curve Constants

Curve Selection	Curve Name	Trip Characteristic Constants					Reset †
		A	B	C	N	K	R
S1	Short Inverse	0.2663	0.03393	1	1.2969	0.028	0.5
S2	Short Inverse	0.0286	0.0208	1	0.9844	0.028	0.094
L1	Long Inverse	5.6143	2.18592	1	1	0.028	15.75
L2	Long Inverse	2.3955	0	1	0.3125	0.028	7.8001
D	Definite Time	0.4797	0.21359	1	1.5625	0.028	0.875
M	Moderately Inverse	0.3022	0.1284	1	0.5	0.028	1.75
I1	Inverse Time	8.9341	0.17966	1	2.0938	0.028	9
I2	Inverse Time	0.2747	0.10426	1	0.4375	0.028	0.8868
V1	Very Inverse	5.4678	0.10814	1	2.0469	0.028	5.5
V2	Very Inverse	4.4309	0.0991	1	1.9531	0.028	5.8231
E1	Extremely Inverse	7.7624	0.02758	1	2.0938	0.028	7.75
E2	Extremely Inverse	4.9883	0.0129	1	2.0469	0.028	4.7742
A	Standard Inverse	0.01414	0	1	0.02	0.028	2
B	Very Inverse (I^2t)	1.4636	0	1	1.0469	0.028	3.25
C	Extremely Inverse (I^2t)	8.2506	0	1	2.0469	0.028	8
G	Long Time Inverse (I^2t)	12.1212	0	1	1	0.028	29
F	Fixed Time ∗	0	1	0	0	0.028	1
P	Programmable §	0 to 600	0 to 25	0 to 1	0.5 to 2.5	0.028	0 to 30
46	Neg.-Seq. Overcurrent	‡	0	0	2	0.028	100

∗ Curve F has a fixed delay of one second times the Time Dial setting.

† For integrated reset, append **R** to the curve name. For example, curve **S1** has instantaneous reset. Curve **S1R** has integrated reset.

‡ Constant A is variable for the 46 curve and is determined, as necessary, based on system full-load current setting, minimum pickup, and K factor settings.

§ The programmable curve allows for four significant digits after the decimal place for every variable.

Time Overcurrent Characteristic Curve Graphs

Figures A-1 through A-16 illustrate the characteristic curves of the BE1-CDS240 relay. Table A-2 cross-references each curve to existing electromechanical relay characteristics. Equivalent time dial settings were calculated at a value of five times pickup.

Table A-2. Characteristic Curve Cross-Reference

Curve	Curve Name	Similar To
S1	Short Inverse	ABB CO-2
S2	Short Inverse	GE IAC-55
L1	Long Inverse	ABB CO-5
L2	Long Inverse	GE IAC-66
D	Definite Time	ABB CO-6
M	Moderately Inverse	ABB CO-7
I1	Inverse Time	ABB CO-8
I2	Inverse Time	GE IAC-51
V1	Very Inverse	ABB CO-9
V2	Very Inverse	GE IAC-53
E1	Extremely Inverse	ABB CO-11
E2	Extremely Inverse	GE IAC-77
A	Standard Inverse	Refer to BS 142
B	Very Inverse (I^2t)	Refer to BS 142
C	Extremely Inverse (I^2t)	Refer to BS 142
G	Long Time Inverse (I^2t)	Refer to BS 142
F	Fixed Time	N/A
P	Programmable	N/A

Time Dial Setting Cross-Reference

Although the time characteristic curve shapes have been optimized for each relay, time dial settings of Basler Electric relays are not identical to the settings of electromechanical induction disk overcurrent relays. Table A-3 helps you convert the time dial settings of induction disk relays to the equivalent setting for Basler Electric relays. Enter time dial settings using BESTCOMS™, S<g>-x51P/x51N/x51Q ASCII commands, or human-machine interface (HMI) Screens \PROT\SG#\51\51P, \PROT\SG#\51\51N, or \PROT\SG#\51\51Q. For more information, refer to Section 4, *Protection and Control, Overcurrent Protection, 51P Time Overcurrent Protection*.

Using Table A-3

Cross-reference table values were obtained by inspection of published electromechanical time current characteristic curves. The time delay for a current of five times tap was entered into the time dial calculator function for each time dial setting. The equivalent Basler Electric time dial setting was then entered into the cross-reference table.

If your electromechanical relay time dial setting is between the values provided in the table, it will be necessary to interpolate (estimate the correct intermediate value) between the electromechanical setting and the Basler Electric setting.

Basler Electric relays have a maximum time dial setting of 9.9. The Basler Electric equivalent time dial setting for the electromechanical maximum setting is provided in the cross-reference table even if it exceeds 9.9. This allows interpolation as noted above.

Basler Electric time current characteristics are determined by a linear mathematical equation. The induction disk of an electromechanical relay has a certain degree of non linearity due to inertial and friction effects. For this reason, even though every effort has been made to provide characteristic curves with minimum deviation from the published electromechanical curves, slight deviations can exist between them.

In applications where the time coordination between curves is extremely close, we recommend that you choose the optimal time dial setting by inspection of the coordination study. In applications where coordination is tight, it is recommended that you retrofit your circuits with Basler Electric electronic relays to ensure high timing accuracy.

Table A-3. Time Dial Setting Cross-Reference

Curve	Equivalent To	Electromechanical Relay Time Dial Setting											
		0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
		Basler Electric Equivalent Time Dial Setting											
S1	ABB CO-2	0.3	0.8	1.7	2.4	3.4	4.2	5.0	5.8	6.7	7.7	8.6	9.7
L1	ABB CO-5	0.4	0.8	1.5	2.3	3.3	4.2	5.0	6.0	7.0	7.8	8.8	9.9
D	ABB CO-6	0.5	1.1	2.0	2.9	3.7	4.5	5.0	5.9	7.2	8.0	8.9	10.1
M	ABB CO-7	0.4	0.8	1.7	2.5	3.3	4.3	5.3	6.1	7.0	8.0	9.0	9.8
I1	ABB CO-8	0.3	0.7	1.5	2.3	3.2	4.0	5.0	5.8	6.8	7.6	8.7	10.0
V1	ABB CO-9	0.3	0.7	1.4	2.1	3.0	3.9	4.8	5.7	6.7	7.8	8.7	9.6
E1	ABB CO-11	0.3	0.7	1.5	2.4	3.2	4.2	5.0	5.7	6.6	7.8	8.5	10.3
I2	GE IAC-51	0.6	1.0	1.9	2.7	3.7	4.8	5.7	6.8	8.0	9.3	10.6	N/A
V2	GE IAC-53	0.4	0.8	1.6	2.4	3.4	4.3	5.1	6.3	7.2	8.4	9.6	N/A
S2	GE IAC-55	0.2	1.0	2.0	3.1	4.0	4.9	6.1	7.2	8.1	8.9	9.8	N/A
L2	GE IAC-66	0.4	0.9	1.8	2.7	3.9	4.9	6.3	7.2	8.5	9.7	10.9	N/A
E2	GE IAC-77	0.5	1.0	1.9	2.7	3.5	4.3	5.2	6.2	7.4	8.2	9.9	N/A

The 46 Curve

The 46 curve (Figure A-17) is a special curve designed to emulate the $(I_2)^2$ t withstand ratings of generators using what is frequently referred to as the generator K factor.

The 46 Curve Characteristics

46 Pickup Current

Generators have a maximum continuous rating for negative sequence current. This is typically expressed as a percent of stator rating. When using the 46 curve, the user should convert the continuous I^2 rating data to actual secondary current at the relay. This value (plus some margin, if appropriate) should be entered as the pickup setting. For example, if a generator's rated full-load current is 5 amperes, a pu setting of 0.5 A would allow 10% continuous I_2.

46 Time Dial (= Generator K factor)

The amount of time that a generator can withstand a given level of unbalance is defined by Equation A-3.

$$t = \frac{K}{(I_2)^2}$$

Equation A-3

The K factor gives the time that a generator can withstand 1 per unit negative sequence current. For example, with a K factor of 20, since $(I_2)^2$ becomes 1 at 1 per unit of current, the generator can withstand the condition for 20 seconds. Typical values for generator K factors are in the 2 to 40 range. The relay uses the "nominal current" setting of the relay (via BESTCOMS or the SG-NOM command) to determine what corresponds to 1 per unit current in the generator.

When curve 46 is selected, the relay changes the range of the allowed time dial to 1 to 99 (instead of the time dial range of 0.1 to 9.9 for all the other curves). The user should enter the "K" factor of the generator into the time dial field.

Relay Equation

When the 46 function is used, the relay uses the K factor (i.e., 46 time dial setting), 46 minimum pickup setting and generator full-load current to create a constant Z (see Equation A-4).

$$Z = 46\ \text{Time Dial}\left(\frac{I_{\text{Nom Setting}}}{\text{46 Pickup Setting}}\right)^2$$ *Equation A-4*

The time to trip equation used in the relay is:

$$T_T = \frac{Z}{M^2} + 0.028\ \text{seconds}$$ *Equation A-5*

where

$$M = \frac{\text{Measured } I_2}{\text{46 Pickup Setting}}$$ *Equation A-6*

which, when M > 1, reduces to:

$$T_T = 46\ \text{Time Dial}\left(\frac{I_{\text{Nom Setting}}}{I_2\ \text{Measured}}\right)^2$$ *Equation A-7*

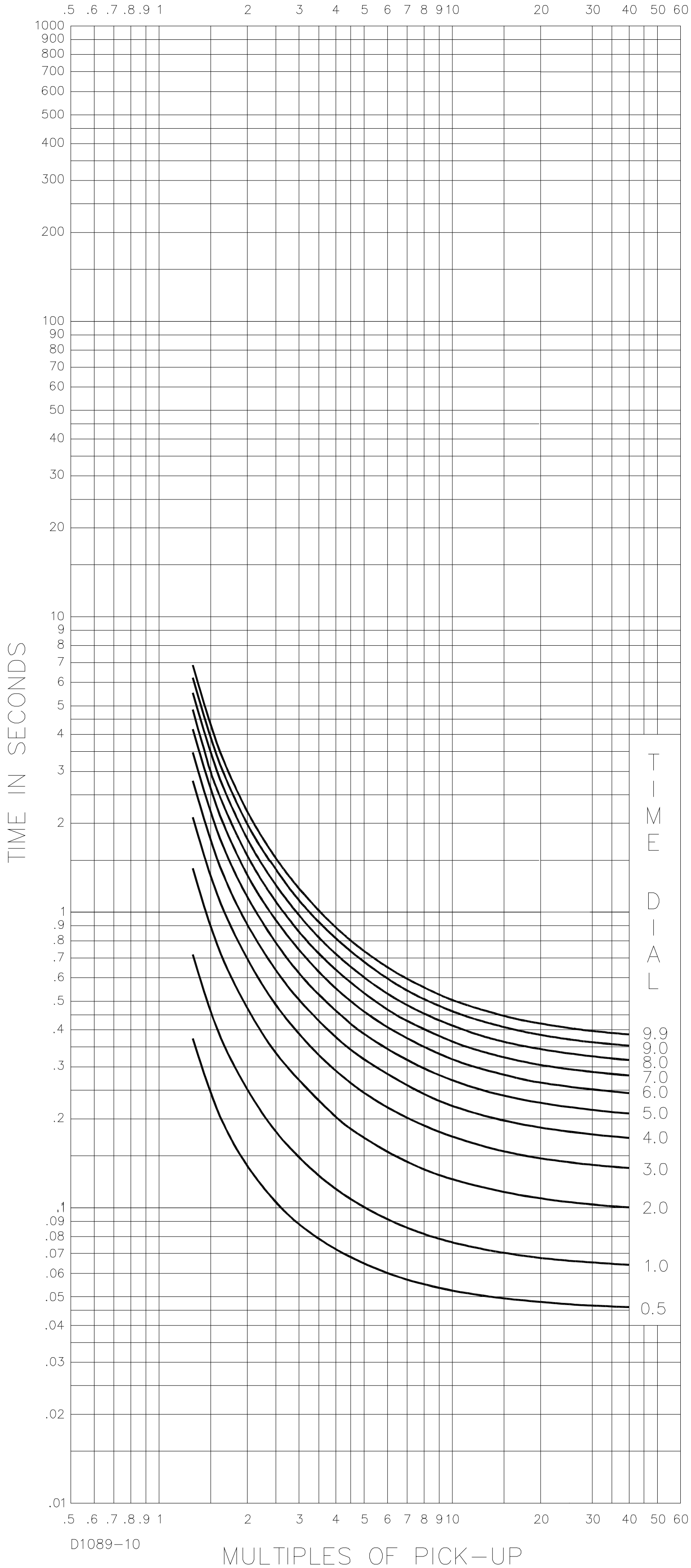


Figure A-1. Time Characteristic Curve S1, Short Inverse (Similar to ABB CO-2)

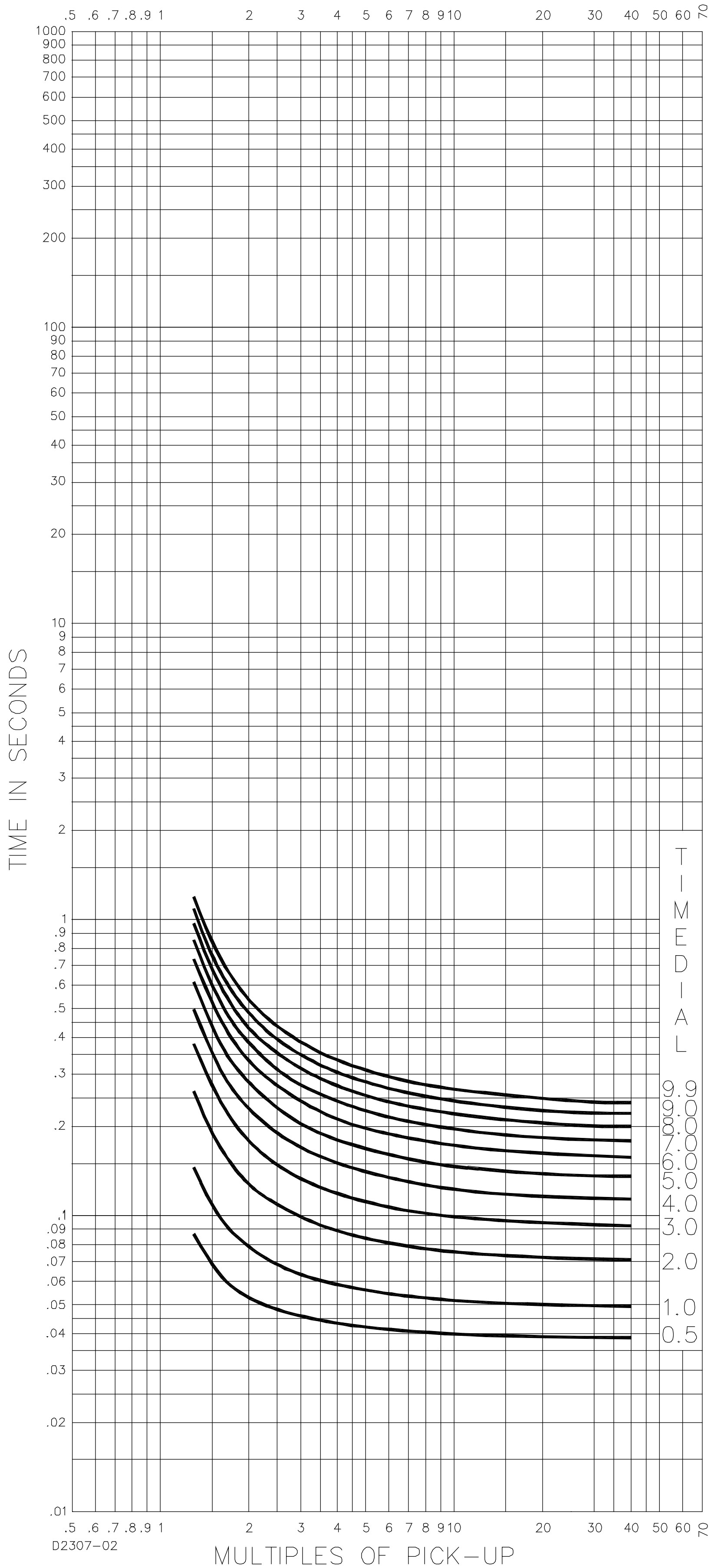


Figure A-2. Time Characteristic Curve S2, Short Inverse (Similar To GE IAC-55)

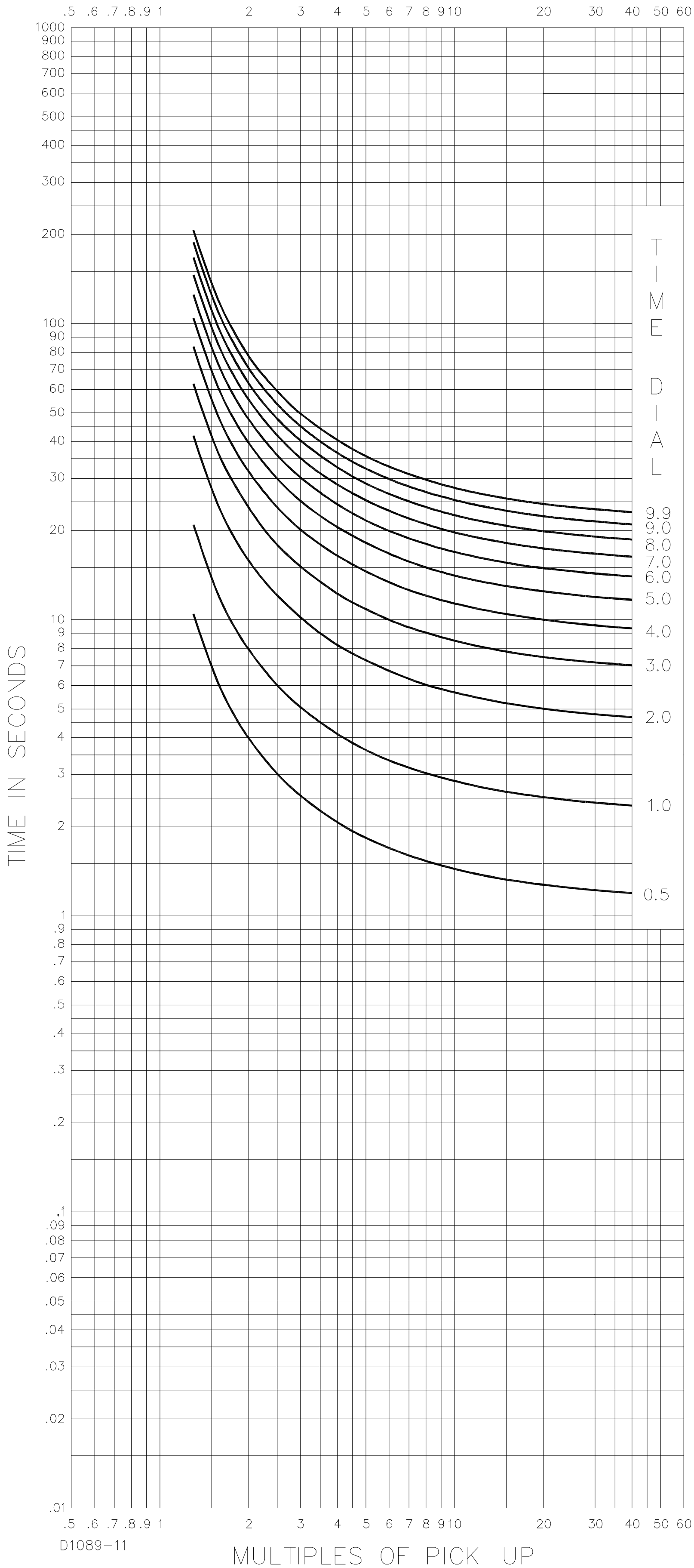


Figure A-3. Time Characteristic Curve L1, Long Inverse (Similar to ABB CO-5)

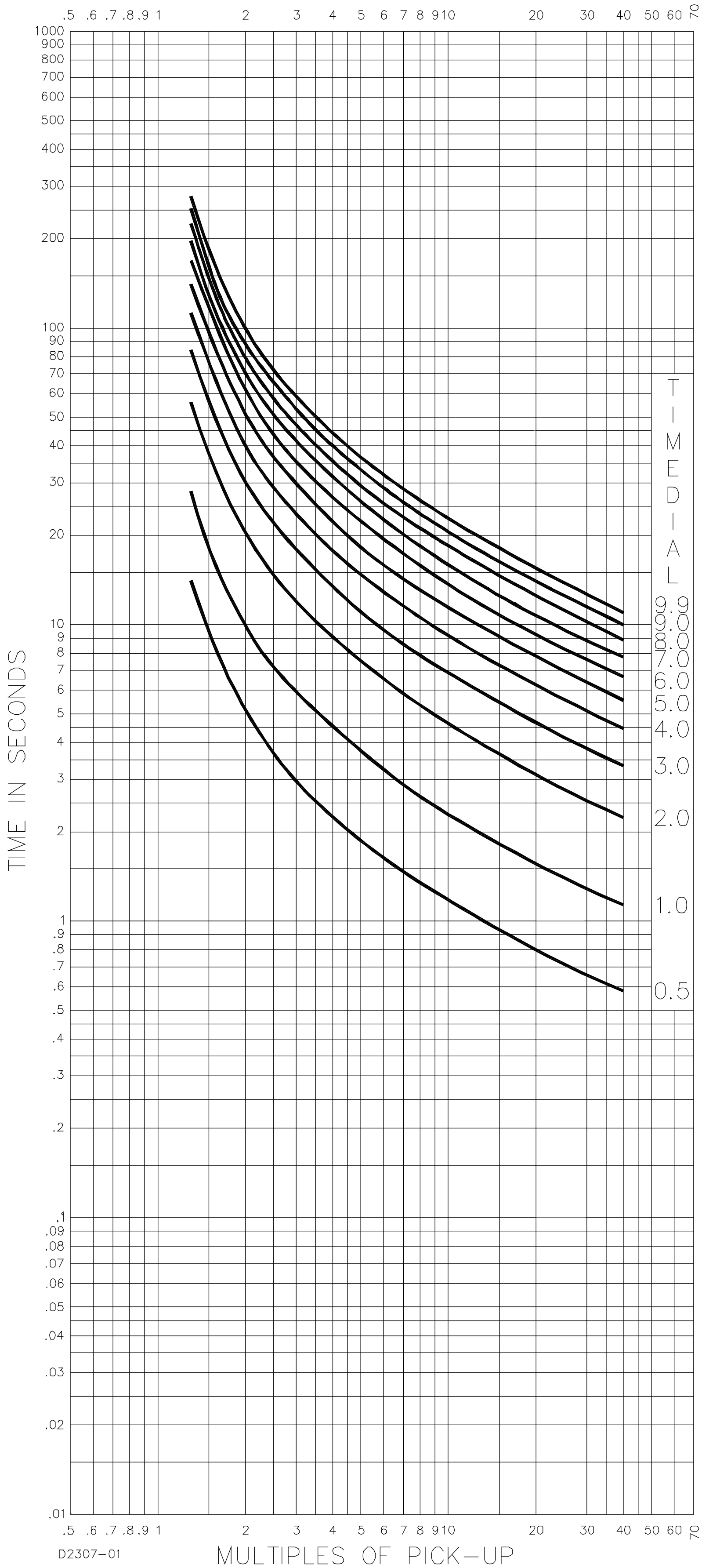


Figure A-4. Time Characteristic Curve L2, Long Inverse (Similar To GE IAC-66)

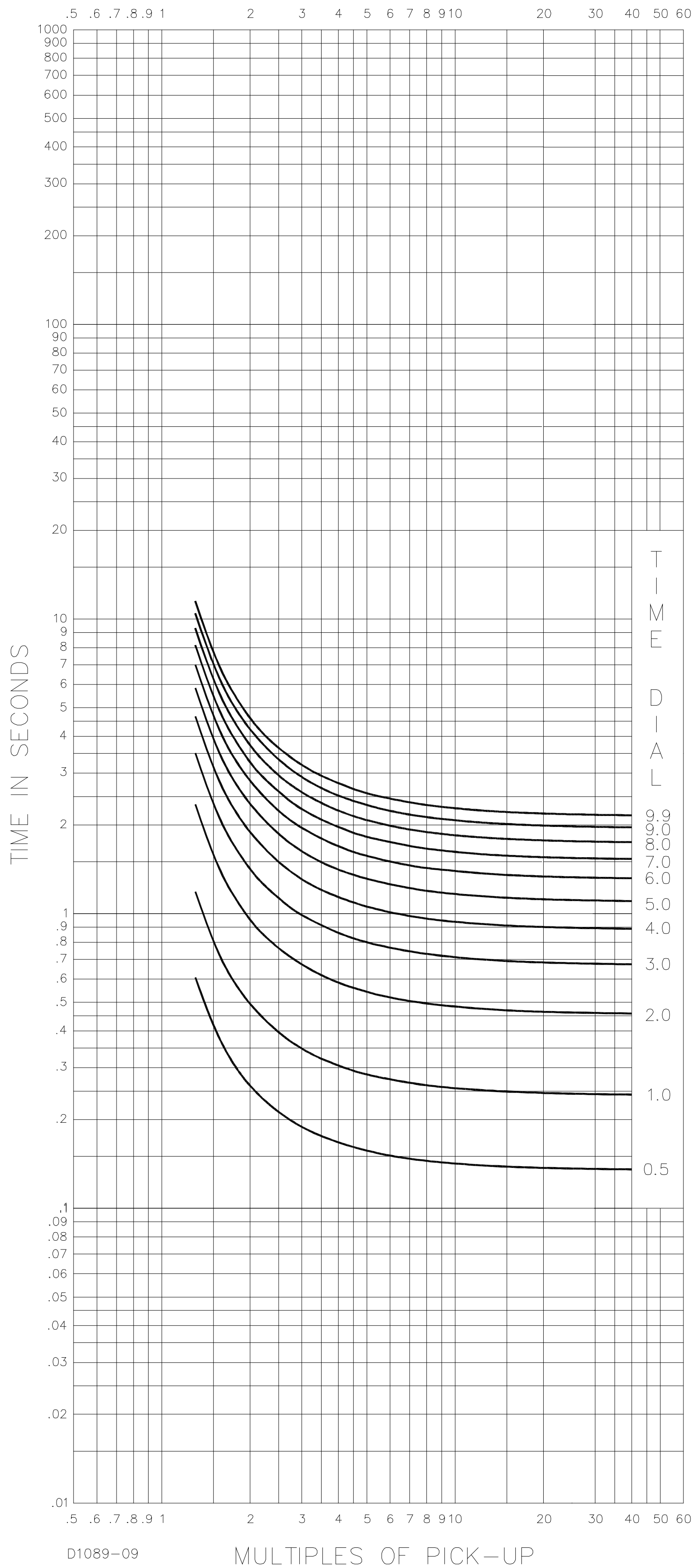


Figure A-5. Time Characteristic Curve D, Definite Time (Similar To ABB CO-6)

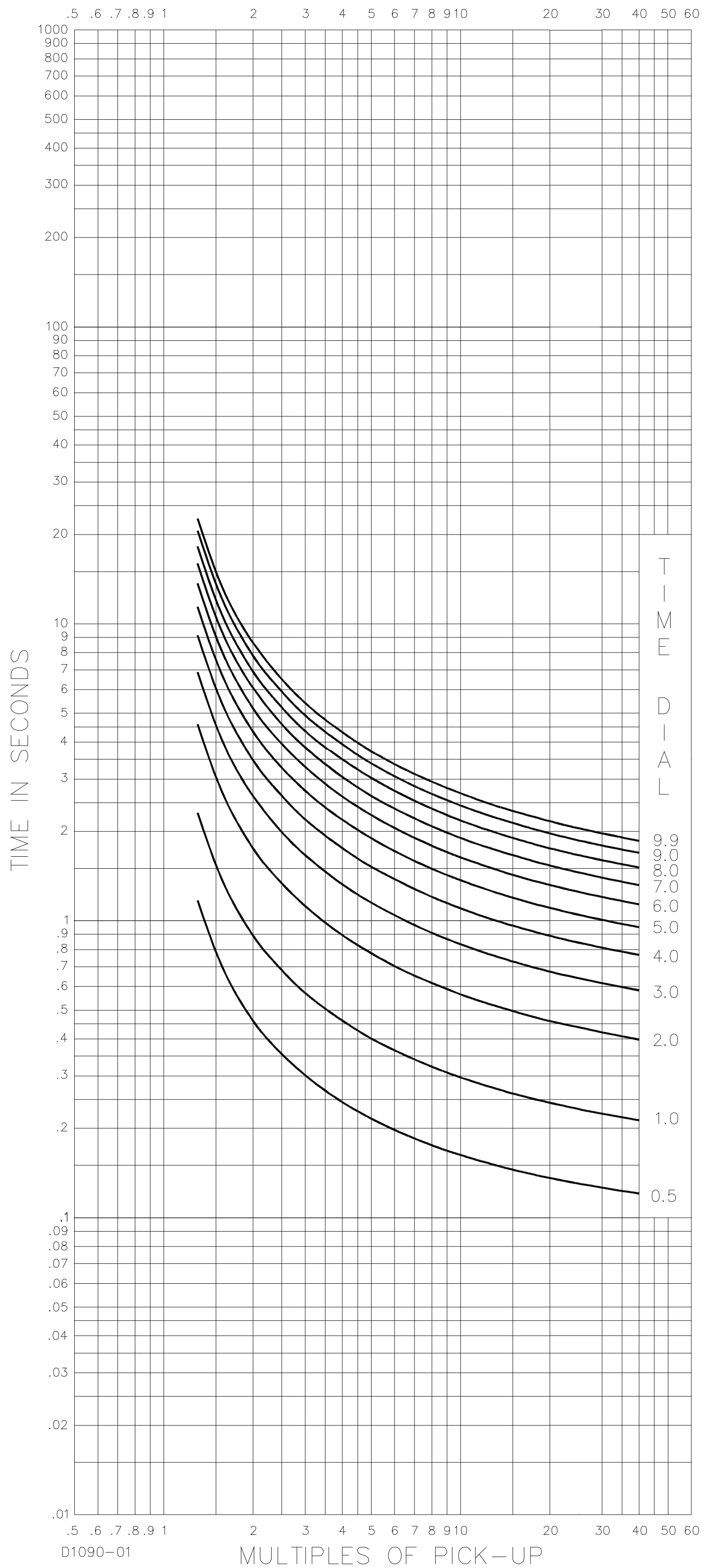


Figure A-6. Time Characteristic Curve M, Moderately Inverse (Similar to ABB CO-7)

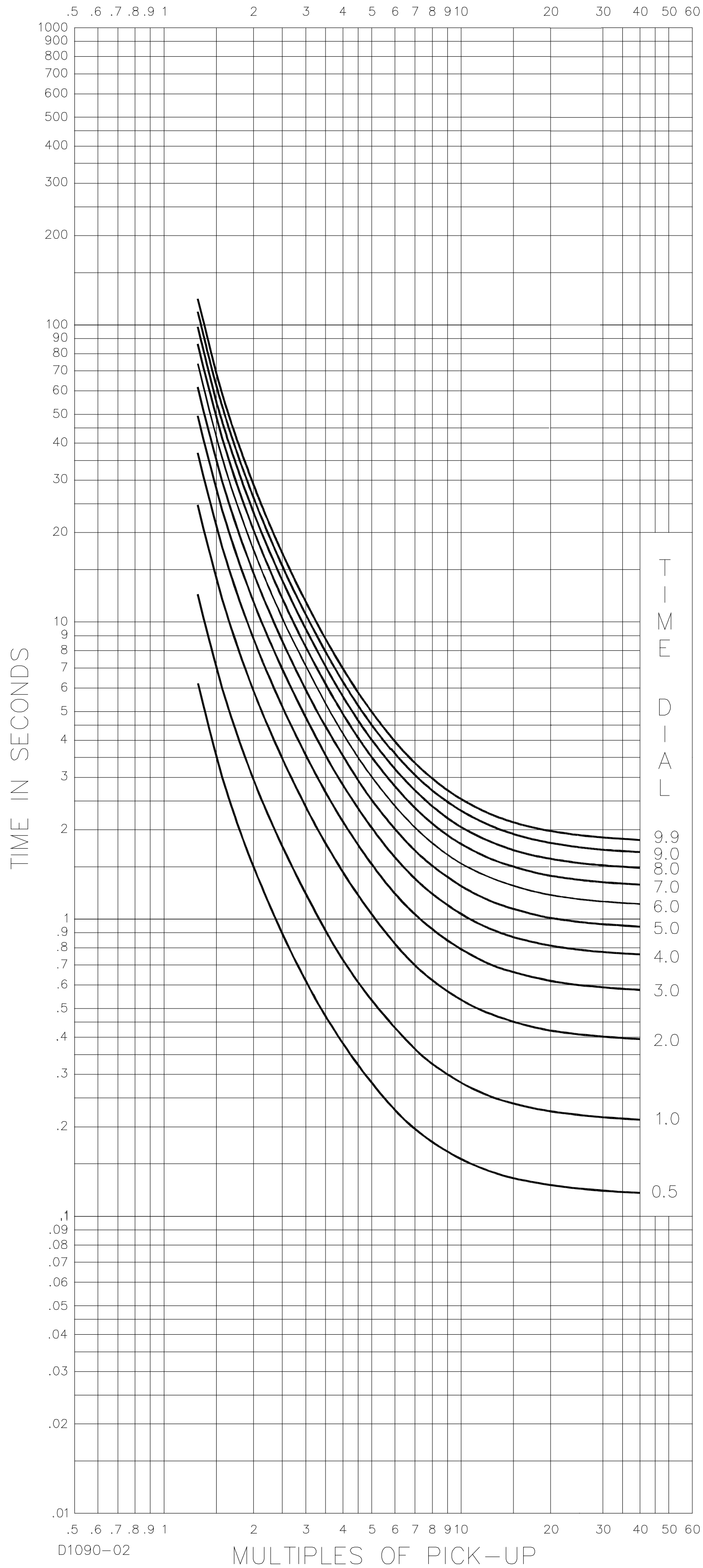


Figure A-7. Time Characteristic Curve I1, Inverse Time (Similar to ABB CO-8)

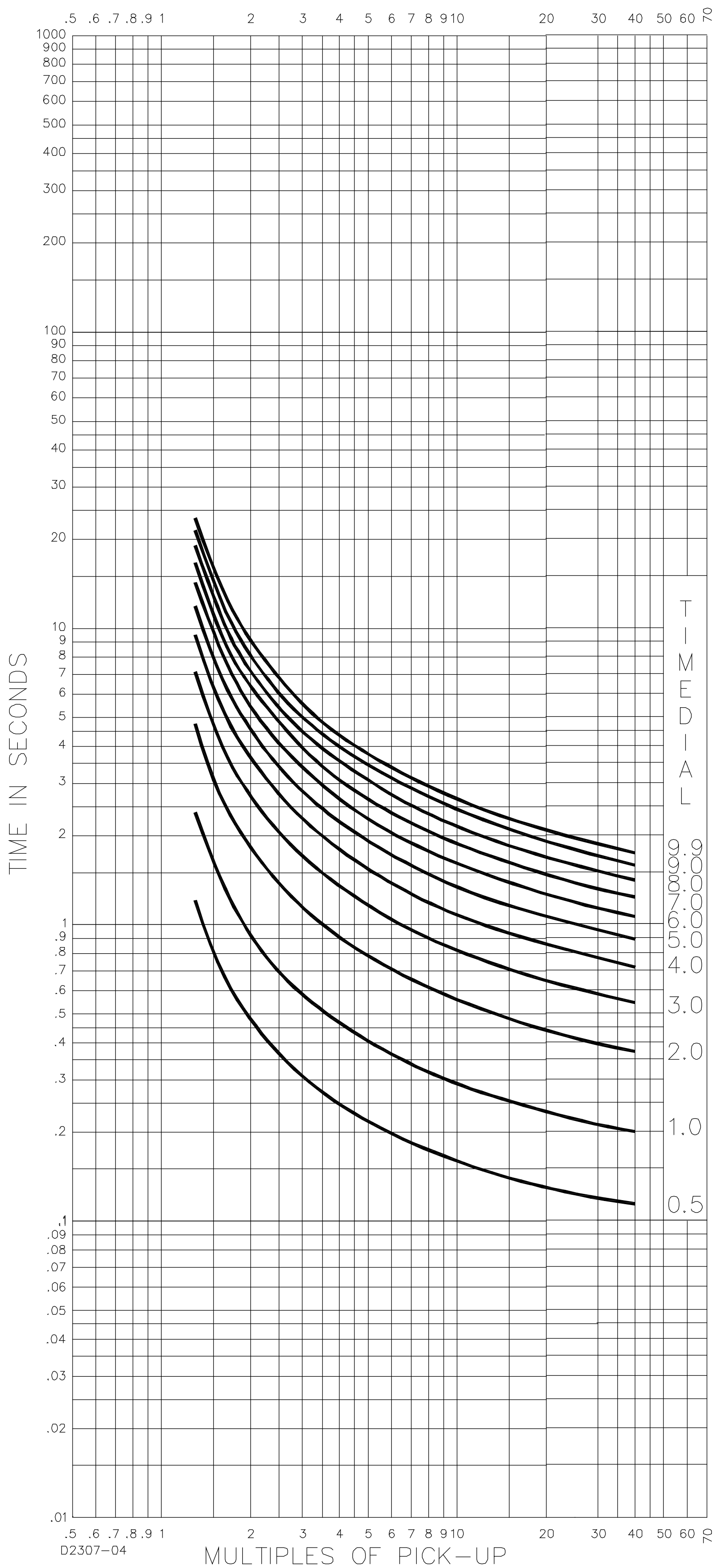


Figure A-8. Time Characteristic Curve I2, Inverse Time (Similar to GE IAC-51)

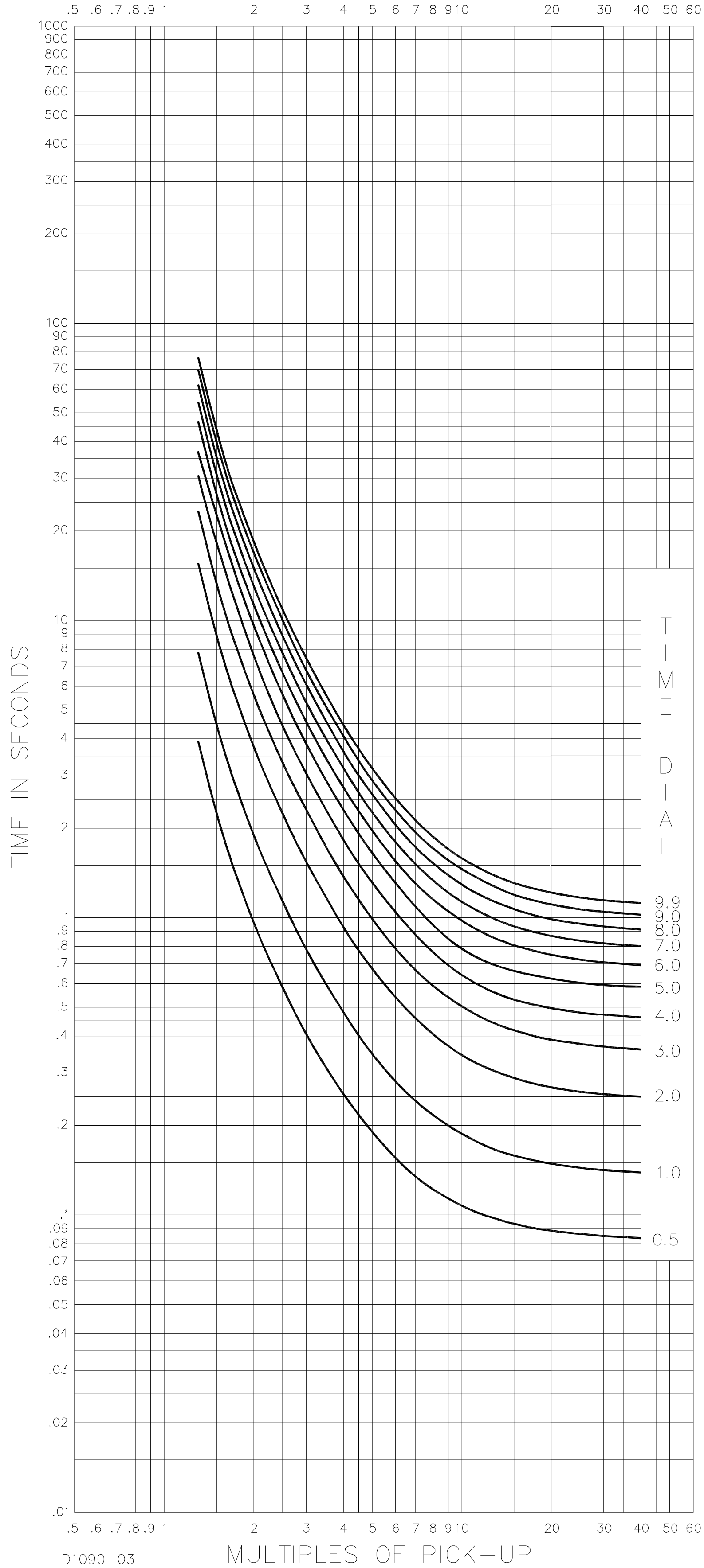


Figure A-9. Time Characteristic Curve V1, Very Inverse (Similar to ABB CO-9)

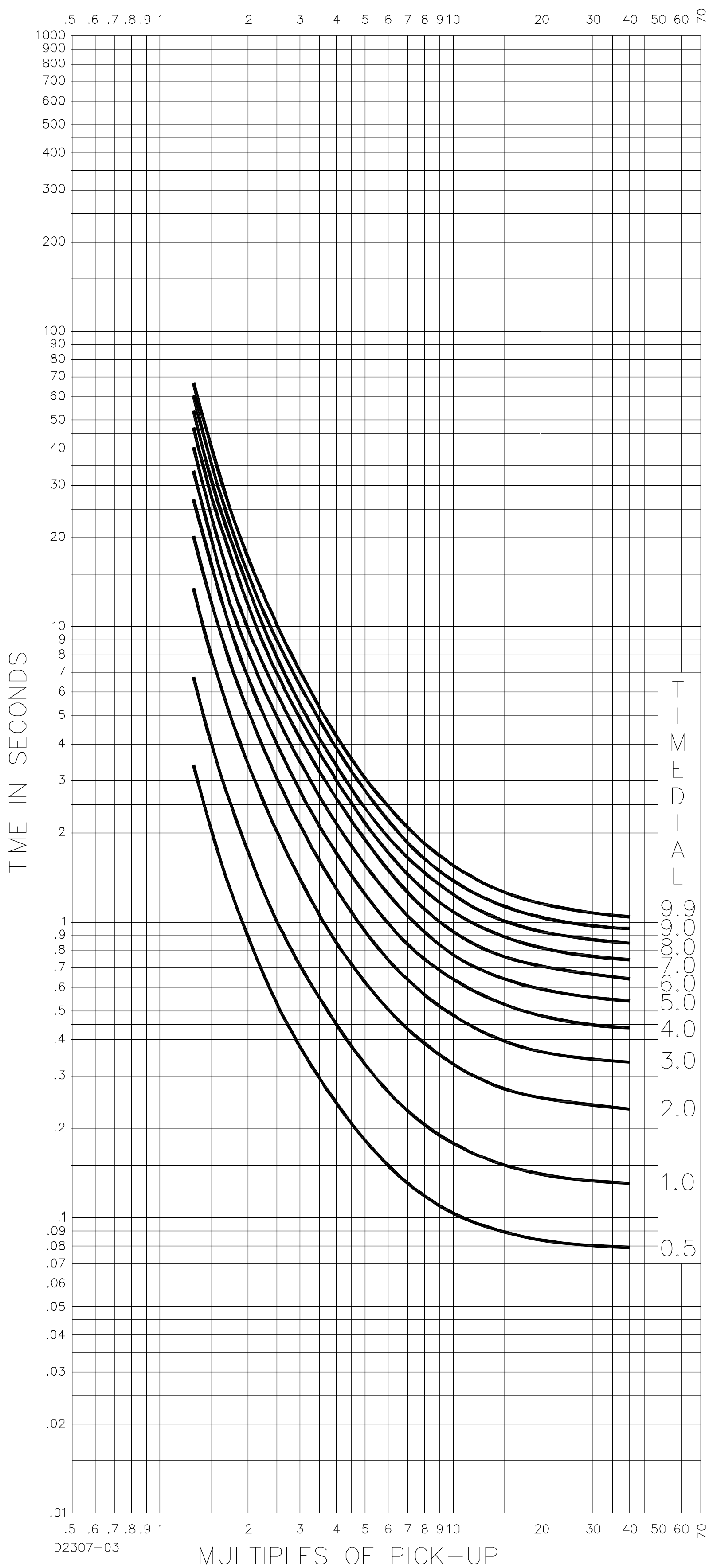


Figure A-10. Time Characteristic Curve V2, Very Inverse (Similar to GE IAC-53)

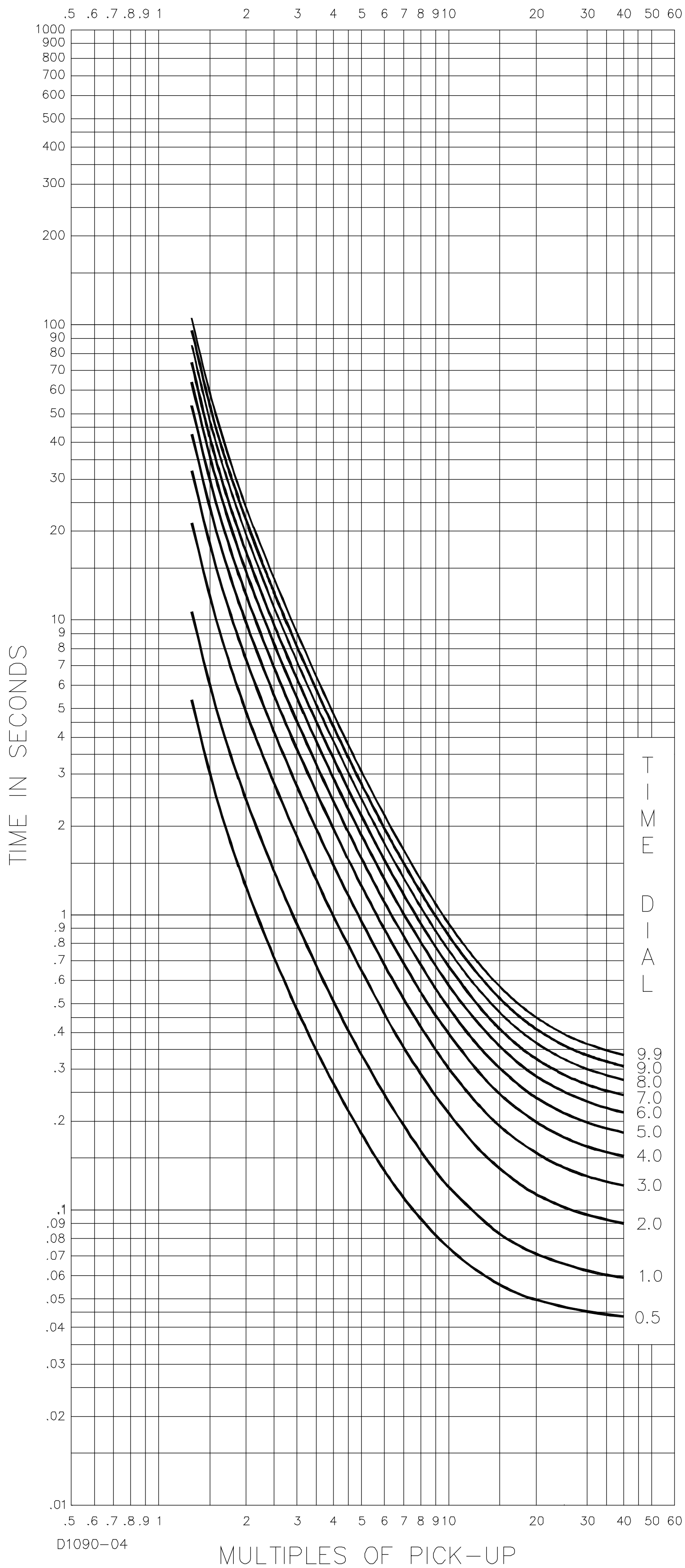


Figure A-11. Time Characteristic Curve E1, Extremely Inverse (Similar to ABB CO-11)

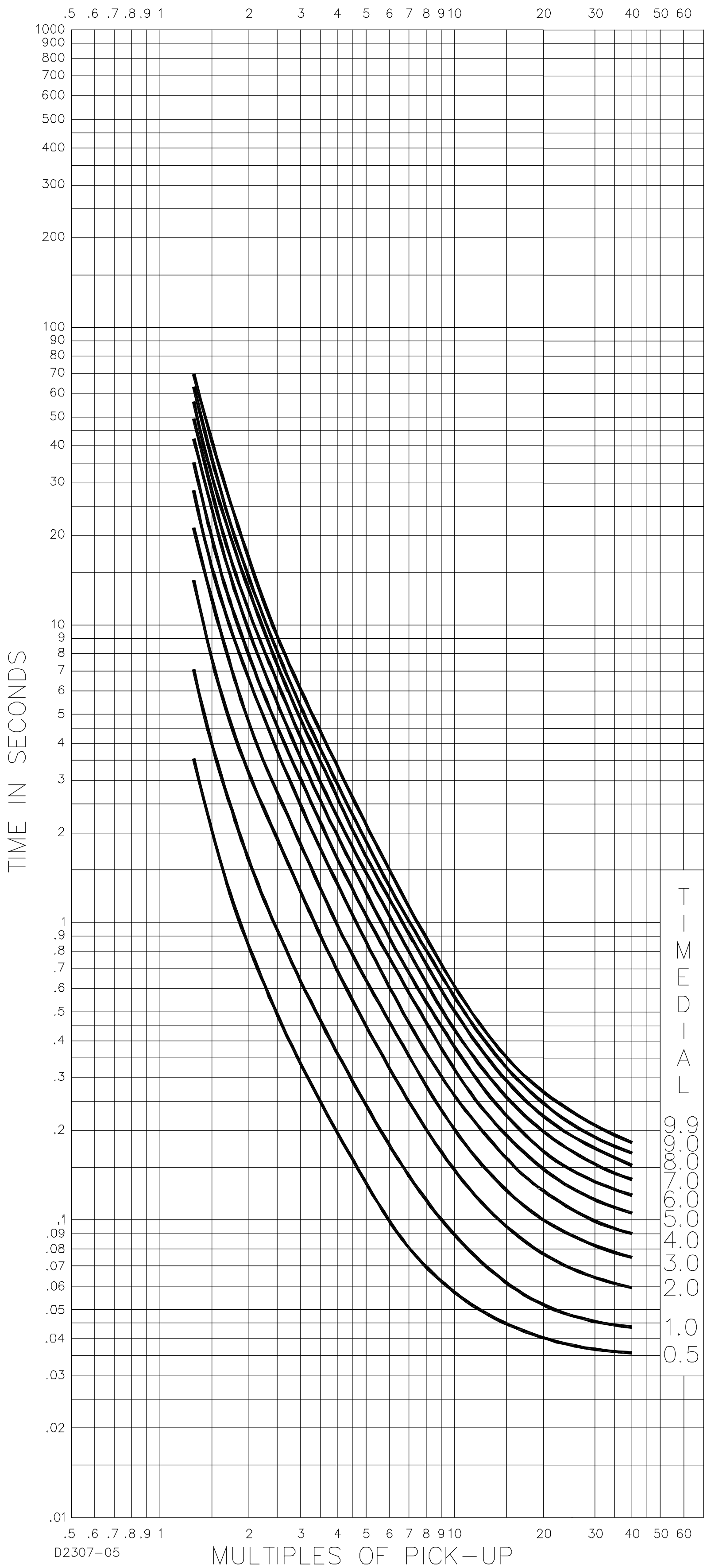


Figure A-12. Time Characteristic Curve E2, Extremely Inverse (Similar to GE IAC-77)

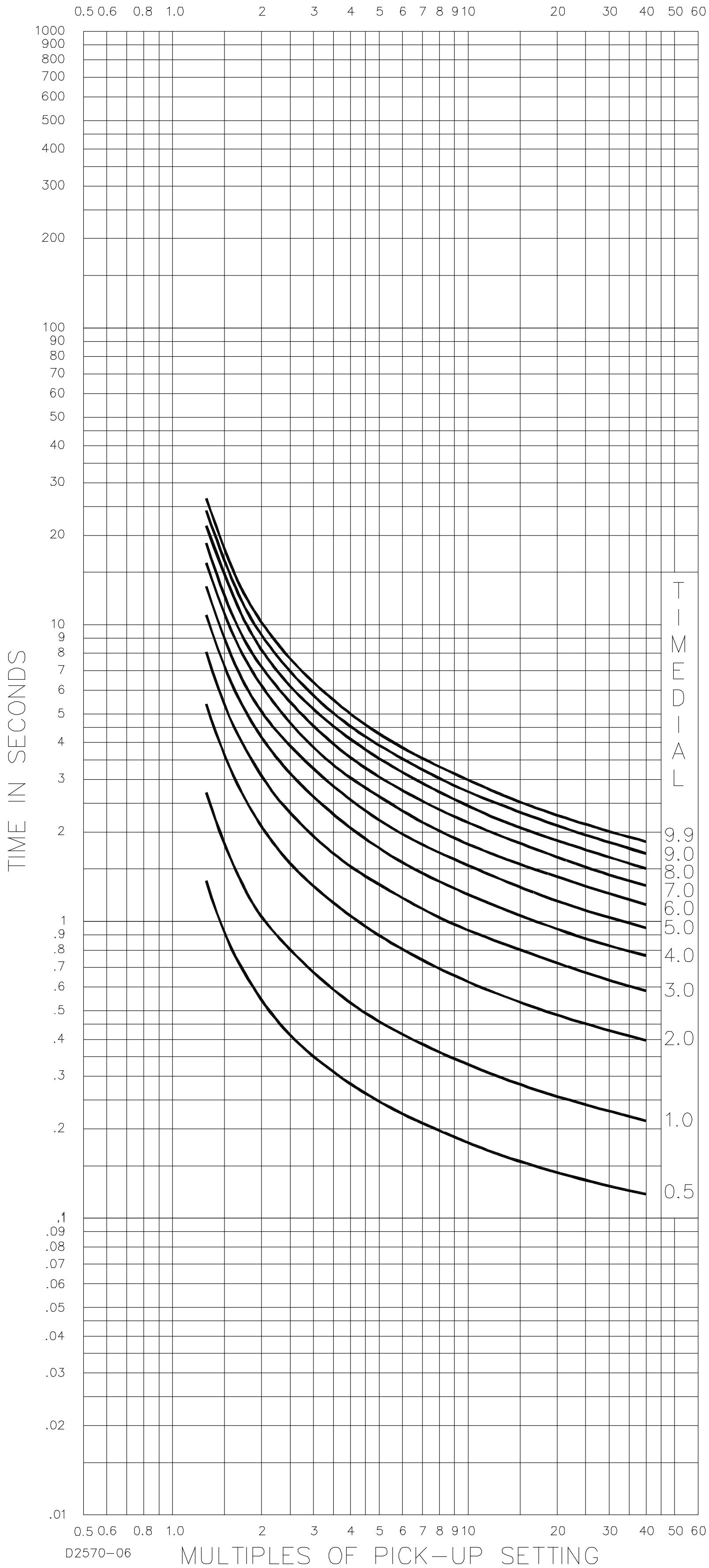


Figure A-13. Time Characteristic Curve A, Standard Inverse

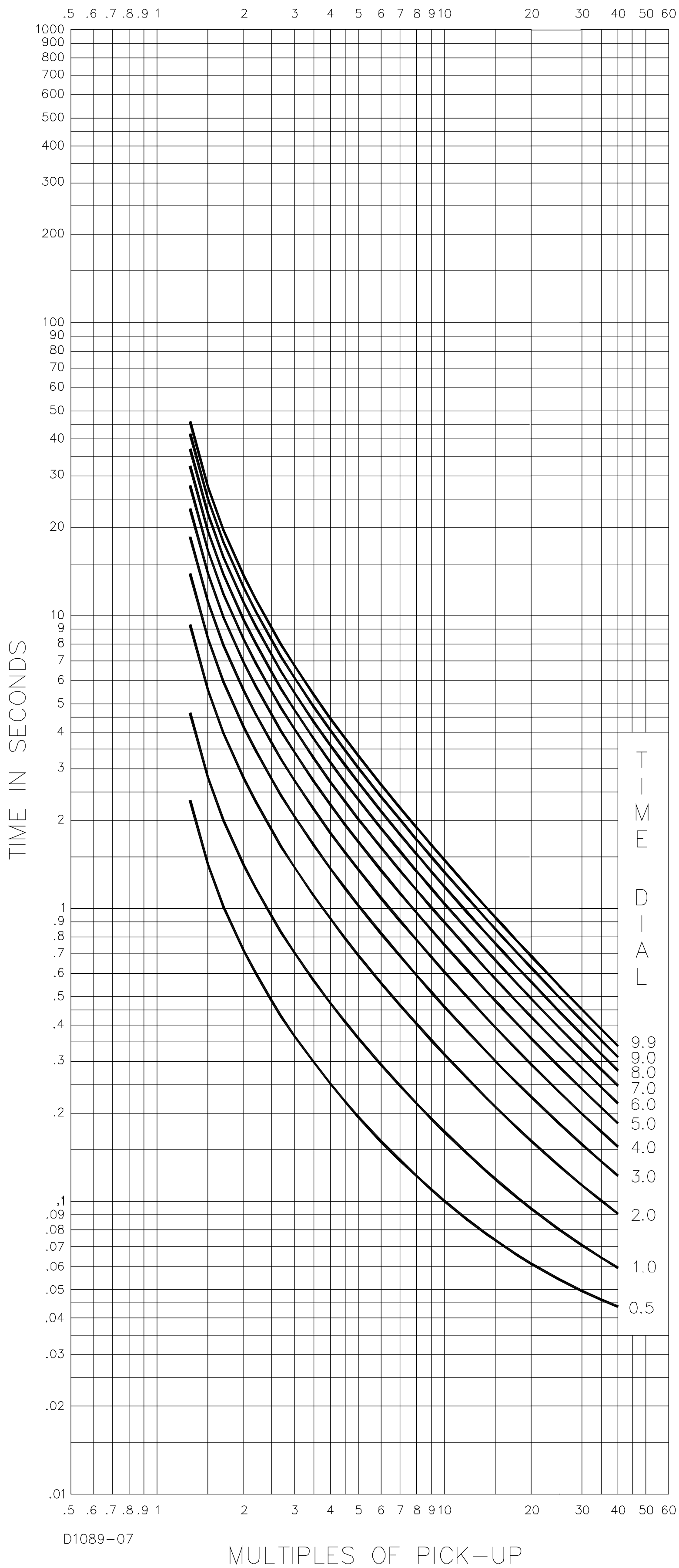


Figure A-14. Time Characteristic Curve B, Very Inverse

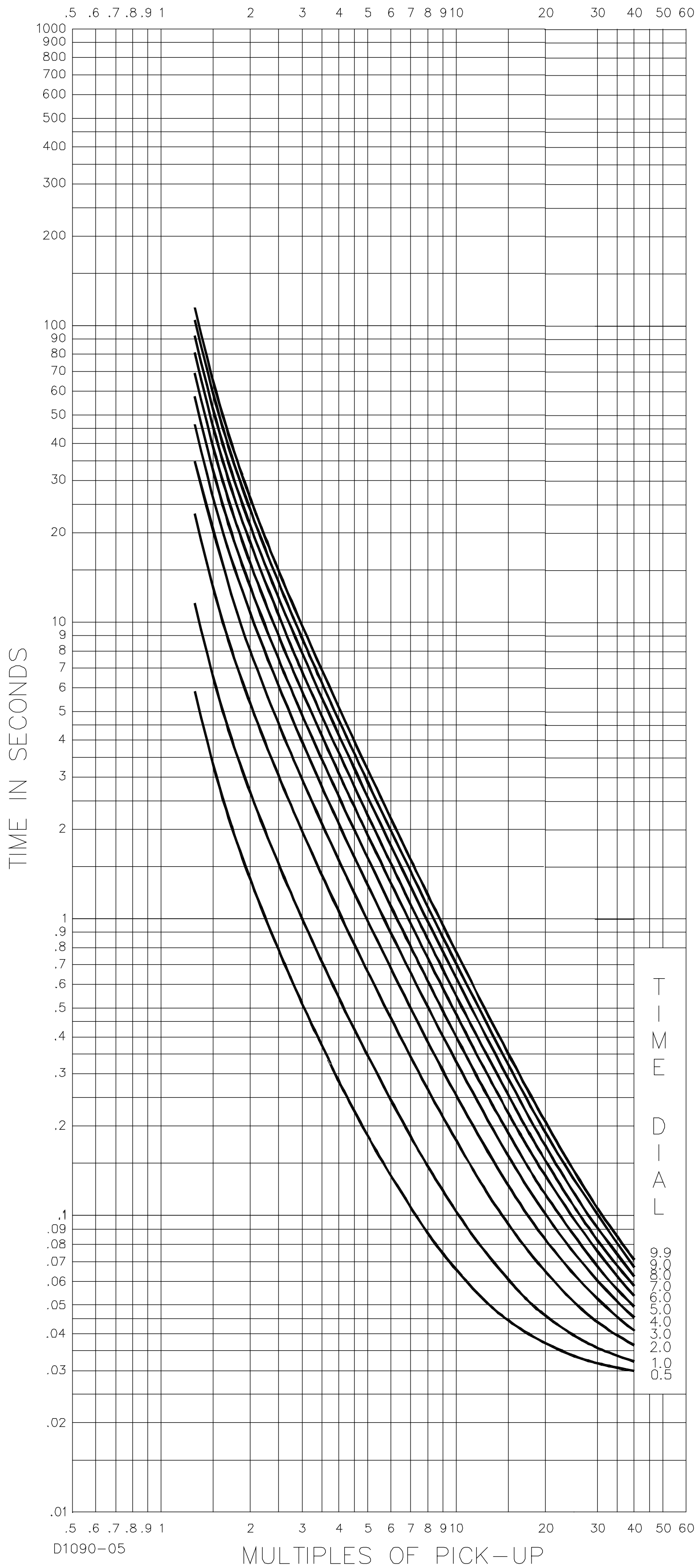


Figure A-15. Time Characteristic Curve C, Extremely Inverse

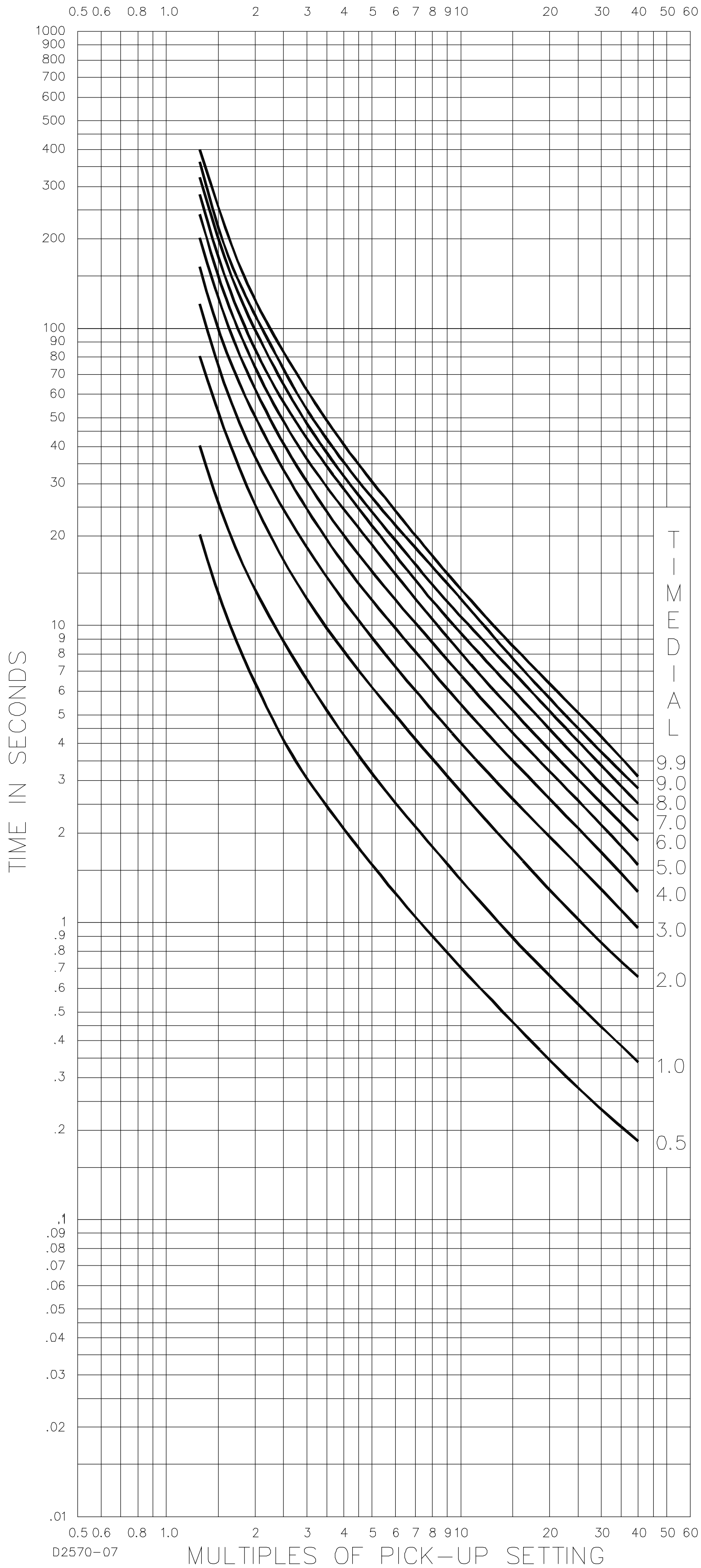
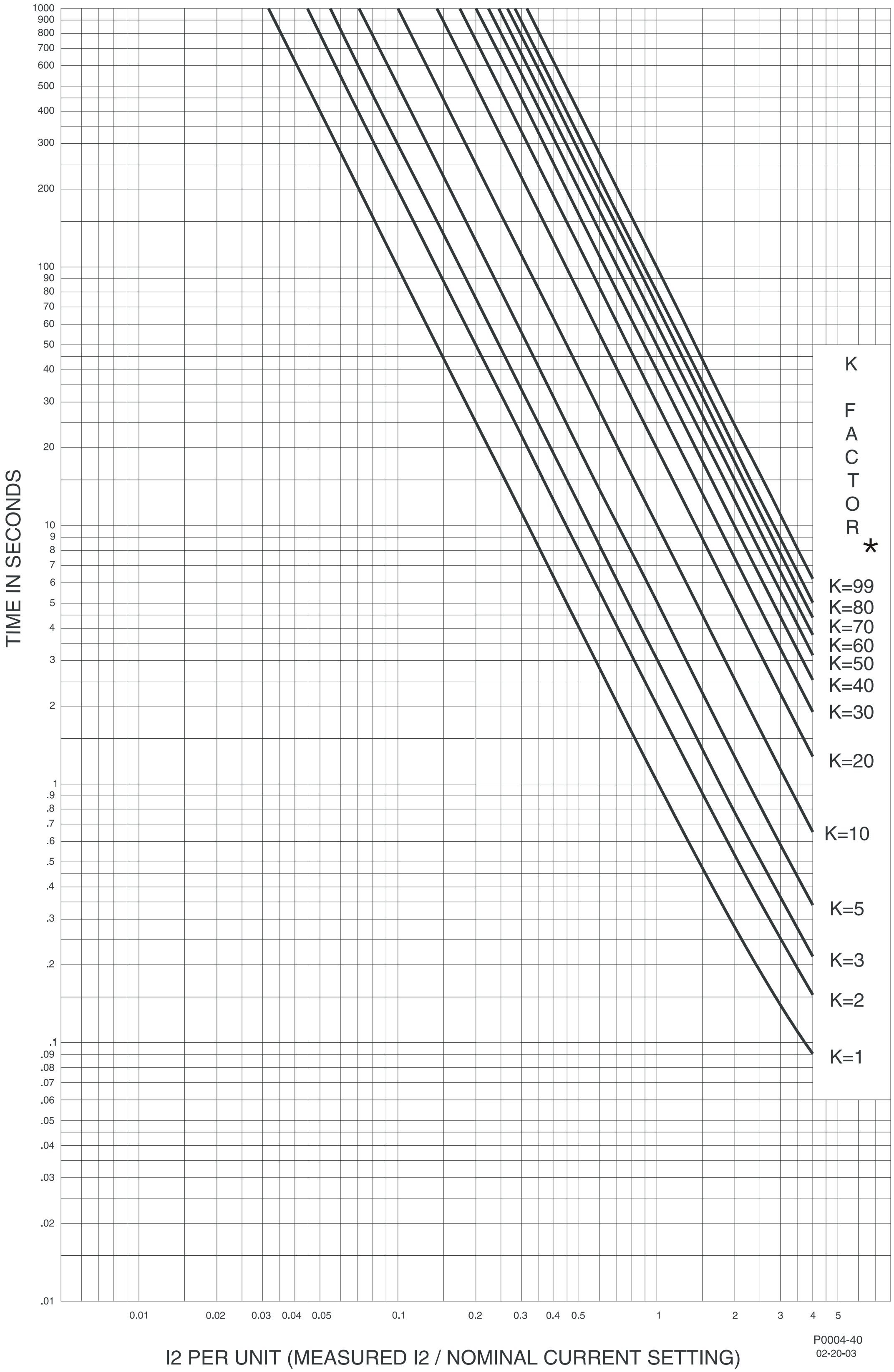


Figure A-16. Time Characteristic Curve G, Long Time Inverse



* The K factor is the time that a generator can withstand 1 per-unit I2, where 1 pu is the user's setting for full-load current.

Figure A-17. 46 Time Characteristic Curve

NOTE: Curves are shown as extending farther to the left than they will in practice. Curves stop at pickup level. For example, if the user selects 5A FLC and a pickup setting of 0.5A, the per-unit pickup is 0.1A. The relay will not pick up at less than 0.1 pu I2 for these settings.

APPENDIX B • OVEREXCITATION (24) INVERSE TIME CURVES

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APPENDIX B • OVEREXCITATION (24) INVERSE TIME CURVES

General

This appendix contains the inverse time curves for the overexcitation element (24). Equations B-1 and B-2 represent the trip time and reset time for constant volts per hertz level. Normally, the V/Hz pickup is set to a value greater than the V/Hz nominal. This ensures that V/Hz measured divided by V/Hz nominal is always greater than 1.000 throughout the pickup range.

Curve Specifications

If the pickup is set less than nominal, then measured values above pickup and below nominal will result in the maximum time delay. The maximum time delay is determined by Equation B-1 with (V/Hz measured / V/Hz nominal) set equal to 1.001. The overall inverse time delay range is limited to 1,000 seconds maximum and 0.2 seconds minimum.

$$T_T = \frac{D_T}{\left(\frac{V/Hz_{\text{MEASURED}}}{V/Hz_{\text{NOMINAL}}} - 1\right)^n}$$

Equation B-1, *Time to Trip*

$$T_R = D_R * \frac{E_T}{FST} \ X\ 100$$

Equation B-2, *Time to Reset*

where:

T_T = Time to trip
T_R = Time to reset
D_T = Time dial trip
D_R = Time dial reset
ET = Elapsed time
n = Curve exponent (0.5, 1, 2)
FST = Full scale trip time (T_T)
ET/FST = Fraction of total travel toward trip that integration had progressed to. (After a trip, this value will be equal to one.)

When the measured volts/hertz rises above a pickup threshold, the pickup element becomes TRUE and integrating or definite time timer starts. If the volts/hertz remains above the pickup threshold and the integration continues for the required time interval as defined by the equations shown above and the set time dial, the trip output becomes TRUE. If the measured volts/hertz drops below pickup before timeout to trip, either an instantaneous or a time delayed integrating reset can be selected.

The following sets of curves are shown first with the time axis on the vertical and then on the horizontal for ease of use.

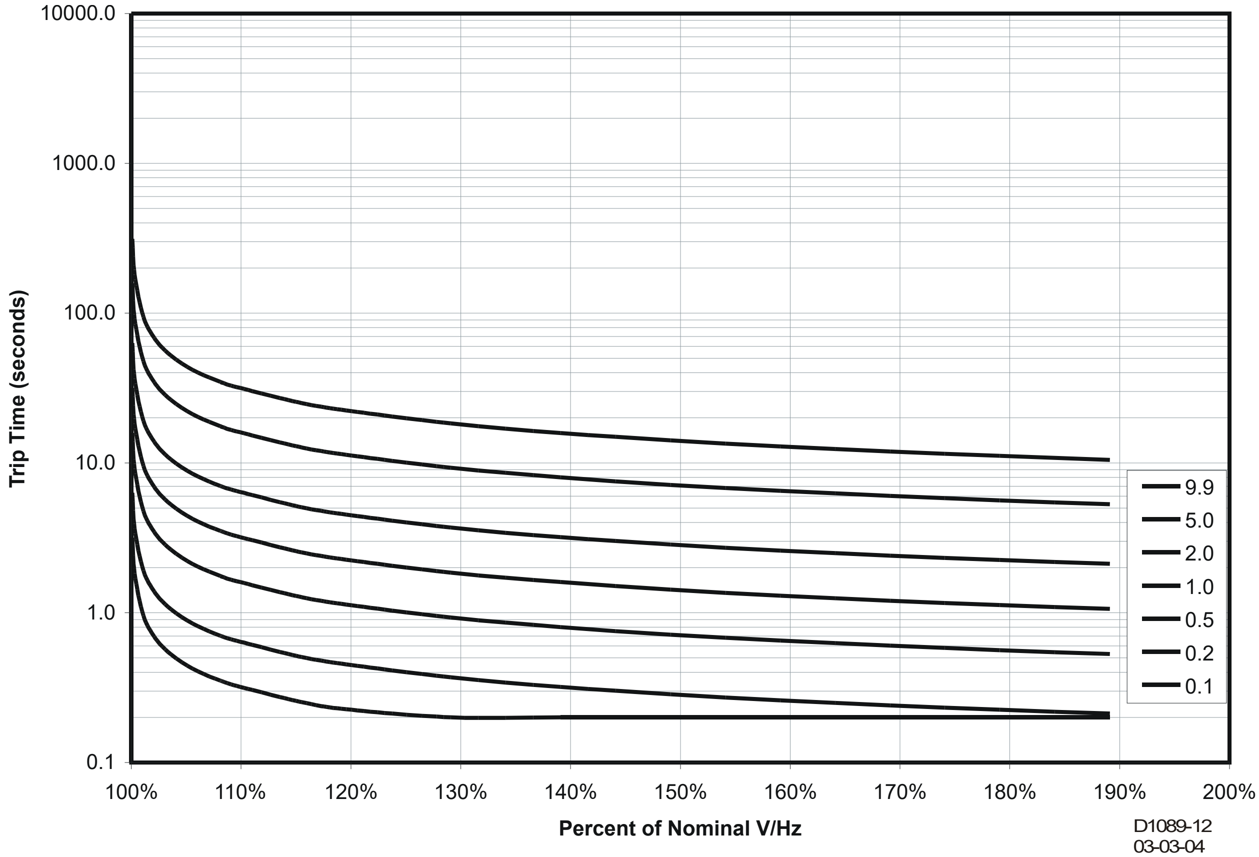

Figure B-1. Volt/Hz Characteristic (M-1)^0.5 – Time on Vertical Axis

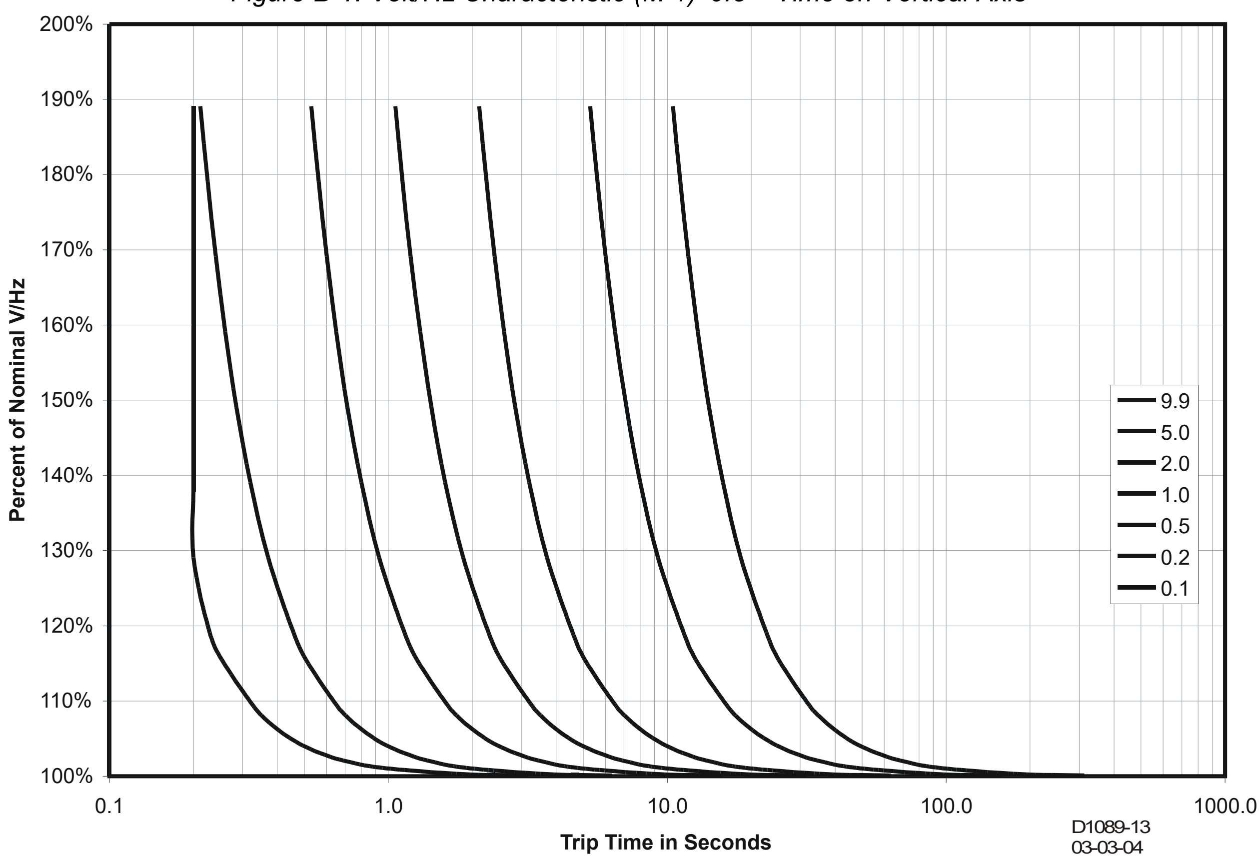

Figure B-2. Volt/Hz Characteristic (M-1)^0.5 – Time on Horizontal Axis

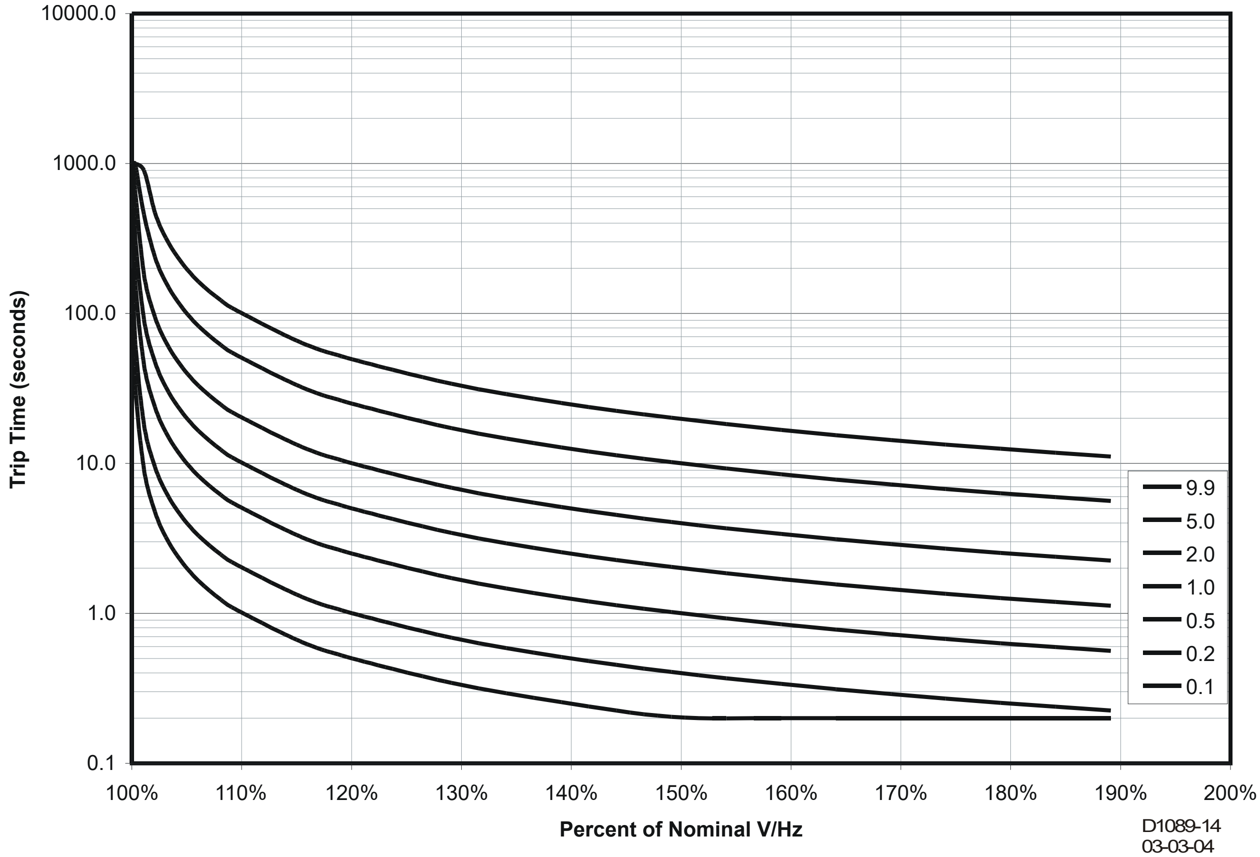

Figure B-3. Volt/Hz Characteristic (M-1)^1 – Time on Vertical Axis

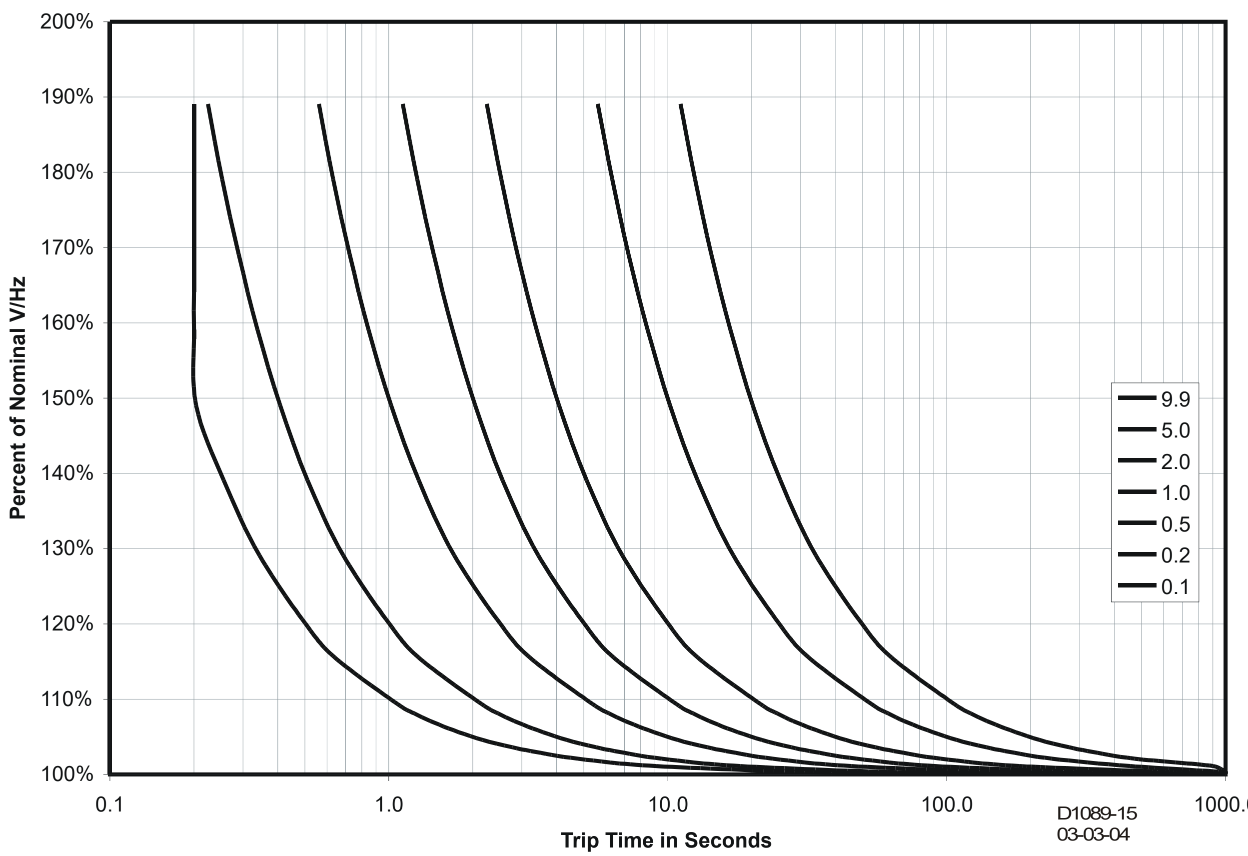

Figure B-4. Volt/Hz Characteristic (M-1)^1 – Time on Horizontal Axis

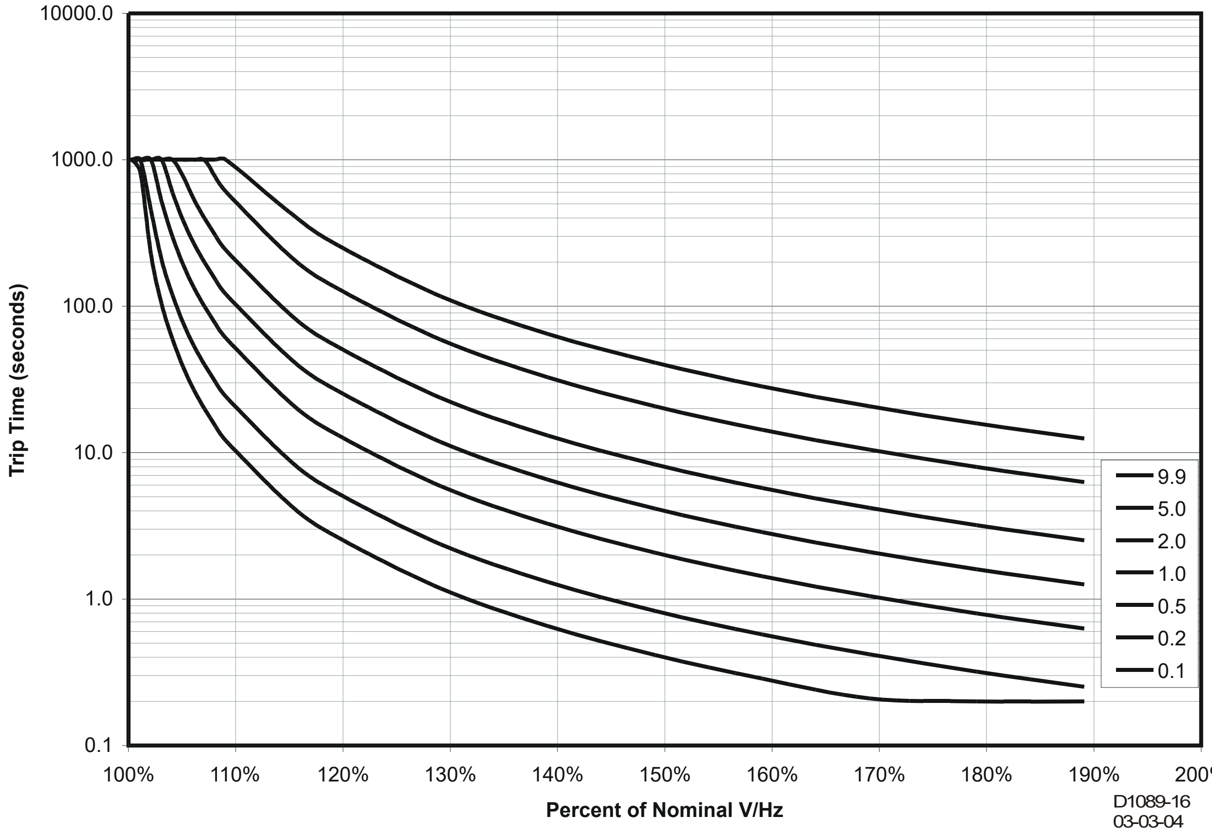

Figure B-5. Volt/Hz Characteristic (M-1)^2 – Time on Vertical Axis

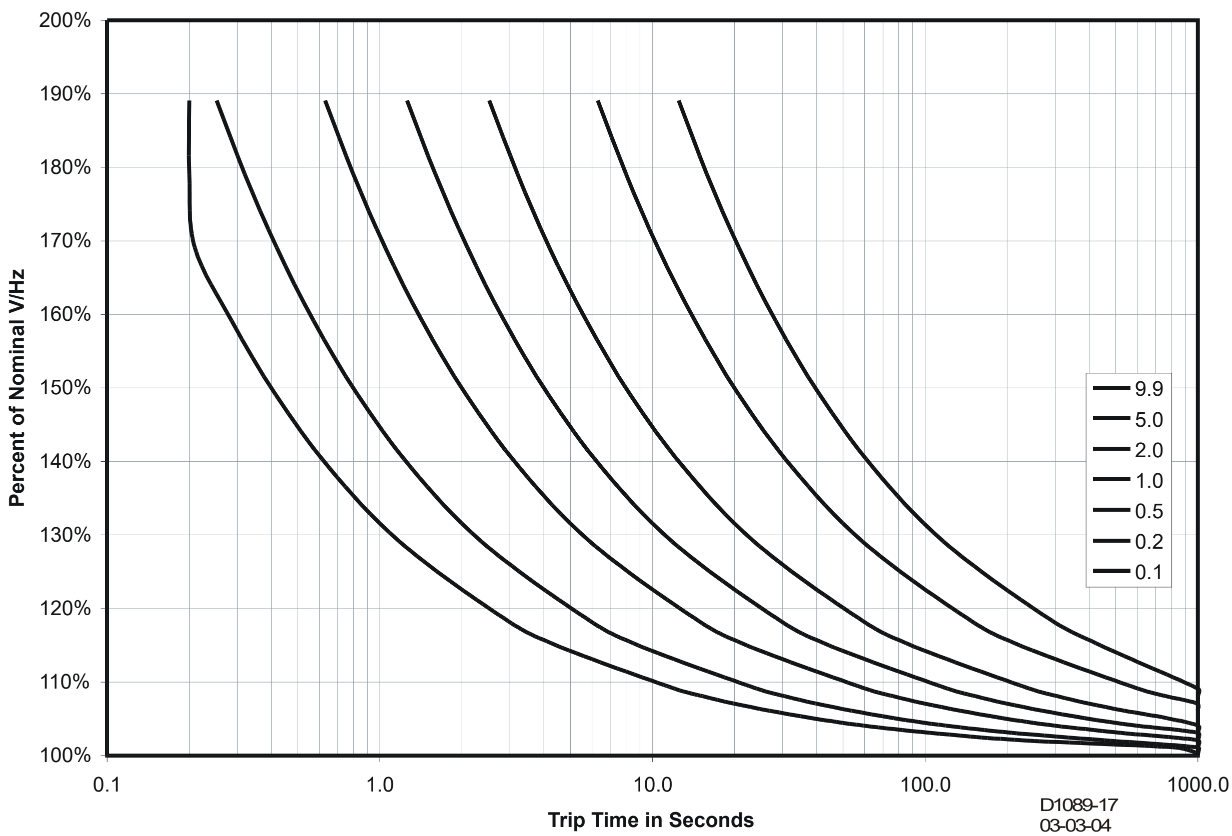

Figure B-6. Volt/Hz Characteristic (M-1)^2 – Time on Horizontal Axis

APPENDIX C • TERMINAL COMMUNICATION

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APPENDIX C • TERMINAL COMMUNICATION

HyperTerminal (provided with Windows® 2000/XP) or other stand-alone software can be used to communicate with a BE1-CDS240 relay. The following instructions are used for configuring HyperTerminal in Windows 2000/XP to communicate with your BE1-CDS240 relay. The configuration of other stand-alone software is similar.

Step 1: Click Start: Highlight *Programs, Accessories, Communication, HyperTerminal.*

Step 2: Click HyperTerminal to open the folder.

Step 3: Select the file or icon labeled Hypertrm or Hypertrm.exe. Once the program has started, you will be presented with a series of dialog boxes.

Step 4: Dialog Box: Connection Description

a. Type the desired file name, for example, BE1-CDS240. See Figure C-1.

b. Click "OK".

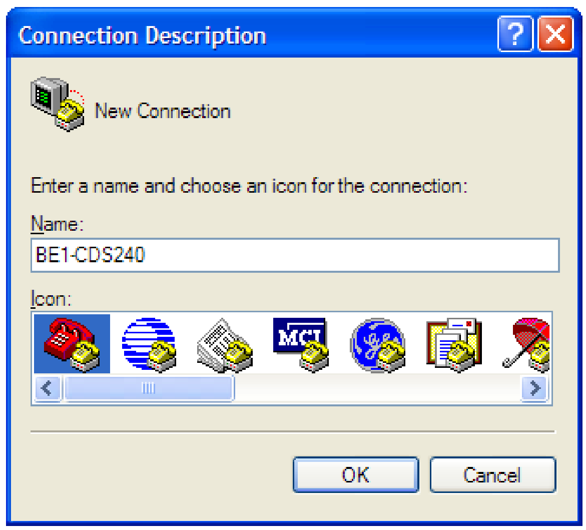

Figure C-1. Connection Description Dialog Box

Step 5: Dialog Box: Connect To

a. Click the Connect using: drop-down menu. See Figure C-2.
Select COMx, where x is the port you are using on your computer.

b. Click "OK".

Figure C-2. Connect To Dialog Box

Step 6: Dialog Box: COMx Properties

a. Make the following selections using Figure C-3 as a guide:

Set the bits per second setting so that it matches the setting of the relay. The default baud rate of the relay is 9,600.

Set the Data bits at 8.

Set the Parity to None.

Set the Stop bits at 1.

Set Flow control to Xon/Xoff.

b. Click “OK”. This creates an icon with the file name entered in Step 4 and places it in the HyperTerminal folder. Future communication sessions can then be started by clicking the appropriate icon.

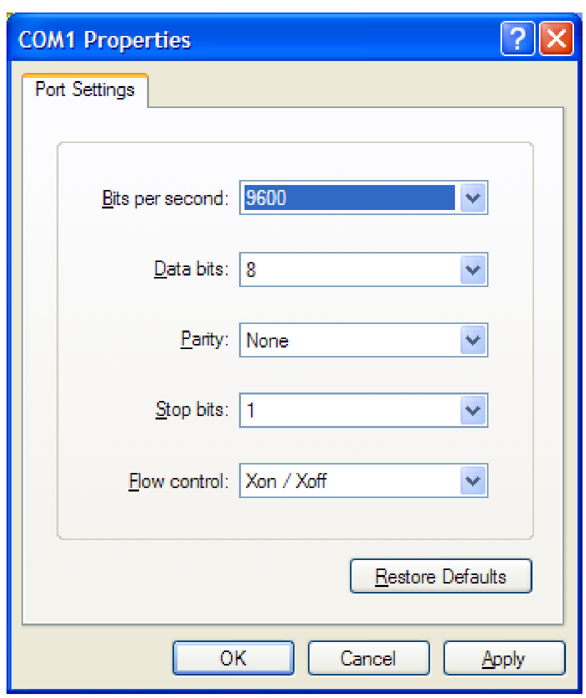

Figure C-3. COM Properties Dialog Box

Step 7: Click File/Properties on the menu bar. Click the Settings tab.

a. Make the following selections using Figure C-4 as a guide:
Check the Terminal Keys radio button.
Select VT-100 emulation.
Set Backscroll buffer lines to the maximum setting of 500.

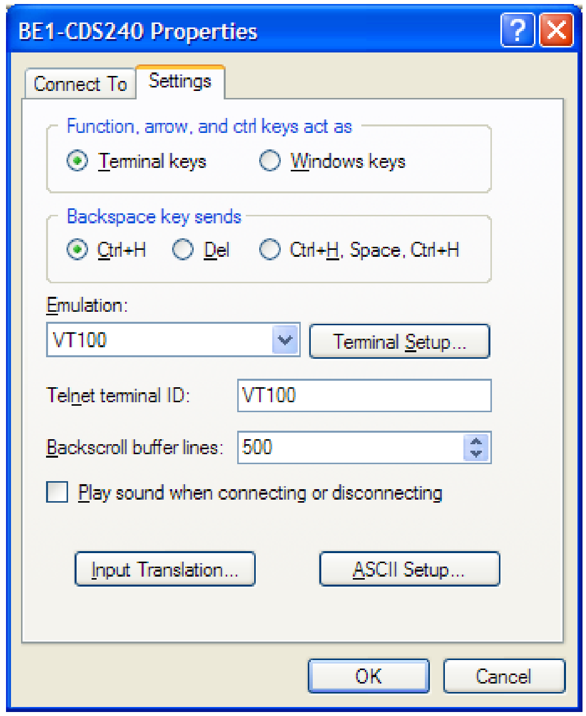

Figure C-4. Properties, Settings Tab

b. Click the ASCII Setup button. Make the following selections using Figure C-5 as a guide:

ASCII Sending

Place a check at Send line ends…

Place a check at Echo typed characters…

Select a Line delay setting of 100 to 200 milliseconds.

Set the Character delay setting to 0 milliseconds.

ASCII Receiving

Disable Append line feeds…by leaving the box unchecked.

Disable Force incoming… by leaving the box unchecked.

Place a check at Wrap lines…

c. Click “OK”.

d. Click “OK”.

Step 8: Click File and click Save.

NOTE
Settings changes do not become active until the settings are saved.

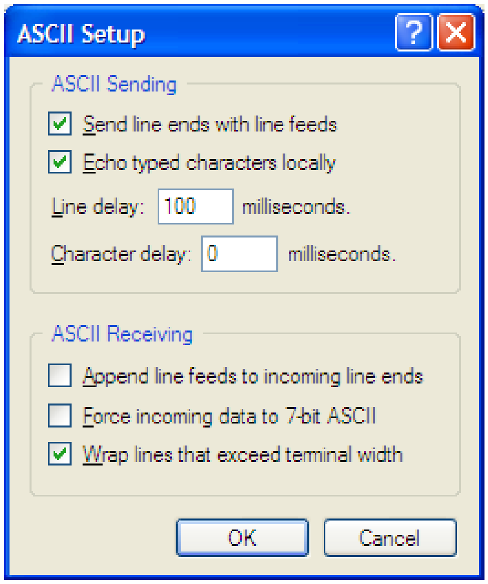

Figure C-5. ASCII Setup Dialog Box

Step 9: HyperTerminal is now ready to communicate with the relay. Table C-1 describes the required connection for each RS-232 port.

Table C-1. RS-232 Communication Ports

Connection	Type
Front Port	9-pin female DCE
PC to Front RS-232 port cable	Straight
Rear Port	9-pin female DCE
PC to Rear RS-232 port cable	Straight

APPENDIX D • SETTINGS CALCULATIONS

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APPENDIX D • SETTINGS CALCULATIONS

General

These settings calculations are provided to assist in developing the required settings for the BE1-CDS240, Current Differential System. To develop these settings, the paragraphs in this section discuss the following tasks:

- Verify CT Performance
- Determine Tap Settings
- Calculate Minimum Pickup Restraint Setting
- Select Unrestrained Pickup Setting
- Calculate Slope
- Select Harmonic Restraint Settings

For additional information on selected examples, see the associated *Setting Notes*.

Example 1 - Three Winding Transformer

Verify CT Performance

Refer to Figure D-1 and Table D-1 for the application parameters used in this example.

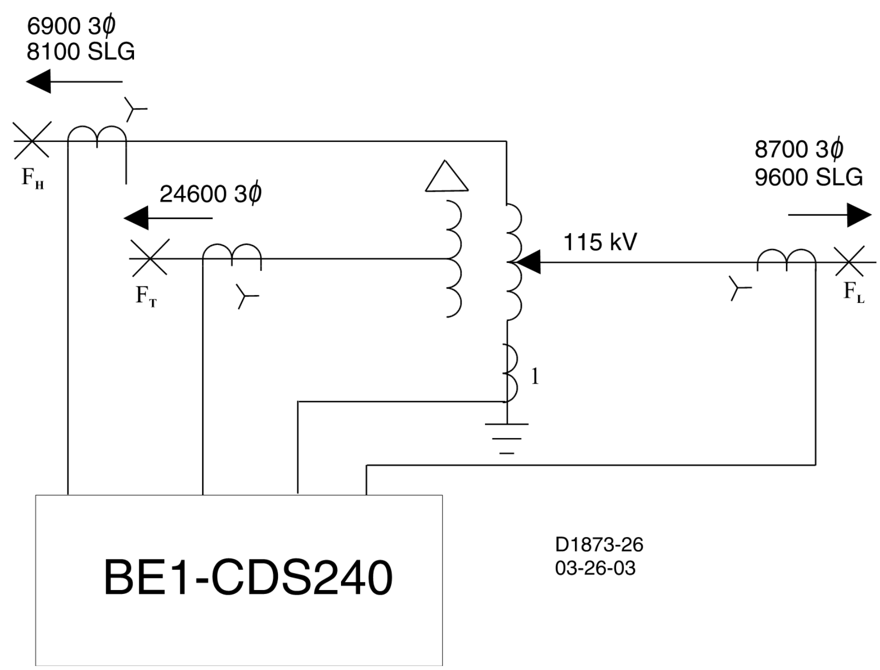


Figure D-1. Auto Transformer with Tertiary Winding, Relay Setting Calculation Example

Table D-1. Example 1 Specifications

SPECIFICATIONS	HIGH SIDE	LOW SIDE	TERTIARY
Nominal voltage and taps	230 kV ±2.5%, 5%	115 kV ±10%, auto, line end connection	13.8 kV ±2.5%, 5%
MVA 3 stage cooling @ 55°C & overload to 65°C	150/200/250/280	150/200/250/280	35/47/58/65
Transformer connection	Wye-Auto	Wye-Auto	Delta
Impedance (150 MVA base)	H-L: 5.5%; H-T: 30% L-T: 25%		
Full Load Current (FLC)	150 MVA: 377A 280 MVA: 703A	150 MVA: 753A 280 MVA: 1406A	35 MVA: 1464 A 65 MVA: 2719 A (280 MVA: 11714 A)
CT connection	Wye	Wye	Wye
Relay Input #	1	2	3
CT ratio, max	800:5	2000:5	5000:5
CT ratio, tap	800:5	1500:5	4000:5
CT secondary @ max primary MVA	4.39A (280 MVA)	4.69 A (280 MVA)	3.40 A (65 MVA) (14.64 A @ 280 MVA)
CT thermal rating factor (max continuous current)	2.0 (10 A)	2.0 (10 A)	1.5 (7.5 A)
CT accuracy class at full ratio	C400	C400	C400
CT resistance at full winding	0.47 Ω	0.76 Ω	1.5 Ω
CT Resistance at Tap	0.47 Ω	0.57 Ω	1.2 Ω
One way CT to relay lead resistance	0.3 Ω	0.3 Ω	0.3 Ω
Through fault current	3-phase: 6,900 A SLG: 8,100 A	3-phase: 8,900 SLG: 9,800	3-phase: 24,600 SLG: 0

To prevent a misoperation of a relay during an external fault, the CTs must be sized to reproduce the appropriate level of secondary AC voltage that the CT will see during the external fault with some level of safety margin to account for the effects of DC offset. The usual approach to checking CT performance is to check only the performance of the CT closest to the external fault, and then perform the check on faults on all sides of the transformer. A more complete approach would be to check what every CT sees for every fault. This can be a detailed task and some fault analysis programs are not well suited to providing fault data in the branches remote from the fault. The example calculations below do not perform this more involved approach.

Another aspect of CT performance is how well it will reproduce current during an internal fault. If a CT will adequately perform during an external fault, it is typically assumed that it will adequately perform during an internal fault. One reason is that internal faults of a level that will cause CT saturation will also tend to cause high levels of tripping current and, hence, fast tripping. Even if the CT saturates during an internal fault due to DC offset, the DC is transient in nature and the effect will be to only delay tripping a few cycles. Hence, the CT does not have to have the same level of safety margin as it does for external faults. One means of checking CT performance during an internal fault is to verify it will adequately reproduce the AC component of current during transformer inrush, typically assumed to be about ten times rated current.

The test of CT performance addressed below is to determine the "Saturation Factor (SF)" that will be seen by the CT closest to an external fault. The saturation factor is a measure of the AC voltage the CT will see during an event divided by the CT's secondary AC voltage rating (one common measure of AC voltage rating is the CT's C-class rating). See *Setting Note 3* for an involved discussion of SF. To obtain good CT performance during external faults, an SF of less than 0.5 is preferred but due to DC offset issues. Even lower SF ratings are desirable. For a CT to reproduce DC offset it needs to be highly overrated when analyzed on an AC current and AC voltage basis. The preferred SF to aim for, though likely not normally obtainable, is the inverse of the X/R ratio for the through fault. For example, if the X/R impedance ratio for the through fault is 10, an SF as near to 1/10 as possible is preferred. An analysis of the effects of DC offset on CTs may be found in the paper on bus protection on the Basler Electric web site (www.basler.com), "*Bus Protective Relaying, Methods and Application*."

> **NOTE**
>
> This procedure calculates the "Saturation Factor" as:
>
> *SF = (I * R) (/ (ANSI C-Class voltage rating) where R includes CT resistance.*
>
> See Setting Note 3 for additional information on other definitions of Saturation Factor.

Step 1. Determine the maximum CT secondary fault current for external faults at F_H, F_L, F_T (I_{F3} for three-phase and I_{FG} for single-phase). Refer to Figure D-1 for this example.

HIGH

$$I_{F3} = \frac{6900}{160} = 43.1\text{ A}$$

$$I_{FG} = \frac{8100}{160} = 50.6\text{ A}$$

LOW

$$I_{F3} = \frac{8900}{300} = 29.7\text{ A}$$

$$I_{FG} = \frac{9800}{300} = 32.7\text{ A}$$

TERTIARY

$$I_{F3} = \frac{24600}{800} = 30.8\text{ A}$$

As previously noted, a more complete analysis of CT performance would include examining the current seen by every CT during the external fault. For brevity, this check is not done in these calculations.

Step 2. Determine the worst case CT burden voltage for a three-phase fault (V_{B3}).

- **For wye-connected CTs:**

$$V_{B3} = I_{F3}\ (R_{CT} + R_L + R_R)$$

- **For delta-connected CTs, for three-phase fault:**

$$V_{B3} = 3\ I_{F3}\ (R_{CT} + R_L + R_R)$$

Note that the wye connection produces a lower burden on the CTs (see Setting Note 1).

where:

R_{CT} = CT internal resistance

R_L = one-way lead resistance in ohms (wire from CT to Relay)

R_R = relay resistance in ohms (< 0.05 ohm)

Neglecting R_R, use R_L from Table D-1.

HIGH

$$V_{B3} = 43.1\left(0.47 * 0.3\right) = 33.2\text{ V}$$

LOW

$$V_{B3} = 29.7\left(0.57 * 0.3\right) = 25.8\text{ V}$$

TERTIARY

$$V_{B3} = 30.8\left(1.2 * 0.3\right) = 46.2\text{ V}$$

Step 3. Determine the worst-case burden voltage for a line-to-ground fault (V_{BG}).

- **For wye-connected CTs:**

$$V_{BG} = I_{FG}\ (R_{CT} + 2R_L + R_R)$$

- **For delta-connected CTs:**

V_{BG} is a function of the proportion of positive-sequence to zero-sequence currents, but may be approximated by the same equation as for wye connected CTs (for worst case).

Neglecting R_R, use R_L from Figure D-1:

HIGH	LOW
$V_{BG} = 50.6\,(0.47 * 0.6)$	$V_{BG} = 29.7\,(0.57 * 0.6)$
$= 54.1\,V$	$= 37.7\,V$

> **NOTE**
>
> Since a phase-to-ground fault looks like a phase-to-phase fault on the delta side of a delta/wye transformer, each CT has to carry only one times the one way lead burden.

Step 4. Determine the effective CT accuracy class (V_{CE}):

$$V_{CE} = \frac{(\text{Base Accuracy})(CTR_{USED})}{CTR_{MAX}} \qquad = V_{C-CLASS}\left(\frac{N_{TAP}}{N_{MAX}}\right)$$

Step 5. Determine the saturation factor (SF):

VB is the largest of the burden voltages calculated in Steps 2 and 3.

HIGH	LOW	TERTIARY
$SF = \frac{54.1}{400}$	$SF = \frac{34.7}{300}$	$SF = \frac{64.2}{320}$
$= 0.135$	$= 0.116$	$= 0.144$

$$SF = \frac{V_B}{V_{CE}}$$

HIGH	LOW	TERTIARY
$SF = \frac{54.1}{400}$	$SF = \frac{34.7}{300}$	$SF = \frac{64.2}{320}$
$= 0.135$	$= 0.116$	$= 0.144$

> **NOTE**
>
> Maximum Recommended $SF = 0.5$. Larger saturation factors will make the relay insecure for external faults, especially during high DC offset conditions. Possible solutions are to increase the CT quality, adjust the CT tap connections to increase effective accuracy class and lower CT currents or to use internal phase compensation instead of delta connecting CTs.

Determine Tap Settings

Calculate Ideal Taps

Step 1. Use the following three equations to calculate ideal taps. Parameters for these equations are in Table D-2.

$$TAP1 = \frac{MVA * 1000 * COMP1}{\sqrt{3} * KV1 * CTR1} \quad TAP2 = \frac{MVA * 1000 * COMP2}{\sqrt{3} * KV2 * CTR2} \quad TAP3 = \frac{MVA * 1000 * COMP3}{\sqrt{3} * KV3 * CTR3}$$

Table D-2. Parameters for the First Two Equations

Parameter	Description	Explanation
MVA	MVA Base	Full load *MVA* or top rating of the protected equipment (see Note below)
KVn	KV Base for CT input *n*	L-L Voltage in KV for each CT input circuit
CTRn	CT Ratio for CT input *n*	Actual ratio, not maximum ratio
COMPn	Phase Compensation Adjustment Factor for CT input *n*	√3 if CT's are connected in Delta (*ctcon* = DAB or DAC). 1 in all other cases.

NOTE: MVA used in Tap Calculation

Typically, the top *MVA* is used for the tap calculations, but actually any *MVA* may be used as long as the same *MVA* is used for every calculation (TAP1, TAP2, and TAP3) even if the *MVA* is much higher or lower than the continuous rating of the winding. The top rating of the main winding is used typically because the tap selection has ramifications on the minimum operate and harmonic blocking features of the relay (recall operate currents and harmonic currents are in terms of "percentage of tap"). One normally tries for a tap setting for the main windings that is in the 3-5 range, but taps well outside this range are frequently done. For the same input current, higher taps will yield a less sensitive relay because the same current level will be a lower percentage of tap.

NOTE: Reduced MVA Winding CT Ratios and Tap Settings

When one winding has a greatly reduced *MVA* rating compared to other windings, the calculation for the tap setting on the low rated winding will result in a very high tap setting and sometimes it will be necessary to set the CT ratio for the reduced *MVA* winding relatively high (resulting in a relatively low secondary current during normal operation) in order to accommodate the maximum tap ratio of the relay.

NOTE

Though CT ratios might end up being affected by the outcome of the tap calculations, recall that this is primarily a step to select taps. The CT ratios would normally be selected before the taps are selected and the CT ratios are normally set so that normal full load current of the winding results in secondary currents that are below the CT's continuous ratings yet high enough to produce currents that the relay can accurately measure. For 5 A nominal CTs, the secondary current at full load is typically on the order of 3 to 5 A, but though abnormal, in theory could be from 0.5 A to as high as the CT's design will allow. It would be a fairly safe assumption that CTs used in large transformers would have a thermal rating factor (TRF) of 1.33 or better, but CTs are on the market with a wide range of TRF of 1.0 to 4.0 (per IEEE C57.13, TRF of 1.0, 1.5, 2.0, 3.0 and 4.0 are other possible standard values) so one should verify the TRF before setting up a condition where continuous current above of 5 A may exist.

NOTE

When calculating the tap adjust settings for the BE1-87T, the √3 COMPn factor had to be included regardless of whether phase compensation was done by connecting the CTs in delta or by using internal delta compensation. The BE1-CDS240 relay does not magnify the secondary current when performing the phase compensation internally. (For more information, see the *Internal Compensation Chart* under the SG-CT command in Section 3.) The COMP factor is 1 unless the CTs are connected in Delta. The BE1-CDS240 automatically takes the √3 factor into account prior to the tap adjustment when internal phase compensation is applied to a set of CT input currents.

Step 2. Calculate ideal tap values. Since all CTs are wye connected, COMP1, COMP2 and COMP3 are 1 per Table D-2. Ideally, the actual transformer voltage ratings at the in-use tap position are used for the KV Base. However, if the taps in the protected transformer could be changed without the BE1-CDS240 tap adjust factors being reset, it would be safer to use the system nominal values and account for the additional mismatch in the slope setting.

$$TAP1 = \frac{280 * 1000 * 1}{\sqrt{3} * 230 * 160} = 4.39 \quad TAP2 = \frac{280 * 1000 * 1}{\sqrt{3} * 115 * 300} = 4.69 \quad TAP3 = \frac{280 * 1000 * 1}{\sqrt{3} * 13.8 * 800} = 14.6$$

Step 3. If the calculated TAP1, TAP2 and TAP3 are in range (2.00 - 20.0 for 5 ampere sensing input types or 0.40 - 4.00 for 1 ampere sensing input types) proceed to Calculate Minpu. If they are not in range, proceed with Step 4.

Step 4. Calculate spread ratio. Determine the ratio of *TAP1* to *TAP2*, *TAP2* to *TAP3* and *TAP1* to *TAP3*. If greater than 10:1 (or conversely, 1:10), adjust the CT ratios to bring the tap ratios to less than 10 (or greater than 0.1). In transformers with a lower *MVA* rated winding relative to the main winding, this typically will mean raising the CT ratio of the lower rated winding to reduce the CT's normal current under full load conditions to a fairly low level.

Step 5. If tap ratios are less than 10, but one of the taps is beyond the range of 2 to 20, the taps may be adjusted as a whole linearly in a direction that maintains the original tap ratios but brings all taps to within acceptable limits. For instance, if *TAP3* had been calculated to some value above 20, then reset *TAP3* to 20 and reset *TAP1* and *TAP2* to a lower value using the equation:

$$NewTAP1 = Old\,TAP1 * \left(\frac{20}{Old\,TAP3}\right)$$

$$NewTAP2 = Old\,TAP2 * \left(\frac{20}{Old\,TAP3}\right)$$

Calculate Minpu

The minimum pickup restraint setting (minpu) adjusts the sensitivity of the relay. In non-numerical relays (e.g., Basler Electric BE1-87T), the minpu was fixed at a typical value of 0.35 of the relay tap. In the BE1-CDS240 relay, the user can choose lower or higher values to optimize the protection in each particular application. Selecting a lower minpu setting will tend to raise the slope setting needed to maintain a given margin at the knee-point of the differential tripping characteristic. (For more information, see the *Calculate Slope* later in this section.) Conversely, it is sometimes necessary to accommodate unmonitored loads in the differential zone. In that case, the minpu setting may be higher. A setting of **0.25** per unit of *transformer full load (FA) rating* (i,e., top MVA) is recommended for typical installations where no unmonitored load needs to be considered. This value is well above the magnetizing current and provides a safe margin at the knee point of the slope characteristic. If unmonitored loads such as station service or small capacitor banks are connected in the differential zone, the minpu must be increased by the magnitude of the unmonitored current in multiples of tap.

> **NOTE**
>
> Unmonitored capacitor banks should be avoided if possible or they must be treated very carefully to avoid false tripping due to inrush currents.

Step 1. Calculate desired minimum pickup setting in times tap. Choose the desired minimum pickup in per unit on the transformer full load base (i.e., 0.25). Multiply this times the factor X calculated using the following equation. If the ideal tap ($TAPn_I$) is equal to the actual tap ($TAPn_A$), the factor will be 1. For this example, this is the case, so the minimum pickup of 0.25 per unit will equal a minimum pickup of 0.25 times tap.

$$X = \frac{TAPn_I}{TAPn_A} = \frac{MVA * 1000 * COMPn}{TAPn_A * \sqrt{3} * KVn * CTRn}$$

Step 2. Calculate the unmonitored load in times tap. Use the following equation:

$$Iunmon = \frac{Iunmon\ pri * COMPn}{TAPn * CTRn}$$

$$Iunmon = 0$$

Step 3. Calculate the Minpu setting. Add the two to get the minpu setting.

$$Minpu = 0.25 * 1 + 0$$
$$= 0.25$$

Step 4. Convert pickup setting to primary amperes.

As a reality check, convert the minimum sensitivity to high side and low side primary amperes. The pickup settings in times tap can be related to primary amperes by this equation:

$$Ipri = \frac{Minpu * TAPn * CTRn}{COMPn}$$

$$Ipri = \frac{0.25 * 4.39 * 160}{1} = 176A \text{ @ 230 kV}$$

$$Ipri = \frac{0.25 * 4.69 * 300}{1} = 252A \text{ @ 115 kV}$$

$$Ipri = \frac{0.25 * 14.6 * 800}{1} = 2930A \text{ @ 3.8 kV}$$

Choose Unrestrained Pickup Setting

This two-step process selects the unrestraint element setting to provide security for both inrush and external fault conditions.

Step 1. Calculate the expected inrush current based upon the self-cooled rating of the transformer.

Asymmetrical CT saturation during a heavy internal fault generates 2nd harmonics that can inhibit the sensitive percentage restrained unit until the CT recovers. The unrestrained unit provides fast clearing for these internal faults. Thus, the unrestrained unit should be set as sensitively as possible without operating on inrush.

Typical numbers used in the industry for inrush have been eight to twelve times the self-cooled (bottom) MVA rating of the transformer. Due to the operating characteristics of the BE1-CDS240 unrestrained differential element, a setting of six times the self-cooled rating provides security for inrush. We can use a lower URO pickup setting and maintain security for unrestrained tripping because inrush current typically has a high peak that is non-sinusoidal. The relay extracts the fundamental component of the operate current for use by the unrestrained element to greatly reduce its sensitivity to this non-sinusoidal inrush current. In addition, the high initial peak generally decays quickly to a lower value. The slight inverseness of the unrestraint tripping characteristic (refer to Section 1, *General Information*) provides additional security from unrestrained tripping on inrush with a sensitive setting.

Since the ***tap values are based upon the forced cooled rating*** and adjusted if necessary by the factor X calculated in *Calculate Minpu,* Step 1, the pickup can be calculated:

$$URO = 6 * X * \frac{MVA \text{ self cooled}}{MVA \text{ forced cooled}} \qquad URO = 6 * 1 * \frac{150}{280} = 3.2$$

$$URO = 3.6$$

This URO value (3.2 is rounded up to 4.0; rounding down should not be done in this application) is the minimum setting to avoid tripping during inrush. The next step will determine the value required to avoid tripping for the maximum external fault under worst case CT saturation.

Check Maximum External Fault Saturation Effects

Step 1. Calculate the maximum external fault (IE) in multiples of tap. Use these two equations:

For wye connected CT's

$$IE = \frac{Maximum Fault}{Tap}$$

For delta connected CT's (See Setting Note 2)

$$IE = \frac{Maximum \text{ Fault } 3phase * \sqrt{3}}{Tap}$$

HIGH

$$IE = \frac{\left(\frac{16900}{160}\right)}{4.39} = 9.8$$

LOW

$$IE = \frac{\left(\frac{8900}{300}\right)}{4.69} = 6.3$$

TERTIARY

$$IE = \frac{\left(\frac{24600}{800}\right)}{14.64} = 2.1$$

Step 2. The transient monitor function provides security from tripping for external through faults by doubling the unrestrained unit pickup setting when saturation is detected. Calculate the unrestrained pickup such that **2 times the unrestrained pickup is greater than 70% of the maximum external through fault** in times tap. This calculation assumes that the CTs carrying the maximum fault saturate severely, yielding only 30% of the expected ratio current. This leaves 70% of the fault current as false differential current.

$$\text{URO} = \frac{0.7 * 9.8}{2} = 3.43 \quad \text{URO} = \frac{0.7 * 6.3}{2} = 2.21 \quad \text{URO} = \frac{0.7 * 2.1}{2} = 0.74$$

As previously noted when examining the CT performance and Saturation Factor SF, a more complete analysis of the unrestrained pickup setting would include applying these calculations to every CT that sees current during the external fault. For brevity, this check is not done in these calculations.

Step 3. Select the unrestrained pickup setting. Choose the larger of the unrestrained pickup values calculated in the above equations on this page and round it up to the next integer value. This results in a setting of **URO = 4 times tap** for this example.

Step 4. Convert pickup setting to primary amperes.

As a reality check, convert the unrestrained pickup sensitivity to high side and low side primary amperes. The equation to do so is similar to the last equation on page D-7. Ignore energization from the tertiary as it will never be done in actual practice.

$$\text{Ipri} = \frac{4 * 4.39 * 160}{1} = 2{,}810\text{A} \ @ \ 230 \text{ kV} \qquad \text{Ipri} = \frac{4 * 5.69 * 300}{1} = 5{,}628\text{A} \ @ \ 115 \text{ kV}$$

Calculate Slope

The percentage restrained tripping characteristic is defined by the slope ratio. The slope setting S is the ratio of the differential current (Iop) versus the restraint current ($Irestraint$) that will cause a trip. The percentage differential characteristic can operate on a slope setting that is a percent of the maximum of the through currents or a percent of the average of the through currents.

Step 1. Calculate the Operating Slope S_i.

The operating slope S_i is the ratio of the differential current (Iop) caused by the sum of all the mismatch sources versus the through current. The following sources of Iop current must be taken into account:

- No load tap changer (this can be compensated for in the tap calculation). You may choose to include this source of mismatch if it is possible that the no load taps may be adjusted without the relay taps being reset.
- Load tap changer.
- Relay tap mismatch (assumed to negligible due to the fine tap adjustment available in the relay).
- Quality of the CTs (If the saturation factor calculated previously is greater than 0.5, additional margin is recommended. For SF <0.5, we assume that the CTs perform within the 10% limit defined in the ANSI Accuracy Class on a steady state basis but this does not assure transient DC offset induced saturation will not occur. When accounting for CT error, the total CT error should be 10% * (n-1) where n is the number of restraint current inputs (2/3/4 for two/three/four restraint relay). If more than one CT is nearing the performance limit, the errors tend to cancel.
- Relay measuring errors. 4% is the worst case (assume 2% high (or low) on incoming side circuits and 2% low (or high) on outgoing side circuits).

The following errors are not included in the S_i operating slope value. (These sources of mismatch do not vary with through current so they affect the minpu setting only.)

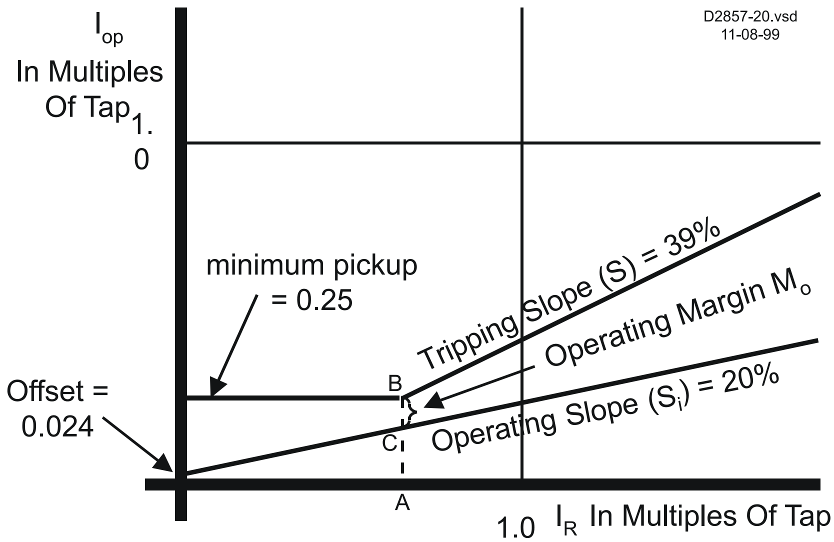
- Transformer excitation current IE (assumed to be less than 4% of the self-cooled rating). This mismatch does not vary with through current (load) so it tends to not add to the slope mismatch line. It will offset the slope characteristic from the origin in the operate direction on the operate versus restraint characteristic (see Figure D-2).

- Unmonitored loads "*Iunmon*" such as station service or small capacitor banks in the differential zone add to the constant excitation current.

When the saturation factor (*SF*) exceeds 0.5 on any of the CTs, slow clearing transient CT saturation is likely. For this condition, the BE1-CDS240 improves security by delaying restrained tripping by two cycles when the transient monitor function detects operate (differential) current that is a result of CT saturation. For applications where the saturation factor is greater than 0.5, additional slope margin is recommended. For applications where the saturation factor exceeds 1.0, severe distortion is likely at high fault current and the **maximum slope setting (60%)** is recommended. For more information, see Setting Note 4.

In the example, the tap factors were calculated on system nominal ratings so the no load tap changer position is included as a source of mismatch.

$$S_i = (5\%\ NLTC) + (10\%\ LTC) + (10\%\ CT) + (4\%\ Relay) = 29\%$$



$$M_o = AB - AC$$

$$M_o = minpu - \left(\frac{S_i minpu}{S} + I_{OFFSET} \right)$$

$$M_o = minpu\left(1 - \frac{S_i}{S} \right) - I_{OFFSET}$$

Figure D-2. Slope and Operating Margin

Step 2. Choose slope setting S. The tripping slope S must be greater than S_i to provide a safety margin at the differential tripping characteristic knee point (intersection of the minimum pickup tripping characteristic and the slope tripping characteristic). This safety margin is required to accommodate the additional mismatch caused by the excitation current and the unmonitored load current. Refer to Figure D-2. A **slope margin of 10%** is recommended.

$$S = S_i + Slope\ Margin \qquad S = 29\% + 10\% = 39\%$$

Step 3. Calculate Offset Current I_{OFFSET}. The margin at the knee point of the tripping characteristic is illustrated in Figure D-2. The additional mismatch caused by excitation current and unmonitored loads does not vary with through current loading so it tends to offset the operating slope S_i upward from the origin. Thus, it decreases the safety margin at the differential tripping characteristic knee point (intersection of the minimum pickup tripping characteristic and the slope tripping characteristic). The offset current is calculated as:

$$I_{Offset} = I_{Exc} + I_{unmon}$$

Assume for the example that excitation current is 4% of full load current on the self-cooled basis. Converting over to percent on the same MVA basis that the tap setting was chosen and including the previously discussed X factor:

$$IE = IE\ self\ cooled * X * \frac{MVA\ self\ cooled}{MVA\ forced\ cooled} \qquad IE = 0.04 * 1 * \frac{12}{20} = 0.024$$

where:

X is the tap conversion factor defined in *Calculate Minpu,* Step 1 (equation, page D-7).
I_{unmon} is the unmonitored load calculated in *Calculate Minpu,* Step 2 (equation, page D-7.

Step 4. Calculate Operating Margin M_o. The Operating Margin M_O is given by:

$$M_o = Minpu \left(1 - \frac{S_i}{S}\right) - I_{OFFSET}$$

The conservative calculation of margin at the knee point uses S_i as calculated in *Calculate Slope*, Step 1.

For this example, M_O in times tap is:

$$M_o = 0.25 * \left(1 - \frac{29}{39}\right) - 0.024 = 0.040\ \text{times tap}$$

The above calculation of margin is conservative. For the low current level where the margin at the tripping characteristic knee point is of interest, the CT error will typically be less than 1%. Thus, calculating the margin using S_i = 20 (replace 10% CT error with 1% CT error in Equation) yields the following result in this equation:

$$M_o = 0.25 * \left(1 - \frac{20}{39}\right) - 0.024 = 0.098\ \text{times tap}$$

If the conservative calculation yielded a margin < or = 0.01, the *minpu* and/or the slope settings should be increased.

Step 5. As a reality check, convert the margin to high side and low side primary amperes. The equation to do so is similar to shown in Step 4 (page D-7).

$$Ipri = \frac{0.098 * 4.39 * 160}{1} = 69A \text{ @ 230 kV} \qquad Ipri = \frac{0.098 * 4.69 * 300}{1} = 138A \text{ @ 115 kV}$$

Harmonic Restraint Settings

The recommended harmonic restraint settings have been in effect successfully for many years. Most applications should use these settings. When second harmonic sharing is enabled, restraint for the A phase differential element is determined by:

$$100 * \left(\frac{|IA_{op2nd}| + |IB_{op2nd}| + |IC_{op2nd}|}{|IA_{op1st}|}\right) \geq 2^{nd}\ \text{Restraint Setting}$$

The B phase and C phase differential elements respond similarly with IB_{op1st} and IC_{op1st} substituted in the respective equation. This unique method of second harmonic sharing is recommended to ensure proper restraint on all phases without blocking tripping on faulted phases.

For special transformers cases, contact the transformer manufacturer or the Basler Electric, Technical Services Department.

Step 1. If second harmonic sharing is enabled, set the second harmonic restraint unit setting at 18%. If second harmonic sharing is disabled, set the second harmonic restraint unit at 12%.

Step 2. Set the fifth harmonic restraint unit setting.

5^{th} = 35%

Example Two - Two Winding Transformer

Verify CT Performance

Refer to Figure D-3 and Table D-3 for the application parameters used in this example.

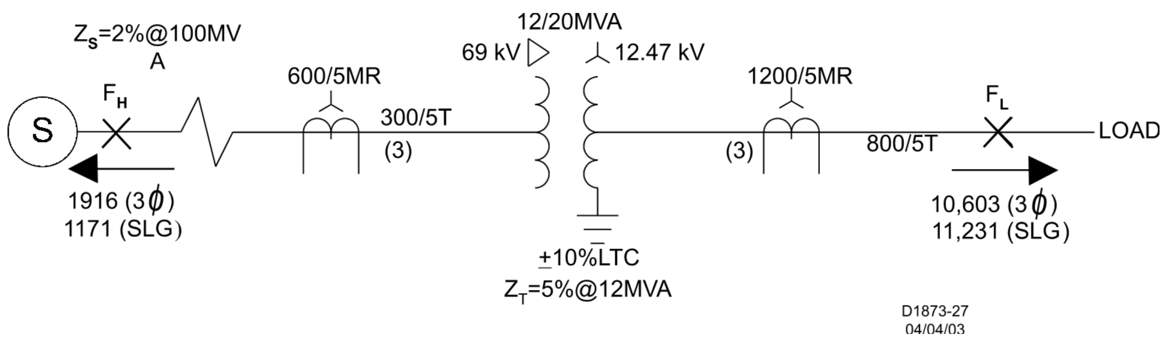


Figure D-3. Two Winding Transformer Relay Setting Calculation Example

Table D-3. Example 2 Specifications

SPECIFICATIONS	**HIGH SIDE**	**LOW SIDE**
Nominal Voltage	69 kV	12.47 kV
Taps	70.725 kV ±2.5%, 5%	12.47 Kv ±10% Auto
MVA, SC, FA	12/20	12/20
XFMR connection ∗	Delta	Wye
CT connection	Wye	Wye
CT ratio	600:5	1200:5
CT tap	300:5	800:5
CT accuracy class	400	800
One-way lead burden (ohms) †	0.7	0.7
Input #	1	2
Fault current (three-phase)	1,916	10,603
Fault current (single-phase)	1,171	11,231

∗ Standard connection: High voltage leads the low voltage by 30°.

† LT resistance at tap and lead resistance (RL + RCT).

NOTE

Unmonitored capacitor banks should be avoided if possible or they must be treated very carefully to avoid false tripping due to inrush currents.

Step 1. Determine the maximum CT secondary fault current for external faults at F (I_{F3} for 3-phase, and I_{FG} for single-phase). Refer to Figure D-10 for this example.

HIGH	LOW
$I_{F3} = \frac{1916}{60} = 32\ A$	$I_{FG} = \frac{1171}{60} = 19.5\ A$
$I_{FG} = \frac{1171}{60} = 19.5\ A$	$I_{FG} = \frac{11231}{160} = 70\ A$

A more complete analysis of CT performance would include examining the current seen by every CT during the external fault. For brevity, this check is not done in these calculations.

Step 2. Determine the worst case CT burden voltage for a 3-phase fault (V_{B3}).

- **For wye-connected CTs:**

$$V_{B3} = I_{F3}\,(R_{CT} + R_L + R_R)$$

- **For delta-connected CTs, for three-phase fault:**

$$V_{B3} = 3\,I_{F3}\,(R_{CT} + R_L + R_R)$$

Note that the wye connection produces a lower burden on the CTs (see Setting Note 1).

where:

I_{F3} = determined in Step 1

R_L = one-way lead resistance in ohms including CT resistance

R_R = relay resistance in ohms (< 0.05 ohm)

R_{CT} = CT internal resistance

Neglecting R_R, use R from Table D-3.

HIGH	LOW
$V_{B3} = 32 * 0.7 = 22.4\ V$	$V_{B3} = 32 * 0.7 = 22.4\ V$

Step 3. Determine the worst-case burden voltage for a line-to-ground fault (V_{BG}).

- **For wye-connected CTs:**

$$V_{BG} = I_{FG}\,(2R_L + R_R)$$

where:

I_{FG} is determined in Step 1

- **For delta-connected CTs:**

V_{BG} is a function of the proportion of positive-sequence to zero-sequence currents but may be approximated by the same equation (for worst case).

Neglecting R_R, use R_L from Figure D-3:

HIGH ∗

$$V_{BG} = 19.5 * 0.7$$
$$= 13.6\ V$$

LOW

$$V_{BG} = 70 * 2 * 0.7$$
$$= 98.0\ V$$

> **NOTE**
>
> Since a phase-to-ground fault looks like a phase-to-phase fault on the delta side of a delta/wye transformer, each CT has to carry only one times the one way lead burden.

Step 4. Determine the effective CT accuracy class (V_{CE}):

$$V_{CE} = \frac{(\text{Base Accurancy})(\text{Number of CT Turns In Use})}{\text{Maximum Ratio}} = V_C\left(\frac{N_A}{N}\right)$$

HIGH

$$V_{CE} = (400)\frac{60}{120}$$
$$= 200$$

LOW

$$V_{CE} = (800)\frac{160}{220}$$
$$= 533.3$$

Step 5. Determine the saturation factor (S_F):

VB is the largest of the burden voltages calculated in Steps 2 and 3.

HIGH

$$S_F = \frac{V_B}{V_{CE}}$$

$$S_F = \frac{22.4}{200}$$
$$= 0.11$$

LOW

$$S_F = \frac{98.0}{533.3}$$
$$= 0.18$$

> **NOTE**
>
> Maximum Recommended S_F = 0.5. Larger saturation factors will make the relay insecure for external faults especially during high DC offset. Possible solutions are to increase the CT quality, adjust the CT tap connections to increase effective accuracy class or to use internal phase compensation instead of delta connecting CTs.

Determine Tap Settings

Calculate Ideal Taps

Step 1. Use the following two equations to calculate ideal taps. Parameters for these equations are in Table D-4. For more information refer to Section 4, Protection And Control Functions, 87 Phase Differential Function, Setting Tap Compensation Settings, 87 Phase Differential Function.

$$TAP1 = \frac{MVA * 1000 * COMP1}{\sqrt{3} * KV1 * CTR1} \qquad TAP2 = \frac{MVA * 1000 * COMP2}{\sqrt{3} * KV2 * CTR2}$$

Table D-4. Parameters for Equations to Calculate Ideal Taps

Parameter	Description	Explanation
MVA	MVA Base	Full load *MVA* or top rating of the protected equipment
KVn	KV Base for CT input *n*	L-L Voltage in KV for each CT input circuit
CTRn	CT Ratio for CT input *n*	Actual ratio not effective ratio
COMPn	Phase Compensation Adjustment Factor for CT input *n*	√3 if CT's are connected in Delta (*ctcon* = DAB or DAC). 1 in all other cases. See Section 3, Table 3-2 and Figure 3-3

NOTE

Please read the following notes found in the Example 1 calculations, *MVA Used in Tap Calculations, CT Ratios* and *Tap Calculations, √3 Factor*.

Step 2. Calculate ideal tap values. Use the top (e.g., FA) MVA rating of the transformer when making the calculations. Since both CTs are wye connected, COMP1 and COMP2 are 1 per Table D-4. If the actual power transformer ratings at the no load tap position are used for the KV Base, the tap adjust factor calculation can completely cancel this source of mismatch. However, if the no load taps in the protected transformer could be changed without the BE1-CDS240 tap adjust factors being reset, it would be safer to use the system nominal values and account for the additional mismatch in the slope setting.

$$TAP1 = \frac{20 * 1000 * 1}{\sqrt{3} * 69 * 60} = 2.79 \qquad TAP2 = \frac{20 * 1000 * 1}{\sqrt{3} * 12.47 * 160} = 5.79$$

Step 3. If the calculated TAP1 and TAP2 are in range, (2.00 - 20.0 for 5 ampere sensing input types or 0.40 - 4.00 for 1 ampere sensing input types) proceed to Calculate Minpu. If they are not in range, proceed with Step 4.

Step 4. Calculate spread ratio. Determine the ratio of *TAP1* to *TAP2*. If greater than 10:1 (or conversely, 1:10), adjust the CT ratios to bring the tap ratios to less than 10 (or greater than 0.1).

Step 5 If tap ratio is less than 10 (and greater than 0.1) but one of the taps is beyond the range of 2 to 20, the taps may be adjusted as a whole linearly in a direction that maintains the original tap ratios but brings all taps to within acceptable limits. For instance, if TAP2 had been calculated to some value above 20, then reset TAP2 to 20 and reset TAP1 to a lower value using the equation:

$$New\,TAP1 = Old\,TAP1\left(\frac{20}{Old\,TAP2}\right)$$

Calculate Minpu

The minimum pickup restraint setting (minpu) adjusts the sensitivity of the relay. In non-numerical relays, the minpu was fixed at a typical value of 0.35 of the relay tap. In the BE1-CDS240 relay, the user can choose lower or higher values to optimize the protection in each particular application. Selecting a lower minpu setting will tend to raise the slope setting to maintain a given margin at the knee-point of the differential tripping characteristic. (For more information, see the *Calculate Slope* later in this section.) Conversely, it is sometimes necessary to accommodate unmonitored loads in the differential zone. In that case, the minpu setting may be higher. A setting of **0.25** per unit of *transformer full load (FA) rating* is recommended for typical installations where no unmonitored load needs to be considered. This value is well above the magnetizing current and provides a safe margin at the knee point of the slope characteristic.

If unmonitored loads such as station service or small capacitor banks are connected in the differential zone, the minpu must be increased by the magnitude of the unmonitored current in multiples of tap.

> **NOTE**
>
> Unmonitored capacitor banks should be avoided if possible. Or, they must be treated very carefully to avoid false tripping due to inrush currents.

Step 1. Calculate desired minimum pickup setting in times tap. Choose the desired minimum pickup in per unit on the transformer full load base (0.25). Multiply this times the factor X calculated using the following equation. If the ideal tap ($TAPn_I$) is equal to the actual tap ($TAPn_A$), the factor will be 1. For this example, this is the case, so the minimum pickup of 0.25 per unit will equal a minimum pickup of 0.25 times tap.

$$X = \frac{TAPn_I}{TAPn_A} = \frac{MVA * 1000 * COMPn}{TAPn_A * \sqrt{3} * KVn * CTRn}$$

Step 2. Calculate the unmonitored load in times tap. Use the following equation:

$$Iunmon = \frac{Iunmon\ pri * COMPn}{TAPn * CTRn}$$

$$Iunmon = 0$$

Step 3. Calculate the Minpu setting. Add the two to get the minpu setting.

Minpu = 0.25 + 0
= 0.25

Step 4. Convert pickup setting to primary amperes.

As a reality check, convert the minimum sensitivity to high side and low side primary amperes. The pickup settings in times tap can be related to primary amperes by this equation:

$$Ipri = \frac{Mpu * TAPn * CTRn}{COMPn} \qquad Ipri = \frac{0.25 * 2.79 * 60}{1} = 41 \text{ amperes @ 69 kV}$$

$$Ipri = \frac{0.25 * 5.79 * 160}{1} = 231 \text{ amperes @ 12.47 kV}$$

Choose Unrestrained Pickup Setting

This two-step process selects the unrestraint element setting to provide security for both inrush and external fault conditions.

Step 1. Calculate the expected inrush current based upon the self-cooled rating of the transformer.

Asymmetrical CT saturation during a heavy internal fault generates 2nd harmonics that can inhibit the sensitive percentage restrained unit until the CT recovers. The unrestrained unit provides fast clearing for these internal faults. Thus, the unrestrained unit should be set as sensitively as possible without operating on inrush.

Typical numbers used in the industry for inrush have been eight to twelve times the rating of the transformer. Due to the operating characteristics of the BE1-CDS240 unrestrained differential element, a setting of six times the self-cooled rating provides security for inrush. We can use a lower URO pickup setting and maintain security for unrestrained tripping because inrush current typically has a high peak that is non-sinusoidal. The relay extracts the fundamental component of the operate current for use by the unrestrained element to greatly reduce its sensitivity to this non-sinusoidal inrush current. In addition, the high initial peak generally decays quickly to a lower value. The slight inverseness of the unrestraint tripping characteristic (refer to Section 1, *General Information)* provides additional security from unrestrained tripping on inrush with a sensitive setting.

Since the **tap values are based upon the forced cooled rating** and adjusted if necessary by the factor X calculated in *Calculate Minpu,* Step 1, equation on the previous page. The pickup can be calculated by the following equation:

$$URO = 6 * X * \frac{\text{MVA self cooled}}{\text{MVA forced cooled}} \qquad URO = 6 * 1 * \frac{12}{20}$$

$$URO = 3.6$$

This URO value (3.6 rounded up to 4.0) is the minimum setting to avoid tripping during inrush. The next step will determine the value required to avoid tripping for the maximum external fault under worst case CT saturation.

Calculate Maximum External Fault

Step 1. Calculate the maximum external fault (IE) in multiples of tap. Use these two equations.

For wye connected CT's

$$IE = \frac{\text{Maximum Fault}}{\text{Tap}}$$

For delta connected CT's (See Setting Note 2)

$$IE = \frac{\text{Maximum Fault 3phase} * \sqrt{3}}{\text{Tap}}$$

69 kV Side

$$IE = \frac{\left(\frac{1916}{60}\right)}{2.79} = 11.5$$

12.47 kV Side

$$IE = \frac{\left(\frac{10603}{160}\right)}{5.79} = 11.4$$

Step 2. The transient monitor function provides security from tripping for external through faults by doubling the unrestrained unit pickup setting when saturation is detected. Calculate the unrestrained pickup such that **2 times the unrestrained pickup is greater than 70% of the maximum external through fault** in times tap. This calculation assumes that the CTs carrying the maximum fault saturate severely, yielding only 30% of the expected ratio current. This leaves 70% of the fault current as false differential current.

$$URO = \frac{0.70 * 11.5}{2} = 4.02 \qquad URO = \frac{0.70 * 11.4}{2} = 3.99$$

Step 3. Select the unrestrained pickup setting. Choose the larger of the unrestrained pickup values calculated in the first equations on this page and above two equations. Round the result up to the next integer value. (In the first URO equation above, because 4.02 is very close to 4.0, do not round up to 5.) This results in a setting of **URO = 4 times tap** for this example.

Step 4. Convert pickup setting to primary amperes.

As a reality check, convert the unrestrained pickup sensitivity to high side and low side primary amperes. The equation to do so is similar to the equation in the middle of page D-16.

$$Ipri = \frac{4 * 2.79 * 60}{1} = 670 \text{ amps @ 69 KV} \qquad Ipri = \frac{4 * 5.79 * 160}{1} = 3{,}706 \text{ amps @ 12.47 KV}$$

Calculate Slope

The percentage restrained tripping characteristic is defined by the slope ratio. The slope setting S is the ratio of the differential current (I_{op}) versus the restraint current ($I_{restraint}$) that will cause a trip. The percentage differential characteristic can operate on a slope setting that is a percent of the maximum of the through currents or a percent of the average of the through currents.

Step 1. Calculate the Operating Slope S_i.

The operating slope S_i is the ratio of the differential current (I_{op}) caused by the sum of all the mismatch sources versus the through current. The following sources of I_{op} current must be taken into account:

- No load tap changer (this can be compensated for in the tap calculation). You may choose to include this source of mismatch if it is possible that the no load taps may be adjusted without the relay taps being reset.
- Load tap changer.
- Tap mismatch (assumed to negligible due to the fine tap adjustment available in the relay).
- Quality of the CTs (If the saturation factor calculated previously is greater than 0.5, additional margin is recommended. For SF<0.5, we assume that the CTs perform within the 10% limit defined in the ANSI Accuracy Class. When accounting for CT error, the total CT error should be 10% * (n-1) where n is the number of restraint current inputs (2 for two restraint relay, 3 for three restraint relay). If more than one CT is nearing the performance limit, the errors tend to cancel.
- Relay measuring errors. 4% applies to the BE1-CDS240 (2% per input circuit).

The following errors are not included in the S_i operating slope value. (These sources of mismatch do not vary with through current so they affect the minpu setting only.)

- Transformer excitation current IE (assumed to be less than 4% of the self-cooled rating). This mismatch does not vary with through current (load) so it tends to not add to the slope mismatch line. It will offset the slope characteristic from the origin in the operate direction on the operate versus restraint characteristic (see Figure D-10).
- Unmonitored loads "$Iunmon$" such as station service or small capacitor banks in the differential zone add to the constant excitation current.

When the saturation factor exceeds 0.5 on any of the CTs, CT saturation is likely. For this condition, the BE1-CDS240 improves security by delaying restrained tripping by two cycles when the transient monitor function detects operate (differential) current that is a result of CT saturation. For applications where the saturation factor is greater than 0.5, additional slope margin is recommended. For applications where the saturation factor exceeds 1.0, severe distortion is likely at high fault current and the **maximum slope setting (60%)** is recommended. For more information, see Setting Note 4.

In the example, the tap factors were calculated on system nominal ratings so the no load tap changer position is included as a source of mismatch.

$$S_I = (5\%\ \text{NLTC}) + (10\%\ \text{LTC}) + (10\%\ \text{CT}) + (4\%\ \text{Relay}) = 29\%$$

$$M_o = AB - AC$$

$$M_o = minpu - \left(\frac{S_i minpu}{S} + I_{OFFSET}\right)$$

$$M_o = minpu\left(1 - \frac{S_i}{S}\right) - I_{OFFSET}$$

Step 2. Choose slope setting S. The tripping slope S must be greater than S_i to provide a safety margin at the differential tripping characteristic knee point (intersection of the minimum pickup tripping characteristic and the slope-tripping characteristic). This safety margin is required to accommodate the additional mismatch caused by the excitation current and the unmonitored load current. Refer to Figure D-2, Slope and Operating Margin. A **slope margin of 10%** is recommended.

$S = S_i + \text{Slope Margin}$ $\qquad\qquad$ $S = 29\% + 10\% = 39\%$

Step 3. Calculate Offset Current I_{OFFSET}. The margin at the knee point of the tripping characteristic is illustrated in Figure D-2. The additional mismatch caused by excitation current and unmonitored loads does not vary with through current loading so it tends to offset the operating slope S_i upward from the origin. Thus, it decreases the safety margin at the differential tripping characteristic knee point (intersection of the minimum pickup tripping characteristic and the slope-tripping characteristic).

$I_{OFFSET} = IE + I_{unmon}$ $I_{OFFSET} = 0.24 + 0 = 0.24$

where:

IE is assumed less than 4% of the self-cooled rating.

$$IE = IE\ \text{self cooled} * X * \frac{\text{MVA self cooled}}{\text{MVA forced cooled}} \qquad IE = 0.04 * 1 * \frac{12}{20} = 0.024$$

where:

X is the tap conversion factor defined in *Calculate Minpu,* Step 1.

I_{unmon} is the unmonitored load calculated in *Calculate Minpu,* Step 2.

Step 4. Calculate Operating Margin M_O. The Operating Margin M_O is given by this equation:

$$M_o = \text{Minpu}\left(1 - \frac{S_i}{S}\right) - I_{OFFSET}$$

The conservative calculation of margin at the knee point uses S_i as calculated in *Calculate Slope*, Step 1. For this example, M_o in times tap is the following equation:

$$M_o = 0.25 * \left(1 - \frac{29}{39}\right) - 0.024 = 0.040 \text{ times tap}$$

The above calculation of margin is conservative. For the low current level where the margin at the tripping characteristic knee point is of interest, the CT error will typically be less than 1%. Thus, calculating the margin using S_I = 20 (replace 10% CT error with 1% CT error) yields the following result in this equation:

$$M_o = 0.25 * \left(1 - \frac{20}{39}\right) - 0.024 = 0.098 \text{ times tap}$$

If the conservative calculation yielded a margin less than or equal to 0, the minpu and/or the slope settings should be increased.

Step 5. Convert the margin to primary amperes. As a reality check, convert the margin to high side and low side primary amperes. The equation to do so is similar to the equation in the middle of page D-16.

$$\text{Ipri} = \frac{0.098 * 2.79 * 60}{1} = 16.4 \text{ amps @ 69 kV} \qquad \text{Ipri} = \frac{0.098 * 5.79 * 160}{1} = 90.8 \text{ amps @ 12.47 kV}$$

Harmonic Restraint Settings

The recommended harmonic restraint settings have been in effect successfully for many years. Most applications should use these settings. When second harmonic sharing is enabled, restraint for the A phase differential element is determined by:

$$100 * \left(\frac{|IA_{op2nd}| + |IB_{op2nd}| + |IC_{op2nd}|}{|IA_{op1st}|}\right) \geq 2^{nd} \text{ Restraint Setting}$$

The B phase and C phase differential elements respond similarly with IB_{op1st} and IC_{op1st} substituted in the respective equation. This unique method of second harmonic sharing is recommended to ensure proper restraint on all phases without blocking tripping on faulted phases.

For special transformers cases, contact the transformer manufacturer or the Basler Electric, Technical Services Department.

Step 1. If second harmonic sharing is enabled, set the second harmonic restraint unit setting at 18%. If second harmonic sharing is disabled, set the second harmonic restraint unit at 12%.

Step 2. Set the fifth harmonic restraint unit setting.

5^{th} = 35%

Example 3 - Dual Breakers

If a two winding transformer has two high side (or low side) breakers brought into two independent inputs on the relay, calculate the differential settings as if breaker two in the figure below was open (see Example 2). Then set the relay with identical settings for input 1 and input 2.

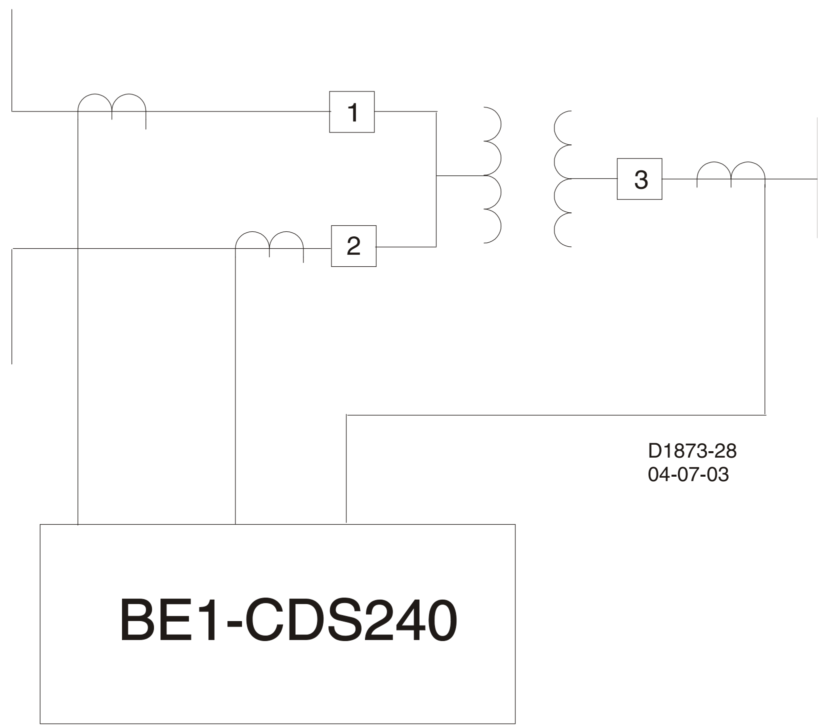
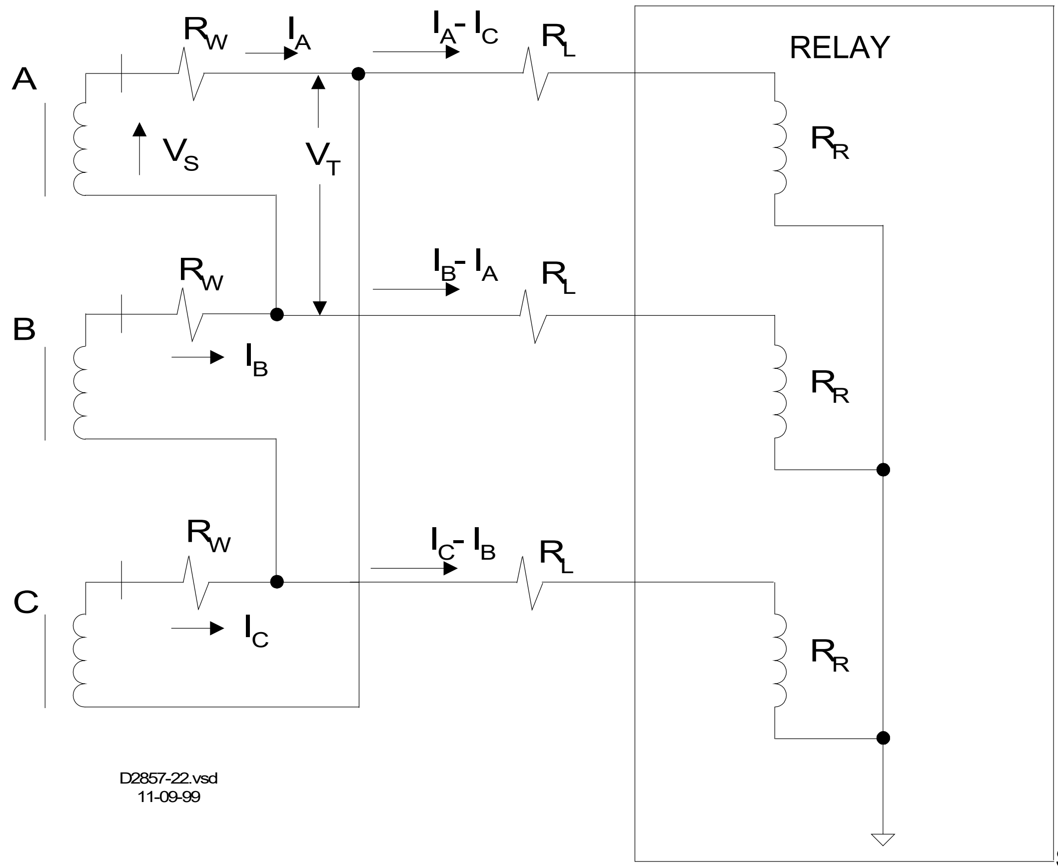


Figure D-4. Dual Breakers



Setting Note 1. CT Burden, Delta Connected CTs, 3-Phase Fault

Figure D-5. CT Burden, Delta Connected CTs, 3-Phase Fault

$I_A+I_B+I_C=0$
$I_A=-(I_B+I_C)$

$V_S=I_AR_W+(I_A-I_C)(R_L+R_R)-(I_B-I_A)(R_L+R_R)$
$=I_A(R_W+R_L+R_R+R_L+R_R)-I_B(R_L+R_R)-I_C(R_L+R_R)$
$=I_A(R_W+2R_L+2R_R)-(I_B+I_C)(R_L+R_R)$

Since: $I_A=-(I_B+I_C)$
$V_S=IA(R_W+3R_L+3R_R)$
$V_T=V_S -R_W I_A$
$V_T=3I_A(R_L+R_R)$

Where:
I_A = 3-phase fault current
R_R = Relay burden
R_L = Lead burden
R_W = Winding burden

Setting Note 2. Phase-To-Phase Fault, Delta Connected CTs

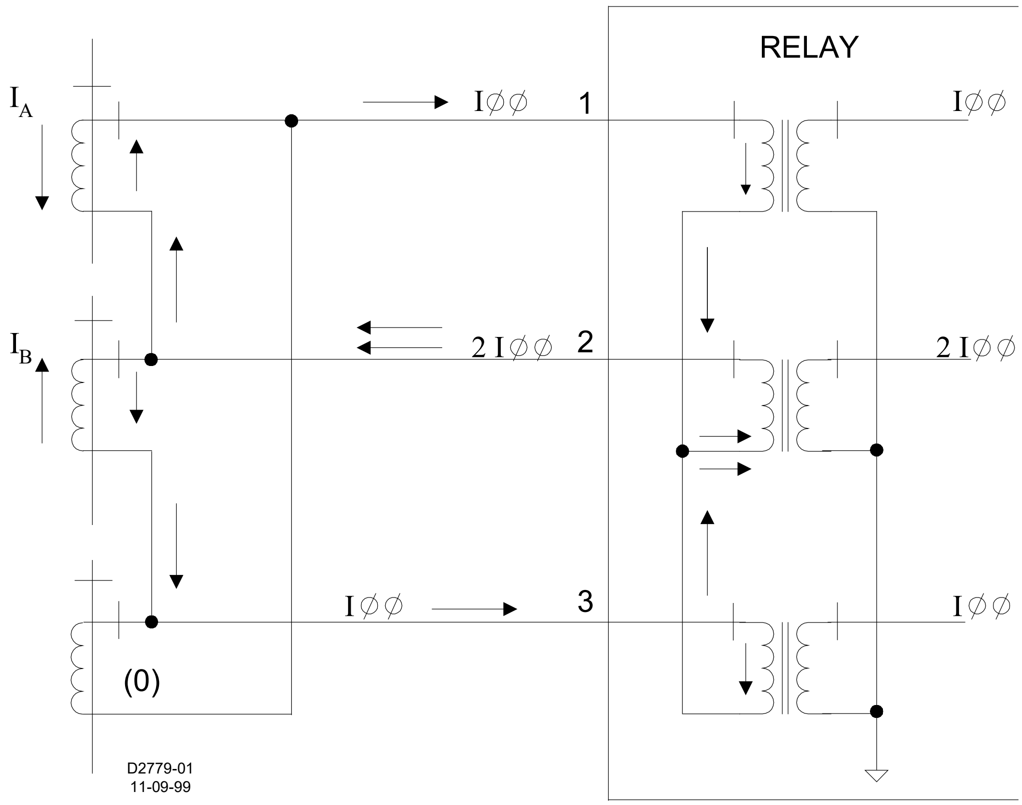


Figure D-6. Phase-To-Phase Fault, Delta Connected CTs

Assuming $Z_1=Z_2$, $I\phi\phi = \frac{\sqrt{3}}{2} \times I_{3\phi}$

Phase 2 carries twice the fault current returning from the relay to the CTs. Therefore, the maximum current is:

$$
\begin{aligned}
I_{MAX} &= 2 \times I\phi\phi \\
&= 2 \times \left(\frac{\sqrt{3}}{2} I_{3\phi}\right) \\
I_{MAX} &= \sqrt{3} \times I_{3\phi}
\end{aligned}
$$

Setting Note 3. CT Performance Evaluation: Saturation Factor

The secondary current delivered by a current transformer to a relay circuit is always less than the current available from an ideal $CTI_{S,\ ideal}$. The ideal or ratio current $I_{SI}=I_P/CTR$ is reduced by the excitation current (I_e) to yield the actual current (I_s). This relationship is illustrated in the CT equivalent circuit shown in Figure D-5.

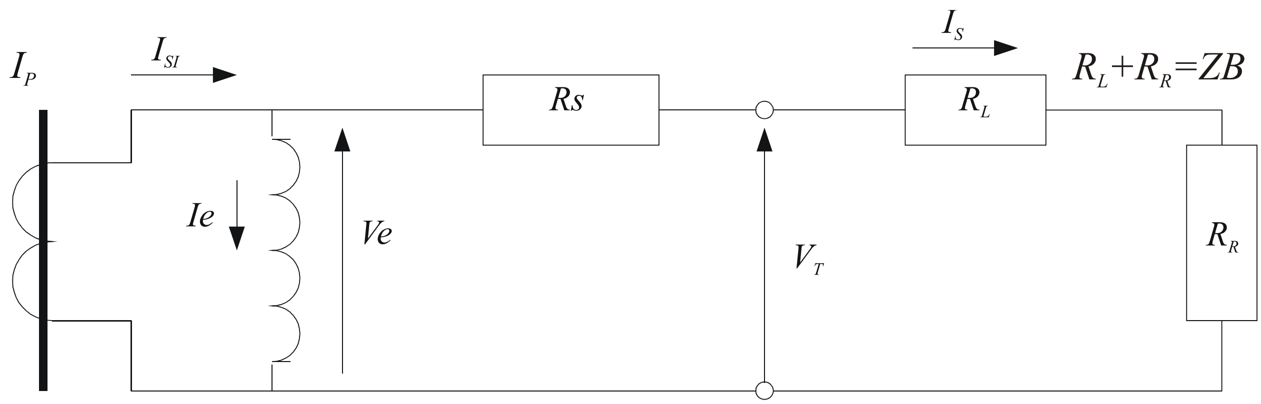


Figure D-7. CT Equivalent Circuit

For relaying applications, the CT performance is considered acceptable if the ratio correction is less than 10%. The ratio error is defined in C57.13-1993, Section 8.1.10 as I_e/I_S. This criterion is expressed in the ANSI C accuracy class, which is defined as follows: Under steady state (symmetrical current) conditions, the excitation current must be less than 10 amperes for a relay current of 100 amperes into the specified standard burden. Of course, no one has a CT burden that is exactly the standard burden and current for which the CT was designed. The definition mainly tells a manufacturer how to design a CT and is not easily translated into assessing whether a CT will saturate for another burden and current level. An alternate and more efficient approach to determining if a CT can reproduce the primary AC current is to understand:

- The voltage the CT can reproduce without excessive CT saturation, and
- The $I \cdot R$ voltage (approximately equal to $I \cdot Z$) the CT will see in a worst case fault, where R includes the entire CT loop, including the internal impedance of the CT, the CT leads and the relaying and metering on the CT.

Two simple methods for determining the AC voltage that a CT can deliver include:

1) Examine the CT excitation curve, and then come to some selection of the voltage the CT can support from the curve. Points on the curve that may be considered include:
   a) The voltage at the knee of the curve (typically the voltage at the 45 degree slope on a log-log excitation plot is used).
   b) The voltage point where I_e is 10A. (This measure is generous, but is not fully justifiable. For example, suppose the ideal secondary current is 20A but 10A is going into the excitation branch, for a 50% error level. This would not be considered a valid application of the CT.)
   c) The voltage found at the intersection of a projection of the linear and saturation portions of the excitation curves.
2) Simply assume that the voltage that the CT can support is equal to the C class rating of the CT. This should be satisfactory for almost all applications and is a readily available voltage rating.

Once one has determined the voltage that the CT can reproduce without excessive excitation current, and then determine the voltage in the entire CT loop using $V = I * R$ analysis. Then compare the two voltages. One should have a low SF at this point if one wants to ensure some relative degree of resistance to transient CT saturation during DC offset conditions. It is generally accepted that a SF of 0.5 or less is acceptable. But an $SF < 1/(Fault\ X/R)$ would offer an even better level of security against transient CT saturation though such a generous CT rating may be hard to obtain.

Saturation Factor Defined from the ANSI C Classification, Ignoring R_S

In Figure D-8, the CT terminal voltage increases linearly with the secondary current along the $V_T=Z_B * I_S$ line where Z_B is the total CT burden (leads plus relays for a particular fault and connection). A terminal voltage (V_T) corresponds to the maximum fault current (I_F). This voltage is lower than the maximum voltage (V_C) that the CT can support. Saturation will occur for secondary currents in excess of IF_S where the corresponding terminal voltage crosses the accuracy class limit VC (point C in Figure D-8). We can define a measure of the degree of saturation with the saturation factor:

$$SF = \frac{IF}{IFs}$$

By examination of triangles OAB and OCD, the same saturation factor can be expressed as:

$$SF = \frac{VT}{VC}$$

Note: In this definition, the voltage drop in the *CT* internal resistance is ignored.

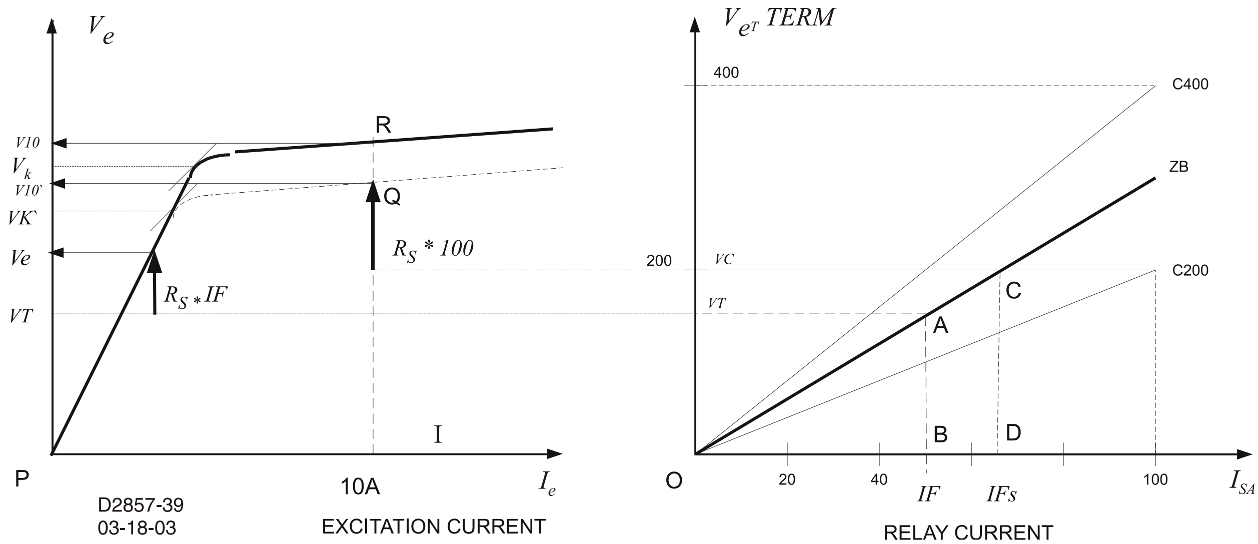


Figure D-8. CT Terminal and Excitation Voltages

This first definition of saturation relates the CT terminal voltage to the accuracy class of the CT (effective class in the case of multi-ratio CTs). It is practical and easy to calculate since it requires only readily available data. An application is considered reasonably secure when *SF* is less than 0.5

Saturation Factor Defined from the CT Excitation Curve and V_{exc} @ IC = 10 A

The definition of the saturation factor given above appears to be conservative because it assumes the worst case ratio error. However, a closer look is required since it neglects the CT internal resistance. It corresponds to an excitation voltage on a curve passing through point Q in Figure D-8 at which the excitation current is 10 amperes (the maximum error allowed by the accuracy class definition). The $R_{CT} * 100$ term represents the voltage drop across the CT internal resistance. An alternative *SF* that takes the internal CT resistance into account can be defined on the excitation curve, as:

where V_e is the internal excitation voltage ($R_{CT} * I_F$) at the maximum fault current I_F and $V10`$ is the voltage

$$SF` = \frac{Ve}{V10`}$$

of the curve passing through point Q where the exciting is 10 amps. This voltage is practically close to the knee-point voltage $VK`$ which would yield nearly the same (a slightly more conservative) result.

Since in all likelihood, the excitation voltage capability of the CT will be higher (passing through point R in Figure D-6, for instance), the saturation factor defined on the excitation curve appears to be lower, i.e., more favorable. A detailed analysis can be performed to compare the two saturation factor definitions.

Saturation Factor SF vs SF' Definitions Compared

Using the equivalent circuit in Figure D-7 and the ANSI Accuracy Class definition that the CT must be able to source 20 times nominal current into a standard burden *Zc*, we now develop a comparative analysis between the two definitions:

$$SF = \frac{VT}{VC} \qquad SF` = \frac{Ve}{V10`}$$

$$SF = \frac{ZB * IF}{100 * Zc} \qquad SF` = \frac{IF * (ZB + Rs)}{100 * (Zc + Rs)}$$

To compare the two expressions, we take the ratio *SF`/SF:*

$$\frac{SF`}{SF} = \frac{Zc}{ZB} * \frac{(ZB + CT')}{(Zc + CT)}$$

Since this expression varies with the ratio of the actual relay circuit burden (*ZB*) to the accuracy class burden (*Zc*) and the CT internal resistance (*Rs*), it is best visualized with a surface plot (Figure D-7) showing simultaneous variations of the parameters. The following example is based on a C200 (*Zc*=2) with R_s varying from 0.1 to 0.8 ohms and *ZB* varying from 0.1 to 2 times *Zc* ohms (load angles are neglected).

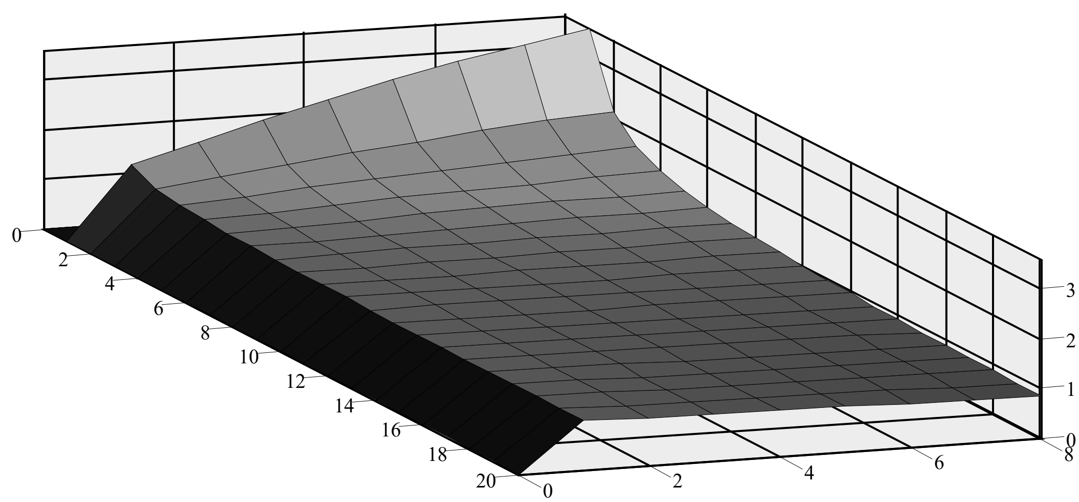


Figure D-9. SF`/SF Ratio

The 0 to 20 axis represents the variations x10 of *ZB* (20 is 2x *Zc*). The 0 to 8 axis represents the variations x10 of R_{CT} in ohms. The vertical axis (0 to 4) shows that for *ZB* values equal to or greater than the burden value Zc, the two saturation factor equations are nearly identical. The ANSI Accuracy Class method yields the larger, more conservative result. For low values of *ZB* and large values of R_{CT}, the Excitation Curve method yields a larger saturation factor. Since the Excitation Curve method is closely following the CT characteristics, it may be said that the ANSI Class method that neglects the CT internal resistance is too optimistic in this range and should be discarded in favor of the Excitation Curve method. The absolute values of *SF* and *SF`* are compared in Figure D-8 for the particular case where *Zc* = 2, *ZB* = 0.5 and R_{CT} = 0.8 when *IF* varies from 0 to 100 A.

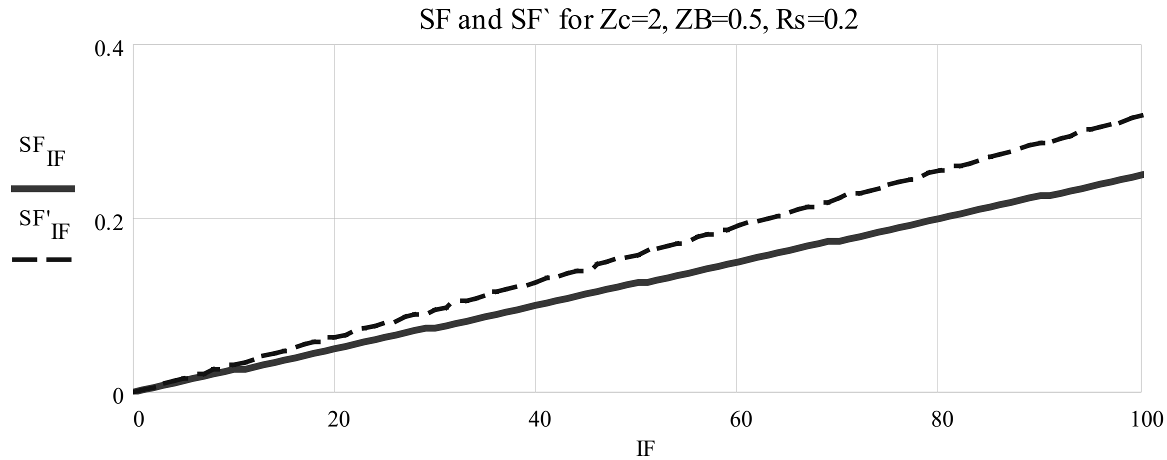


Figure D-10. Comparing SF and SF`

Figure D-11 illustrates how a lower Rs value reduces the difference between SF and SF`.

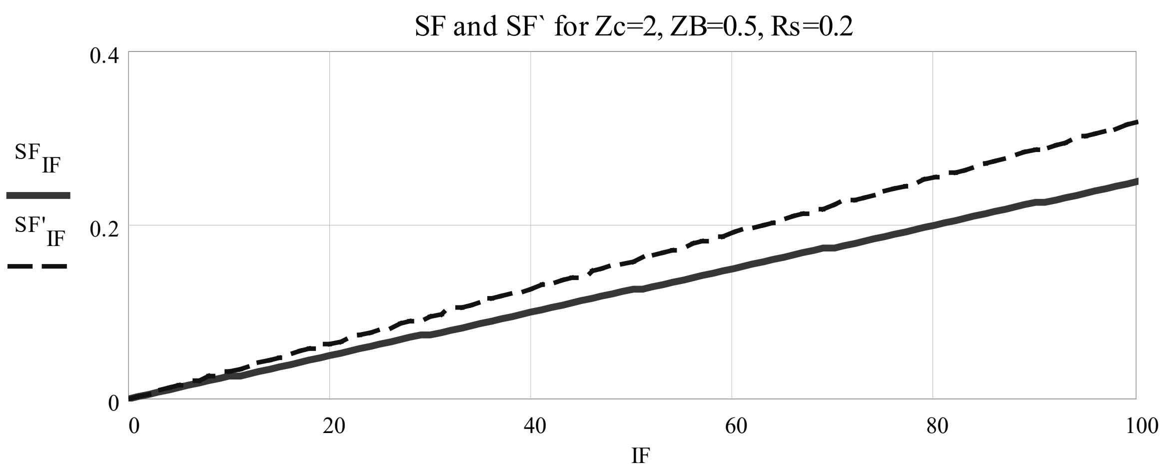


Figure D-11. Reducing the Difference between SF and SF'

Saturation Factor Defined from the CT C-Class and Including CT Impedance

Likely the easiest data to obtain on a CT is its C-Class. This provides a convenient means to approximate the maximum AC voltage that the CT can sustain. An examination of the CT excitation curve indicates that the C-class typically falls somewhere between the 45^{O} knee point voltage and the excitation voltage at Ie = 10 A (i.e., $V10$ herein). Further, including the CT internal impedance in the voltage drop analysis ensures that the CT internal resistance is not overlooked as a source of saturation. In some inexpensive CTs or old installations, the internal resistance is not readily found in published data. But, if this is a transformer that is being protected, it is assumed that high quality CT are being purchased or good documentation records have been kept and hence the internal resistance of the CT is easily obtainable, at least by examining comparably equivalent CTs. Once the C Class and the internal impedance is obtained, a third saturation factor definition is obtained:

$$SF'' = \frac{IF * (ZB + R_S)}{\text{CT C - Class Voltage Rating}}$$

This form of SF should be easy to work with. It is likely the most intuitive form of SF and provides a reasonably conservative yet accurate enough assessment of CT performance. This form for SF is used in the settings calculations.

Conclusion

This analysis showed three measurements of the SF value. The third version, using the C-class of the CT and including the CT internal resistance in the voltage drop calculations is used to determine CT saturation measurements in the calculations for the relay.

Setting Note 4. Slope Setting when CT Saturation Factor (SF) > 0.5

In this case, the maximum slope is set to 60 percent (S = 60). This occurs when poor CTs are used. This situation should be avoided if possible, since no accurate calculations can be made to verify the security of the protection.

The effect of this setting is illustrated in the following hypothetical case, where it can be seen that the slope based on the linear operation may be too low when severe saturation occurs.

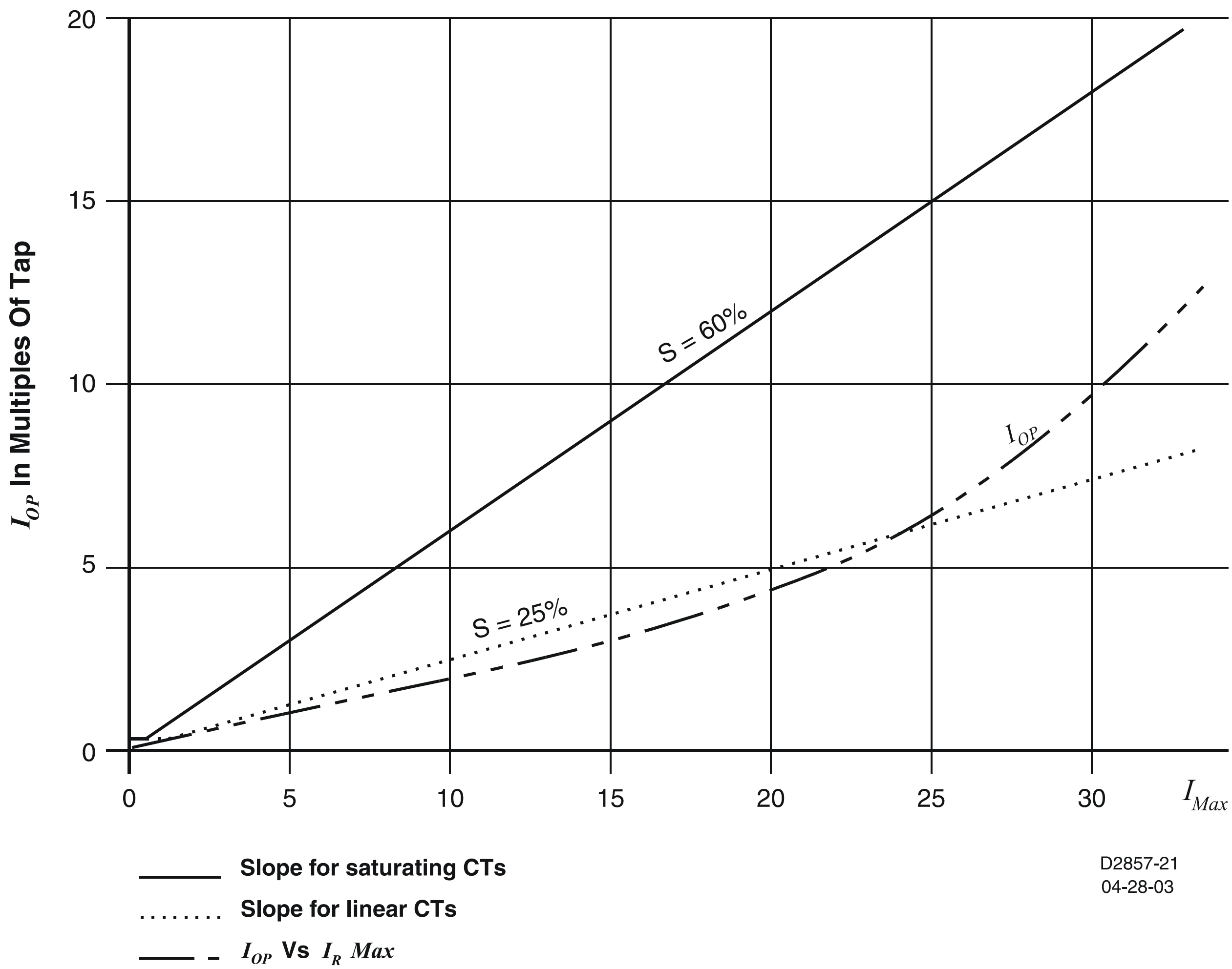


Figure D-12. I_R in Multiples of TAP

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