SEL-487B Relay

Protection
Automation
Control

Instruction Manual

20210514

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This product is covered by the standard SEL 10-year warranty. For warranty details, visit www.selinc.com or contact your customer service representative.

PM487B-01

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Preface

Overview

This manual provides information and instructions for installing, setting, configuring, and operating the SEL-487B Relay. The manual is for use by power engineers and others experienced in protective relaying applications. Included are detailed technical descriptions of the relay and application examples.

Manual Overview

The SEL-487B Instruction Manual consists of three volumes:

- User's Guide
- Applications Handbook
- Reference Manual

In addition, the SEL-487B Instruction Manual contains a comprehensive *Index* that encompasses the entire manual and a *Glossary* that lists and defines technical terms used throughout the manual.

Read the sections that pertain to your application to gain valuable information about using the SEL-487B. For example, to learn about relay protection functions, read the protection sections of this manual and skim the automation sections. You can concentrate on the operation sections or on the automation sections of this manual as your job needs and responsibilities dictate. An overview of each manual section and section topics follows.

User's Guide

Preface. Describes manual organization and conventions used to present information.

Section 1: Introduction and Specifications. Introduces SEL-487B features; summarizes relay functions and applications; lists relay specifications, type tests, and ratings.

Section 2: Installation. Discusses the ordering configurations and interface features (control inputs, control outputs, and analog inputs, for example); provides information about how to design a new physical installation and secure the relay in a panel or rack; details how to set relay board jumpers and make proper rear-panel connections (including wiring to CTs and PTs); explains basic connections for the relay communications ports and how to install optional communications cards (such as the Ethernet card).

Section 3: PC Software. Introduces how to use the ACSELERATOR QuickSet® SEL-5030 Software Program.

Section 4: Basic Relay Operations. Describes how to perform fundamental operations such as applying power and communicating with the relay, setting and viewing passwords, checking relay status, viewing metering data, reading event reports and SER (Sequential Events Recorder) records, and operating relay control outputs and control inputs.

Section 5: Front-Panel Operations. Describes the LCD display messages and menu screens; shows you how to use front-panel pushbuttons and read targets; provides information about local substation control and how to make relay settings via the front panel.

Section 6: Testing and Troubleshooting. Describes techniques for testing, troubleshooting, and maintaining the SEL-487B; includes the list of status notification messages and a troubleshooting chart.

Appendix A: Firmware and Manual Versions. Lists the current firmware versions and details differences between the current and previous versions.

Appendix B: Firmware Upgrade Instructions. Provides information about upgrading firmware in your SEL-487B.

Applications Handbook

Section 1: System Configuration Guideline and Application Examples. Provides general guidelines for implementing the relay in single-relay and three-relay applications; provides CT and disconnect auxiliary contact requirements for proper differential protection application. The section also provides application examples for the following busbar layouts:

- Single bus and tie breaker, three-relay application
- Single bus and tie breaker, single-relay application
- Breaker-and-a half
- Single bus and transfer bus with buscoupler
- Double bus with buscoupler
- Double bus and transfer bus with two busbars
- Double and transfer bus (outboard CTs)
- Double and transfer bus (inboard CTs)

Use the worksheets provided on the SEL-487B *Product Literature CD* to collect and organize data before configuring and setting the relay.

Section 2: Monitoring and Metering. Describes how to use the substation dc battery monitors; provides information on viewing metering quantities for voltages and currents.

Section 3: Analyzing Data. Explains how to obtain raw data and filtered data event reports, event summaries, history reports, and SER reports; discusses how to enter SER trigger and alias settings.

Section 4: SEL Communications Processor Applications. Provides examples of how to use the SEL-487B with the SEL-2020, SEL-2030, and SEL-2032 Communications Processors for total substation automation solutions.

Section 5: Direct Network Communications. Explains how to use DNP3 (serial and LAN/WAN) and other Ethernet protocols such as Telnet, FTP, and IEC 61850.

Reference Manual

Section 1: Protection Functions. Describes the protection, monitoring, and control elements in the SEL-487B and how the relay processes these elements.

Section 2: SELOGIC Control Equation Programming. Describes SELOGIC® control equations and how to apply these equations; discusses expanded SELOGIC control equation features such as PLC-style commands, math functions, counters, and conditioning timers; provides a tutorial for converting older format SELOGIC control equations to new free-form equations.

Section 3: Communications Interfaces. Explains the physical connection of the SEL-487B to various communications network topologies.

Section 4: SEL Communications Protocols. Describes the various SEL software protocols and how to apply these protocols to substation integration and automation; includes details about SEL ASCII, SEL Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, and enhanced MIRRORED BITS® communications.

Section 5: DNP3 Communications. Explains how to use DNP3 (serial and LAN/WAN) and other Ethernet protocols such as Telnet, FTP, and IEC 61850.

Section 6: IEC 61850 Communications. Describes the IEC 61850 protocol and how to apply this protocol to substation automation and integration. Includes IEC 61850 protocol compliance statements.

Section 7: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 8: Settings. Provides a list of all SEL-487B settings and defaults. The organization of the settings is the same as for the settings organization in the relay and in the ACSELERATOR QuickSet software.

Appendix A: Relay Word Bits. Contains a summary of Relay Word bits.

Appendix B: Analog Quantities. Contains a summary of analog quantities.

SEL-487B Relay Command Summary. Contains a listing of SEL-487B commands.

CD-ROM

The CD-ROM contains the SEL-487B Instruction Manual in an electronic form that you can search easily.

Conventions

The SEL-487B Instruction Manual uses certain conventions that identify particular terms and help you find information. To benefit fully from reading this manual, take a moment to familiarize yourself with these conventions.

Typographic Conventions

There are three ways to communicate with the SEL-487B:

- Using a command line interface on a PC terminal emulation window, such as Microsoft® HyperTerminal®.
- Using the front-panel menus and pushbuttons.
- Using ACSELERATOR QuickSet SEL-5030 Software.

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions.

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SUM *n***	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
{CLOSE}	Relay front-panel pushbuttons.
ENABLE	Relay front- or rear-panel labels.
`RELAY RESPONSE` `MAIN > METER`	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.
U.3.1 A.3.1 R.3.1	Page numbers include a reference to the volume, section, and page number. U stands for User's Guide A stands for Applications Handbook R stands for Reference Manual
SELOGIC control equations	SEL trademarks and registered trademarks contain the appropriate symbol on first reference in a section. In the SEL-487B Instruction Manual, certain SEL trademarks appear in small caps. These include SELOGIC control equations, MIRRORED BITS communications, and ACSELERATOR QuickSet software program.
Modbus®	Registered trademarks of other companies include the registered trademark symbol with the first occurrence of the term in a section.

Commands

You can simplify the task of entering commands by shortening any ASCII command to the first three characters (upper- or lowercase); for example, **ACCESS** becomes **ACC**.

Always send a carriage return **<CR>** character, or a carriage return character followed by a line feed character **<CR><LF>**, to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a **<CR>**. For example, to send the **ACCESS** command, type the following:

ACC <Enter>

Safety Information

This manual uses three kinds of hazard statements, formatted as follows:

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury or equipment damage.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

Notes

Margin notes present valuable or important points about relay features or functions. Use these notes as tips to easier and more efficient operation of the relay.

Step-by-Step Procedures

The SEL-487B Instruction Manual contains many step-by-step procedures. These procedures lead you easily and efficiently through complex tasks. Each procedure lists required equipment, as well as the basic knowledge you need to perform the steps in the procedure. Throughout the procedure, the documentation references other SEL-487B Instruction Manual sections where you can find more information.

Read the entire procedure before performing the listed steps. Read each step again before you perform it. The following text shows sample steps. Steps include explanations, text references, table references, and figure references to further illustrate the step.

Step 1. Press **<Ctrl+T>** to use the serial communications terminal in the ACSELERATOR software.

Step 2. Press **<Enter>** to see if the communications link is active between the software and the relay.

You should see the Access Level 0 = prompt in the terminal window.

Step 3. Open the **Communication** menu and click **Port Parameters**.

Step 4. Confirm that you have entered the correct passwords in the **Level One Password** dialog box and the **Level Two Password** dialog box.

Step 5. On the **Settings** menu, click **Read**.

The relay sends all configuration and settings data to ACSELERATOR.

Step 6. Click the **+** mark next to the **Group** you want to program on the **Settings** tree view.

This example uses **Group 1**, as shown in *Figure 1.2*.

Figure Reference

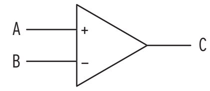
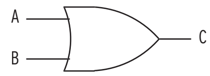
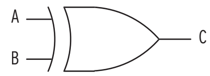
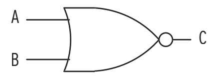
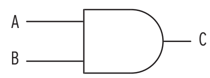
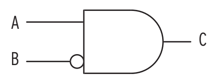
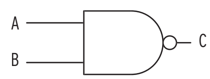
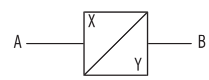
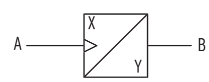
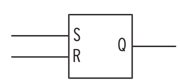
Sample Step-by-Step Instructions

Numbers

This manual displays numbers as decimal values. Hexadecimal numbers include the letter h appended to the number. Alternatively, the prefix 0X or 0x can also indicate a hexadecimal number. For instance, 11 is the decimal number eleven, but 11h and 0X11 are hexadecimal representations of the decimal value seventeen.

Logic Diagrams

Logic diagrams in this manual follow the conventions and definitions shown below.

NAME	SYMBOL	FUNCTION
COMPARATOR		Input A is compared to input B. Output C asserts if A is greater than B.
INPUT FLAG		Input A comes from other logic.
OR		Either input A or input B asserted cause output C to assert.
EXCLUSIVE OR		If either A or B is asserted, output C is asserted. If A and B are of the same state, C is deasserted.
NOR		If neither A nor B asserts, output C asserts.
AND		Input A and input B must assert to assert output C.
AND W/ INVERTED INPUT		If input A is asserted and input B is deasserted, output C asserts. Inverter "O" inverts any input or output on any gate.
NAND		If A and/or B are deasserted, output C is asserted.
TIME DELAYED PICK UP AND/OR TIME DELAYED DROP OUT		X is a time-delay-pickup value; Y is a time-delay-dropout value. B asserts time X after input A asserts; B will not assert if A does not remain asserted for time X. If X is zero, B will assert when A asserts. If Y is zero, B will deassert when A deasserts.
EDGE TRIGGER TIMER		Rising edge of A starts timers. Output B will assert time X after the rising edge of A. B will remain asserted for time Y. If Y is zero, B will assert for a single processing interval. Input A is ignored while the timers are running.
SET RESET FLIP FLOP		Input S asserts output Q until input R asserts. Output Q deasserts or resets when R asserts.
FALLING EDGE		B asserts at the falling edge of input A.

SEL-487B Cautions, Warnings, and Dangers

The following hazard statements appear in the body of this manual in English. See the following table for the English and French translation of these statements.

English	French
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.	⚠ATTENTION Il y a un danger d'explosion si la pile électrique n'est pas correctement remplacée. Utiliser exclusivement Ray-O-Vac® No. BR2335 ou un équivalent recommandé par le fabricant. Se débarrasser des piles usagées suivant les instructions du fabricant.
⚠CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	⚠ATTENTION L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Otherwise, equipment damage can result.	⚠ATTENTION Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de mettre en marche.
⚠CAUTION Do not install a jumper on positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A and J18D.	⚠ATTENTION Ne pas installer de cavalier sur les positions A ou D sur le connecteur J18 de la carte principale. Une défaillance du relais pourrait survenir si un cavalier était installé sur les positions J18A et J18D.
⚠CAUTION Setting E87ZSUP := Y enables the zone supervision in all six zones. If you do not enter any supervision conditions for a particular zone, be sure to enter a 1 at the SELogic control equation prompt.	⚠ATTENTION Le réglage E87ZSUP := Y autorise la supervision de zone des six zones. Si vous n'entrez aucune condition de supervision pour une zone particulière, assurez-vous d'entrer un 1 au message de l'équation de commande SELogic.
⚠CAUTION Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use Standard null-modem cables with this equipment.	⚠ATTENTION Des problèmes sévères d'alimentation et de masse pourraient survenir sur les ports de communication suite à l'usage de câbles autres que ceux fournis par SEL. Ne jamais utiliser des câbles standards de type modem nul avec cet équipement.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.

English	French
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.
⚠WARNING Do not look into the fiber (laser) ports/connectors.	⚠AVERTISSEMENT Ne pas regarder vers l'extremité des ports ou connecteurs de fibres pour laser.
⚠WARNING Do not look into the end of an optical cable connected to an optical output.	⚠AVERTISSEMENT Ne pas regarder vers l'extrémité d'un câble optique raccordé à une sortie optique.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.
⚠WARNING Incorporated components, such as LEDs, transceivers, and laser emitters, are not user serviceable. Return units to SEL for repair or replacement.	⚠AVERTISSEMENT Les composants internes tels que les leds (diodes électroluminescentes), émetteurs-récepteurs ou émetteurs pour rayon laser ne peuvent pas être entretenus par l'usager. Retourner ces unités à SEL pour toute réparation ou remplacement.
⚠WARNING Do not use Relay Word bit 51PnnT in any trip equation if inverse-time overcurrent protection is not required.	⚠AVERTISSEMENT Ne pas utiliser le bit de "Relay Word" 51PnnT dans une équation de déclenchement si la protection de type temps-courant à temps inverse n'est pas requise.
⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.

Section 1
System Configuration Guideline and Application Examples

Overview

Configuring the system is the most challenging of the many activities associated with using the SEL-487B Busbar Protective Relay. System configuration includes renaming (aliasing) terminals and bus-zones, assigning input contacts to selected relay logics, declaring terminal-to-bus-zone connections, declaring bus-zone-to-bus-zone connections, configuring buscouplers and check zones, and assigning logics to relay outputs. System configuration requires careful consideration of the following items because they both influence the number of SEL-487B relays and ordering options needed:

- primary layout of the substation
- choice of protection elements

For example, substations with six or fewer terminals require only one relay. To monitor both 89A and 89B contacts, however, you must equip this relay with the correct number of interface boards to ensure an adequate number of input contacts.

The following discussion provides general guidelines and outlines general factors that should be considered when using ASCII commands to configure your relay. The section also provides application examples for some of the more common busbar layouts. Included in this section are the following topics:

- Input, logic, and output assigning process
- Relay differential element composition
  - Single-relay application
  - Three-relay application
- CT requirements
  - CT connections
  - CT sizing
  - CT ratio selection
  - CT grounding
  - Polarity
- Disconnect requirements
- Alias names
- Bus-zone configurations

    - Terminal configurations
    - Buscoupler and bus section (tie breaker) configurations
- Bus-zone-to-bus-zone connections
- Zone supervision
- Trip logic
- Output assignments
- Summary
- Application 1: Single bus and tie breaker (three relays)
- Application 2: Single bus and tie breaker (single relay)
- Application 3: Breaker-and-a-half
- Application 4: Single bus and transfer bus with buscoupler
- Application 5: Double bus with buscoupler
- Application 6: Double and transfer bus with two busbars
- Application 7: Double and transfer bus (outboard CTs)
- Application 8: Double and transfer bus (inboard CTs)

Input, Logic, and Output Assigning Process

Figure 1.1 shows a block diagram of the SEL-487B input, logic, and output assigning process for system configuration and protection element settings. Digital input sources include disconnect and breaker auxiliary contacts, breaker failure initiate signals, and breaker close signals. Current and potential transformers provide analog inputs. Use alias settings to assign more meaningful names to primitive Relay Word bits and/or analog names, or use the primitive names of the input quantities to configure and set the relay. The relay has many ready-made logic functions available; however, assign these functions before they become operative. System configuration includes terminal-to-bus-zone and bus-zone-to-bus-zone assignments, zone supervision, and zone-switching supervision settings. Scheme settings include enable settings, differential and sensitive differential element settings, directional element settings, selected relay logic settings, and output assignment.

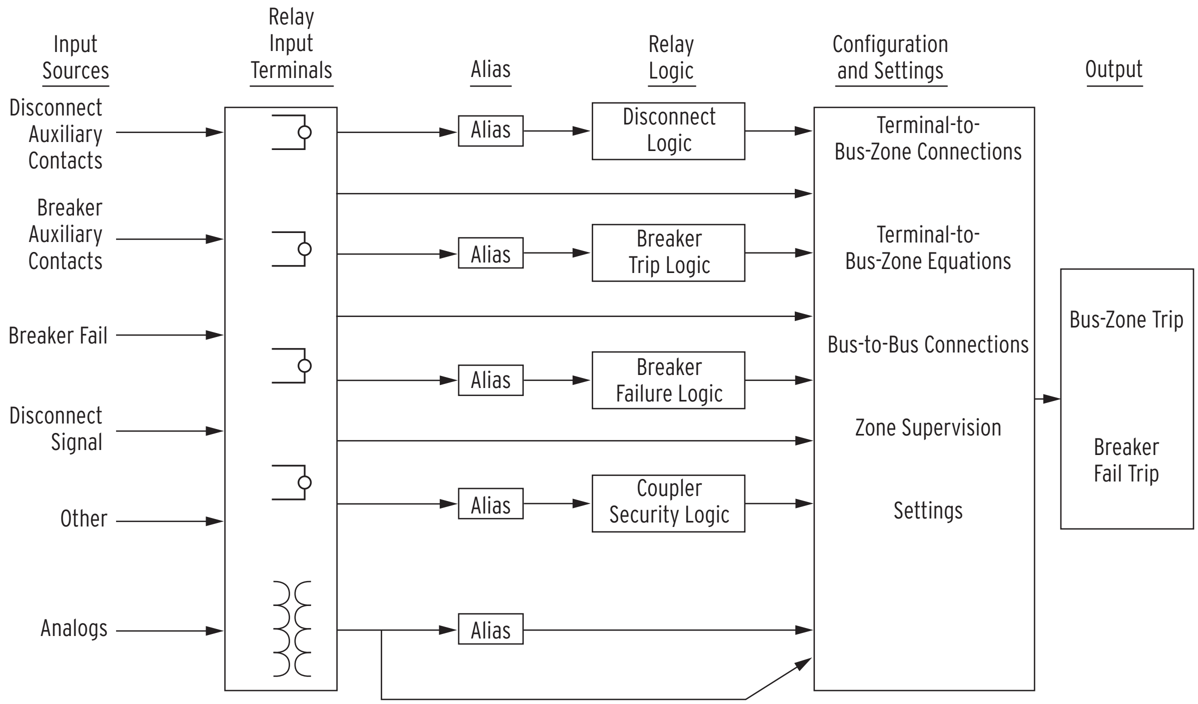


Figure 1.1 Block Diagram of the Input, Logic, and Output Assigning Process for System Configuration Protection Element Settings

Relay Differential Element Composition

Each SEL-487B accepts up to 18 current inputs (I01 through I18) and then assigns these inputs to any of six differential elements (BZ1 through BZ6). *Figure 1.2* shows a block diagram of the arrangement.

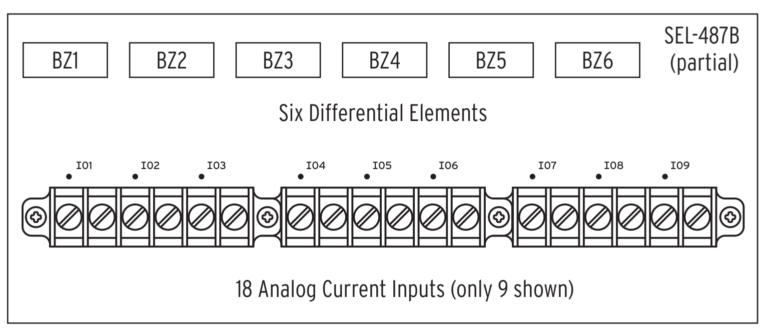


Figure 1.2 Block Diagram Showing Nine Current Inputs and Six Differential Elements

Single-Relay Application

Because differential calculations occur on a per-phase basis, each phase of a three-phase system must bear a unique identification. *Figure 1.3* shows a typical single-line diagram of a station consisting of two busbars (NORTH and SOUTH), a tie breaker (Z), and four terminals.

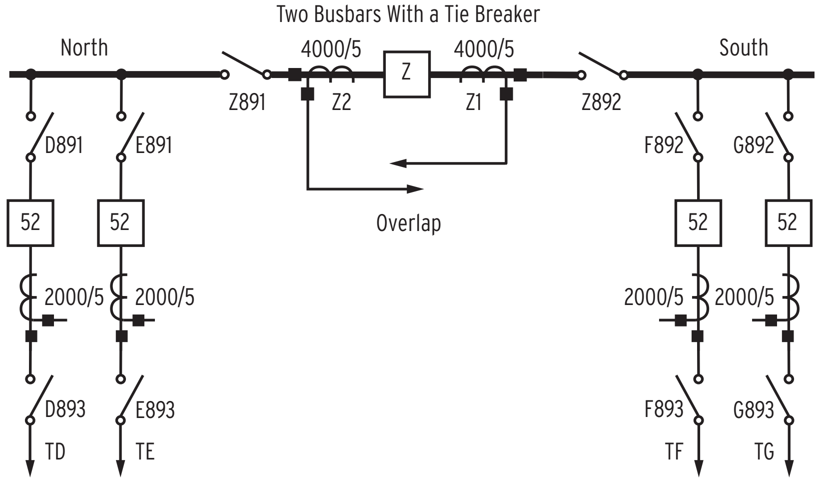


Figure 1.3 Single-Line Diagram of a Station With Two Busbars and a Tie Breaker

Because the station has no more than six terminals, a single SEL-487B suffices. *Figure 1.4* shows the SEL-487B and a three-phase representation of TD, one of the terminals at the station.

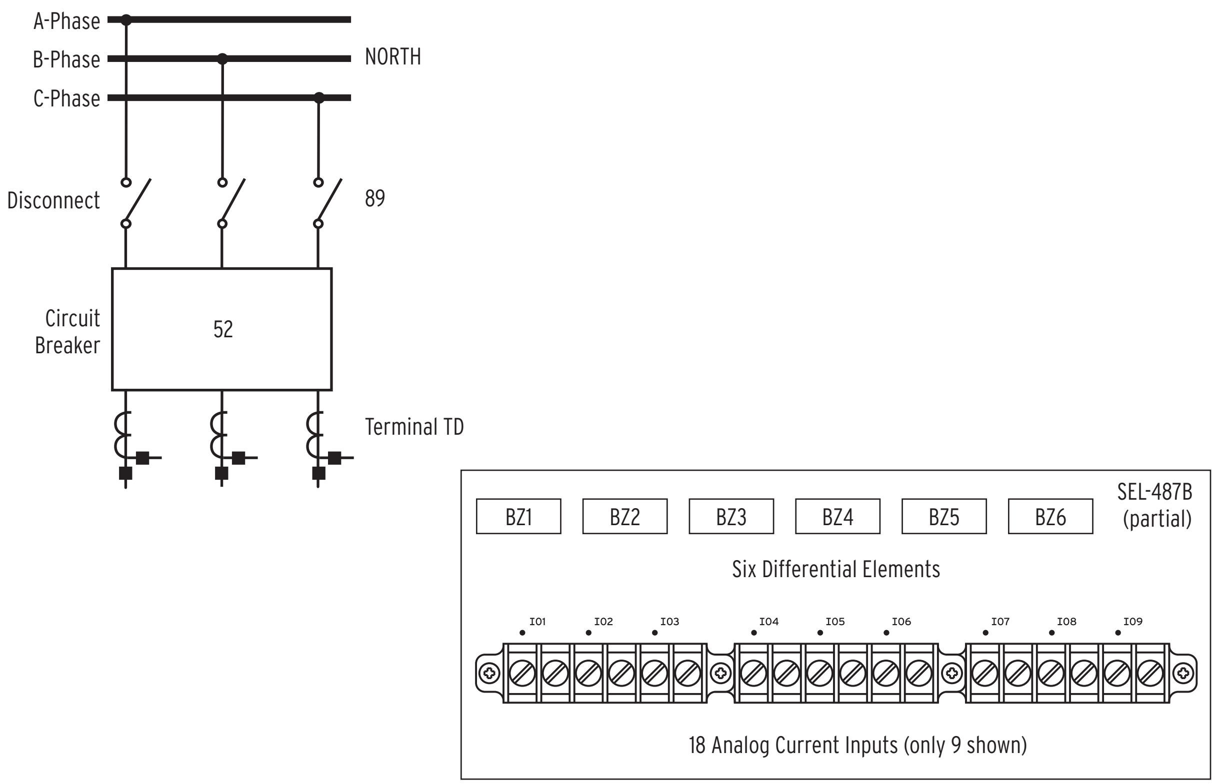


Figure 1.4 Three-Phase Diagram of Terminal TD, the NORTH Busbar, and the SEL-487B

Because differential calculations for each protection zone require an individual differential element, assign an individual differential element to each phase. This assignment uses three of the available six differential elements in the relay for Busbar NORTH. In this example, assign the phases and differential elements as shown in *Figure 1.5*. Each assignment is a software assignment, as indicated by the dotted lines; no electrical wires are required.

Assign the A-phase differential element of Busbar NORTH to differential element BZ1

Assign the B-phase differential element of Busbar NORTH to differential element BZ2

Assign the C-phase differential element of Busbar NORTH to differential element BZ3

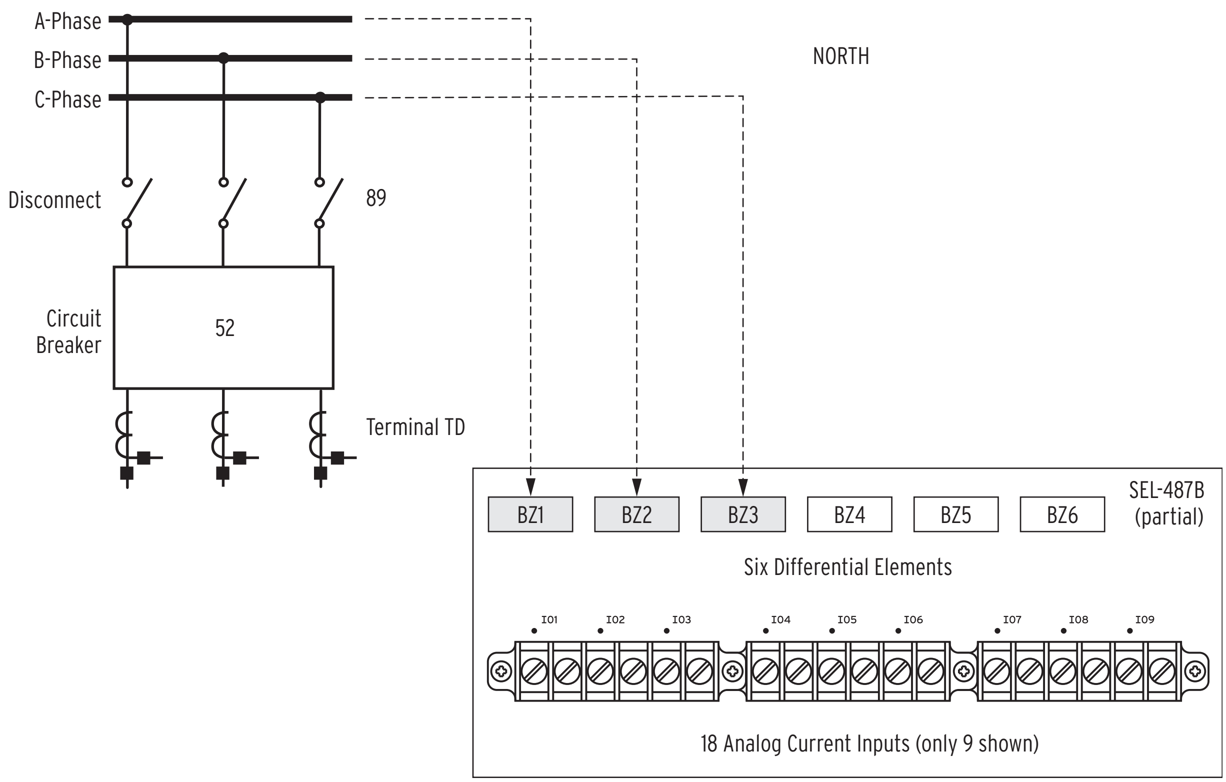


Figure 1.5 A Three-Phase Zone Requires Three Differential Elements

To make the bus-zone labels more substation specific, assign the following alias names to the bus-zones, as shown in *Figure 1.6*:

For the A-phase differential element BZ1, assign NORTH_A

For the B-phase differential element BZ2, assign NORTH_B

For the C-phase differential element BZ3, assign NORTH_C

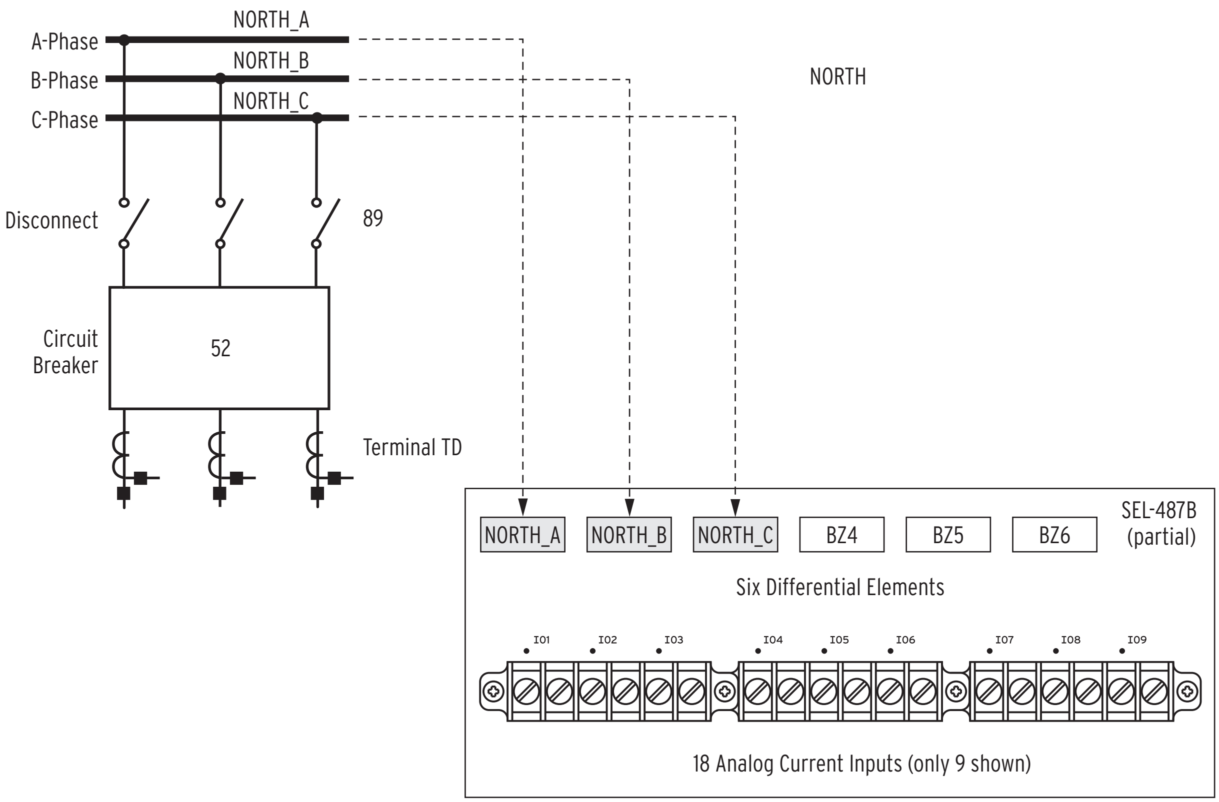


Figure 1.6 Three Differential Elements With Alias Names for a Three-Phase Bus-Zone in a Single Relay Application

For the current inputs in a single-relay application, wire A-phase, B-phase, and C-phase to adjacent terminal connections such as I01, I02, and I03, as shown in *Figure 1.7*. These connections are copper wires connecting the CTs to the relay.

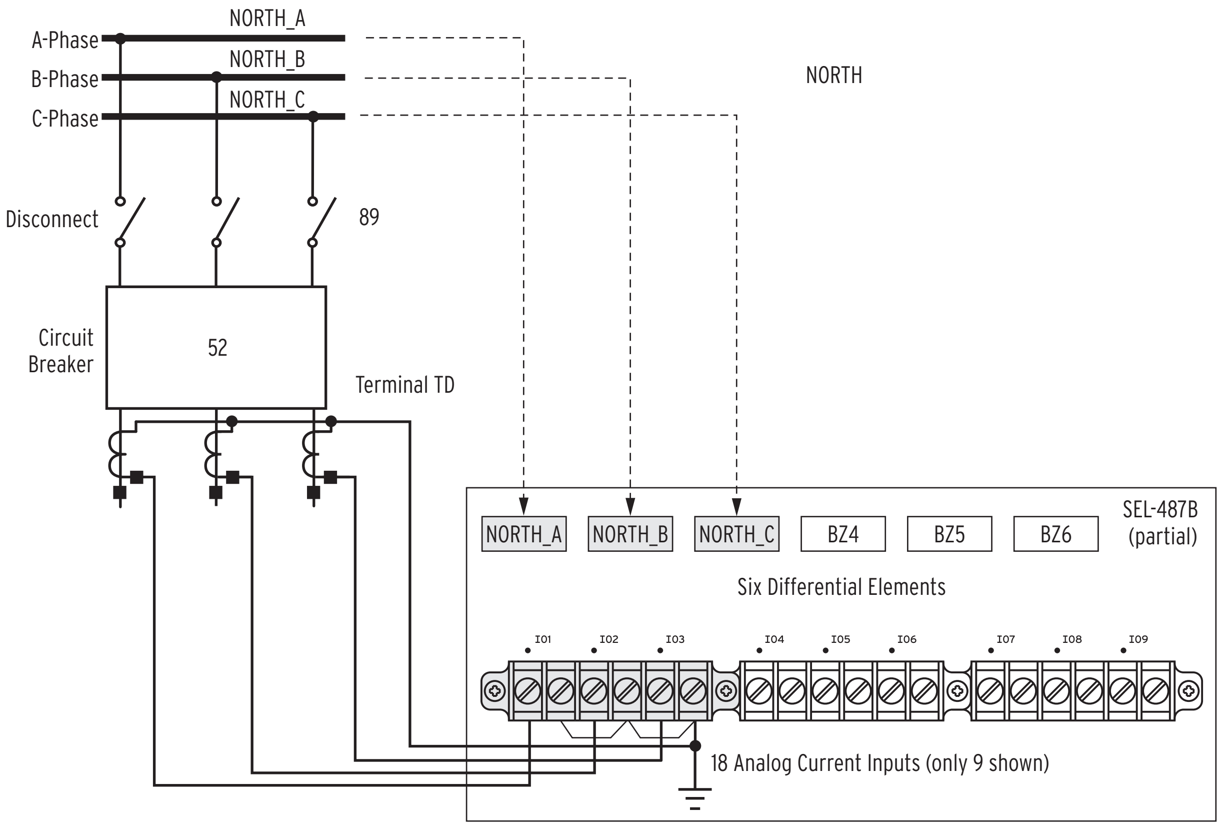


Figure 1.7 Three Differential Elements and Three CT Inputs in a Single-Relay Application

Reference *Figure 1.3* and continue CT connections by wiring the CT inputs from TE (I04 through I06) and Z1 (tie breaker configured in overlap) to I07 through I09. Connect the CTs from Z2, TF, and TG, following the same procedure to complete protection for both bus-zones.

Digital inputs control the dynamic assignment of input currents to differential elements. If you need dynamic zone selection, wire into the relay the auxiliary contacts from the disconnect (89), the circuit breaker (52), or any other conditions that must ultimately be considered in the zone selection logic. *Figure 1.8* shows the disconnect and circuit breaker wiring for Terminal TD.

Only the differential elements are enabled for this example. If you need other functions such as breaker failure protection, wire those inputs to the relay. You need all six zones and all 18 current channels to configure the remaining terminals in the same way. *Figure 1.9* shows the complete station analog channel configuration.

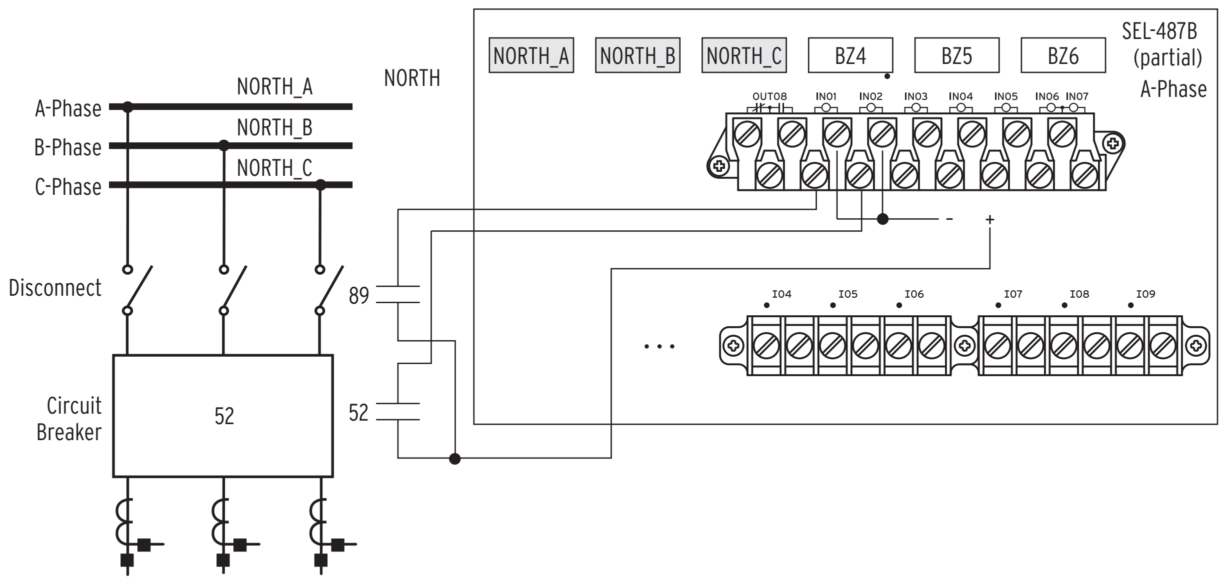


Figure 1.8 Disconnect and Circuit Breaker Wiring for Terminal TD

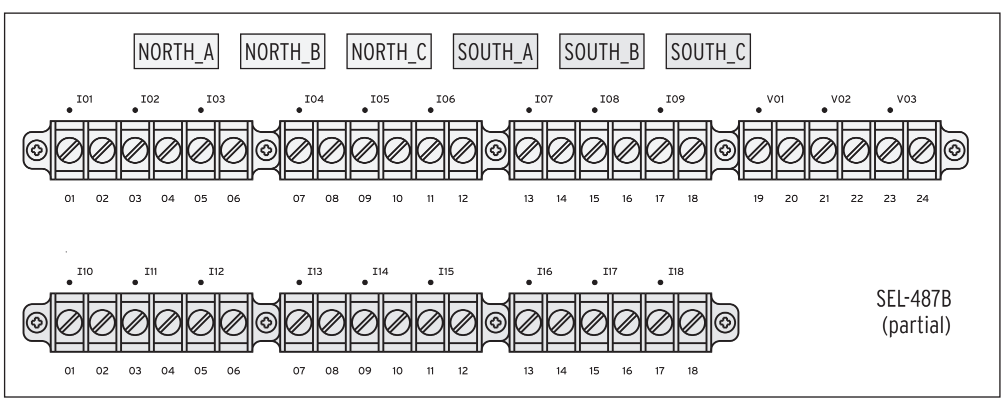


Figure 1.9 Complete Station Configuration, Using Two Three-Phase Bus-Zones and All 18 Current Inputs in a Single-Relay Application

Three-Relay Application

Consider now the same station, configured with three relays instead of one. In the three-relay application, a total of 18 differential elements are available. As before, the label NORTH in the single-line diagram consists of A-phase, B-phase, and C-phase, and each of the three phases is assigned to a differential element. NORTH still requires three differential elements, but the application uses one differential element from each of the three relays, as shown in *Figure 1.10*, instead of three elements in the same relay.

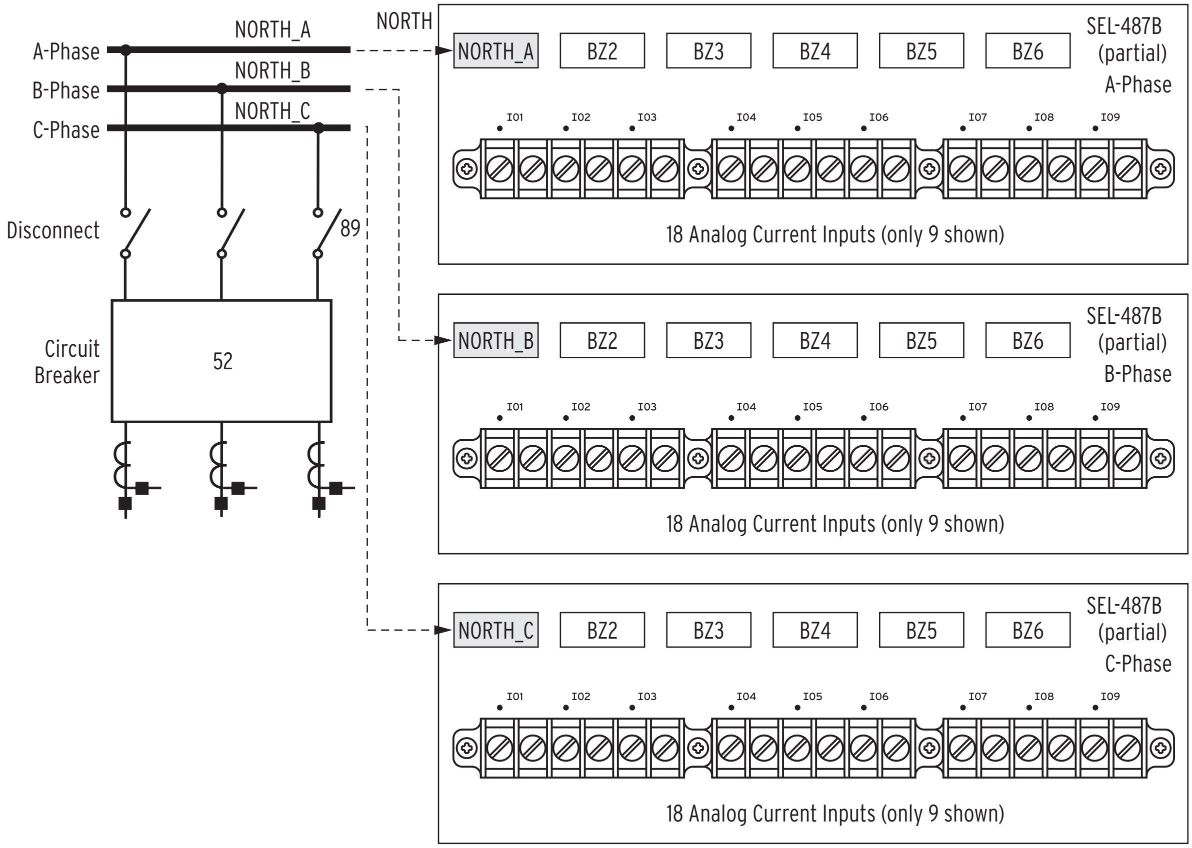


Figure 1.10 One Differential Element From Each of the Three Relays in a Three-Relay Application

Instead of wiring A-phase, B-phase, and C-phase to adjacent terminal connections on the same relay, as with the single-relay application shown in *Figure 1.7*, wire each phase to a separate relay. For example, wire A-phase to the A-Phase SEL-487B Terminal I01, B-phase to the B-Phase SEL-487B Terminal I01, and C-phase to the C-Phase SEL-487B Terminal I01, as shown in *Figure 1.11*.

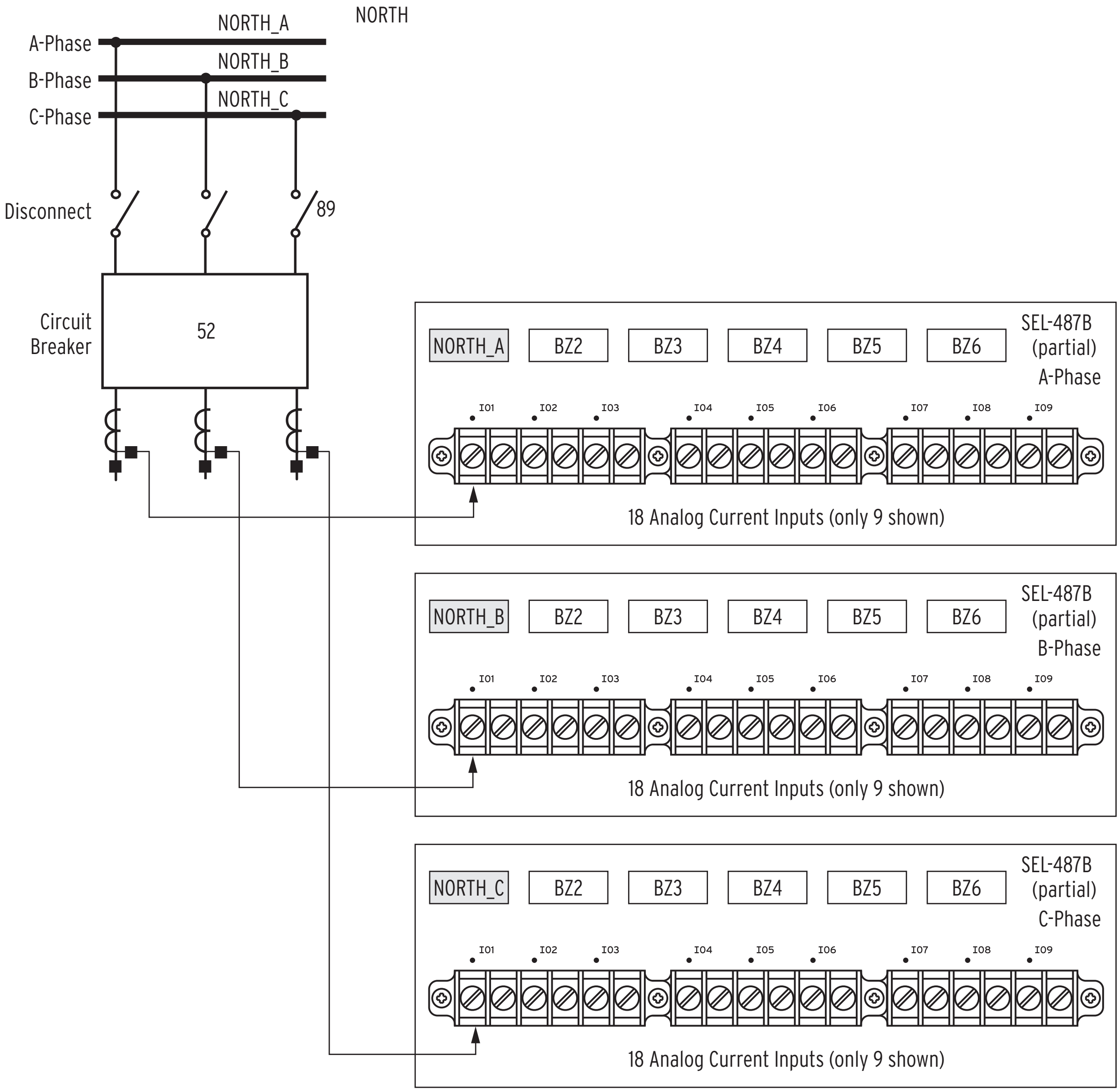


Figure 1.11 CT Wiring in a Three-Relay Application Showing One CT Input to Each of the Three Relays

Figure 1.12 shows the CT wiring for one of the three relays with all A-phase inputs of the station, and two bus-zones assigned. B-phase and C-phase relays have similar arrangements.

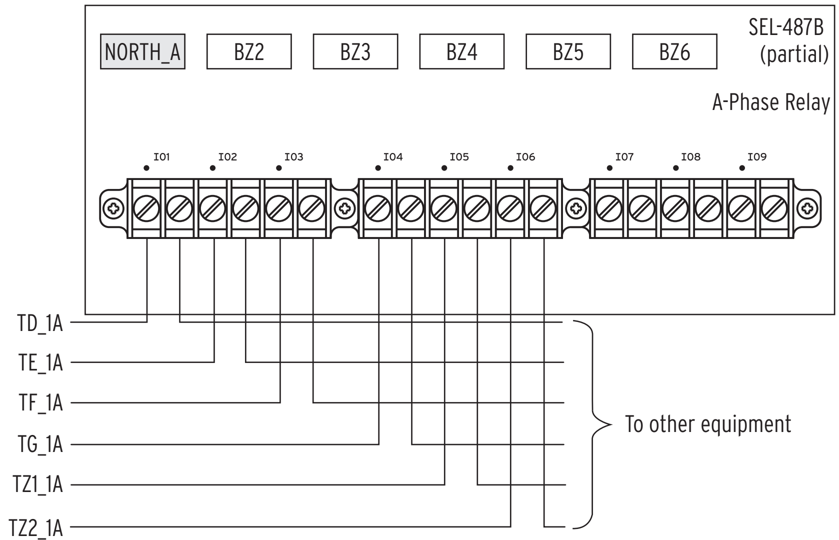


Figure 1.12 CT Wiring for A-Phase Relay, With All A-Phase Inputs of the Station and Two Bus-Zones Assigned

Because the differential elements are in three different relays, each of these relays must receive the same information from the digital inputs. *Figure 1.13* shows jumpers between relays for the case where only one 89 contact and one 52 auxiliary contact are available.

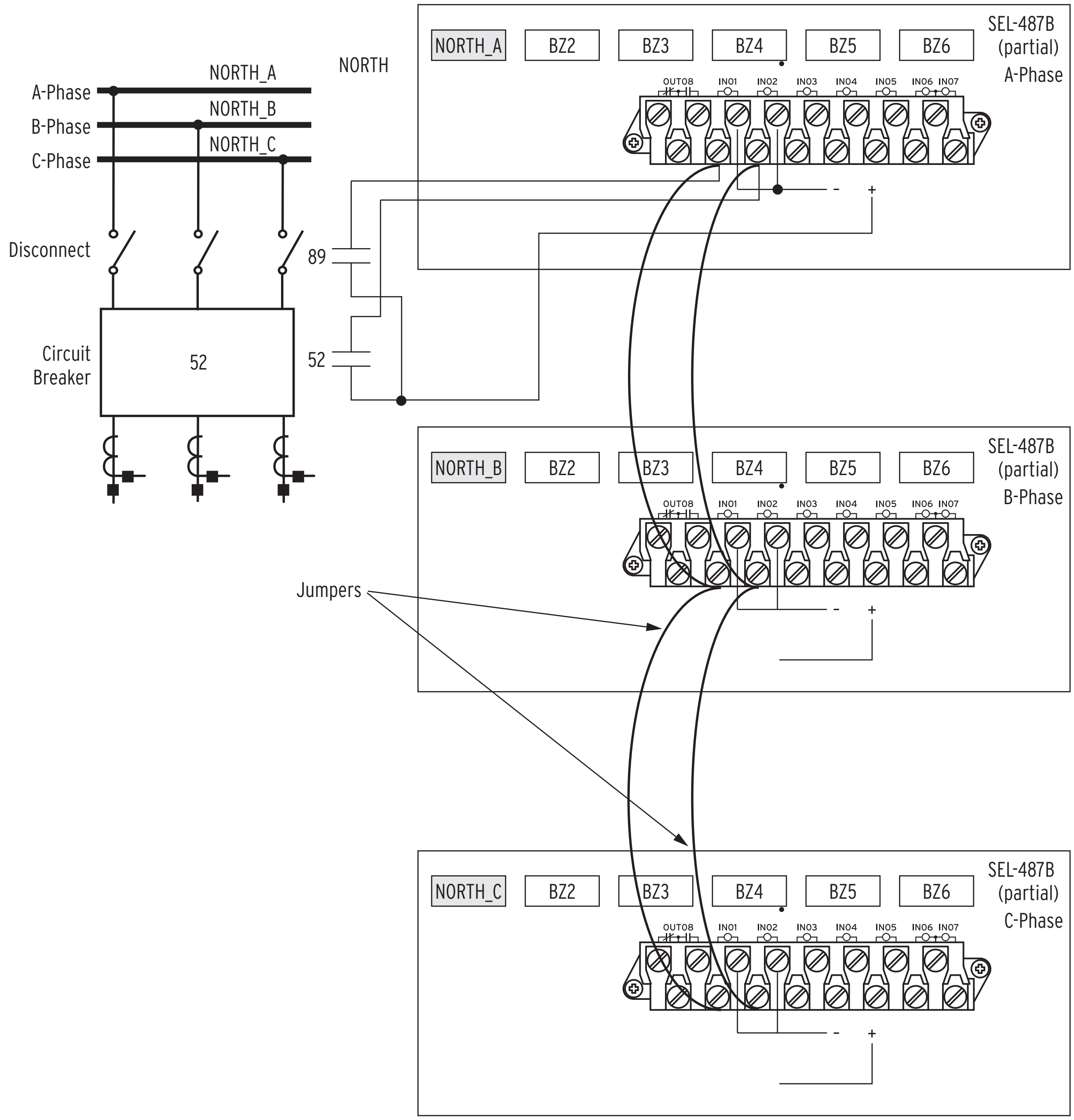


Figure 1.13 Jumpers Between Relays from Digital Inputs 52 and 89

CT Requirements

CT Connections

Connect all CTs to the relay in wye configuration.

CT Sizing

Sizing a CT to avoid saturation for maximum asymmetrical fault current is ideal but not always possible. Such sizing requires CTs with C voltage ratings greater than (1 + X/R) times the burden voltage for the maximum symmetrical fault current, where X/R is the reactance-to-resistance ratio of the primary system.

As a rule of thumb, CT performance will be satisfactory if the CT secondary maximum symmetrical external fault current multiplied by the total secondary burden in ohms is less than half the C voltage rating of the CT.

CT Ratio Selection

For correct operation, the relay algorithm requires that the CTs not saturate for 2 ms following an external fault inception. The IEEE Document *C37.110 Guide for the Application of Current Transformers Used for Protective Relaying Purposes* contains guidelines that will provide a conservative recommendation of the proper CT characteristics needed for low impedance bus differential protection using the SEL-487B. SEL also offers an executable CT saturation program called SEL Two_CTs to assist in determining the CT performance. This program is available on the Product Literature CD-ROM.

For installations with different CT ratios, be sure that the highest/lowest CT ratio does not exceed 10. The SEL-487B selects the highest CT ratio and calculates settings TAP01 through TAP18, provided that the ratio TAP_{MAX}/TAP_{MIN} is less than or equal to 10. If the ratio TAP_{MAX}/TAP_{MIN} is greater than 10, select a different CT ratio.

CT Grounding

Because each of the 18 current channels is independent, be sure to apply a ground to each set of three CTs forming the current input from each terminal. Such grounding connections are usually in the form of short jumpers on the rear of the relay that together create a common connection among terminals. For example, in a three-relay application that uses all 18 terminals, apply 17 jumpers to create a common ground connection point (a single-relay that uses all 18 terminals requires 5 jumpers). Then connect this common point at one location to the station ground mat. Be sure to make ground connections in accordance with ANSI/IEEE® C57.13.3-1983.

Polarity

IEEE Std C37.110-1996 provides the following definition of polarity:

> The designation of the relative instantaneous directions of the currents entering the primary terminals and leaving the secondary terminals during most of each half cycle. Primary and secondary terminals are said to have the same polarity when, at a given instant during most of each cycle, the current enters the identified, similarly marked primary lead and leaves the identified, similarly marked secondary terminals in the same direction, as though the two terminals formed a continuous circuit.

Figure 1.14 shows some of the common polarity marks used to indicate CT polarity.

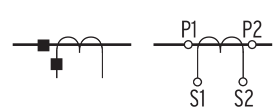


Figure 1.14 Polarity Marks

Polarity marks are also declared on the relay analog input terminals as dots above the relay terminal. When connecting the CTs to the relay, always make sure the wire connected to the polarity terminal on the CT (S1) is also connected to the polarity marked terminal on the relay (Y01, Y03, etc.). *Figure 1.15* shows the polarity marks on the relay.

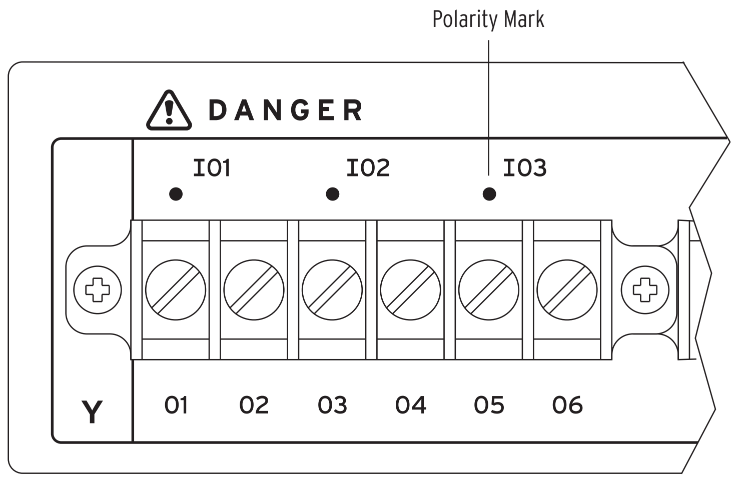


Figure 1.15 Polarity Marks Above the Odd-Numbered CT Terminals at the Rear of the Relay

Connecting the CT terminal with polarity marking to the relay terminal with polarity marking eliminates one possible source of polarity error; the polarity declaration in the software remains the only other potential source of polarity error.

Guideline for Establishing CT Polarity

Use either the ASCII **SET Z** command or the ACSELERATOR QuickSet® SEL-5030 Software to enter relay zone configuration group settings. Prompts in the following steps are those that appear with use of the ASCII **SET Z** command.

Perform the following on the premise that the wire connected to the polarity terminal on the CT is also connected to the polarity terminal on the relay:

Step 1. Start at the CT polarity markings.

Step 2. Move toward the protected bus-zone and determine polarity.

- ➢ Polarity is positive (P) when the movement is through the CT, (*Figure 1.16*), or
- ➢ Polarity is negative (N) when the movement is away from the CT (*Figure 1.17*).

Where **Bus-Zone** is the busbar that will be entered as the **Bus-Zone** argument of the **Terminal**, **Bus-Zone**, and **Polarity (P, N)** prompt, as shown in *Figure 1.16* and *Figure 1.17*.

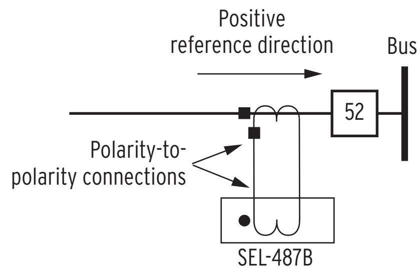


Figure 1.16 Positive Reference Direction

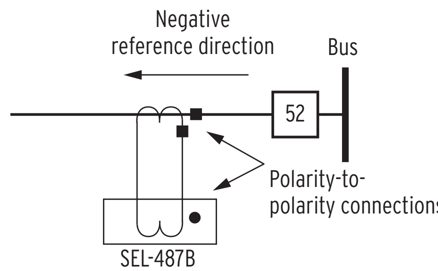


Figure 1.17 Negative Reference Direction

Disconnect Requirements

Disconnect auxiliary contacts provide Zone Selection Logic with the information required to dynamically assign the appropriate current inputs to the correct differential elements. To ensure correct differential element operation, the contacts must comply with the requirements listed in *Table 1.1*.

Table 1.1 Disconnect Auxiliary Contact Requirements to Ensure Correct Differential Element Operation

Operation	Requirement
From disconnect open to disconnect close operation.	Assign the currents to the applicable differential element before the disconnect reaches the “arcing” point, the point where primary current starts to flow.
From disconnect close to disconnect open operation.	Remove the current from the applicable differential element only once the disconnect has passed the “arcing” point, the point where primary current has stopped flowing.

Figure 1.18 shows the disconnect auxiliary contact requirements with respect to the arcing point. The position of 0% travel in *Figure 1.18* indicates the position when the main contacts are fully open, and the 100% position when the main contacts are fully closed.

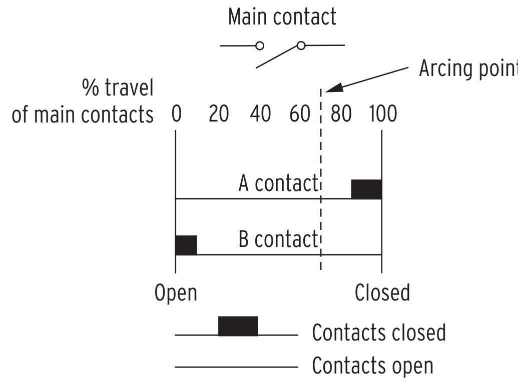


Figure 1.18 Disconnect Auxiliary Contact Requirements With Respect to the Arcing Point for an Open-to-Close Disconnect Operation

When both 89A and 89B contacts are available, use the disconnect monitoring logic in the SEL-487B to establish the principle of

(disconnect) NOT OPEN = (disconnect) CLOSED

Applying this principle, the relay properly coordinates the primary current flow and the CT current assignment to the appropriate differential element. When both 89A and 89B disconnect auxiliary contacts are available, use the disconnect monitoring logic to monitor the disconnect operating time and disconnect status. *Table 1.2* shows the four possible disconnect auxiliary contact combinations and the way the relay interprets these combinations.

Table 1.2 Disconnect A and B Auxiliary Contact Status Interpretation

Case	89A01	89B01	Disconnect Status (89 CLnn)
1	0	0	Closed (1)
2	0	1	Open (0)
3	1	0	Closed (1)
4	1	1	Closed (1)

Table 1.2 (Disconnect Status column) shows that the output from the disconnect monitor logic interprets the disconnect as always closed, except for Case 2. With this interpretation, the relay assigns the input currents to the applicable differential elements for Case 1, Case 3, and Case 4. The following discussion considers the four cases in more detail.

Disconnect Open to Close Operation

Figure 1.19 shows the disconnect main contact starting to travel in an open-to-close operation. Auxiliary contact B is still closed, and auxiliary contact A is open. *Table 1.2* shows this as Case 2; the disconnect is considered open, and the current is removed from all differential elements. This is the only combination of auxiliary contacts for which the relay considers the disconnect main contacts to be open.

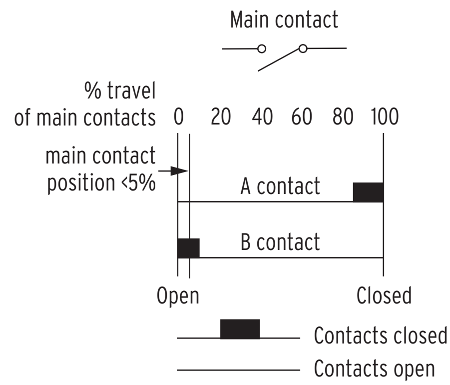


Figure 1.19 Disconnect Main Contacts and Auxiliary Contact A Open, Auxiliary Contact B Closed; Disconnect Is Considered Open

Intermediate Position

NOTE: The relay includes 48 alarm timers that provide individual time settings for 48 disconnect logic circuits. These individual timers are useful in installations where the disconnect travel times differ substantially. In particular, sequentially operated devices (pantographs, for example) have travel times much longer than normal disconnects. Relay Word bit 89OIP represents the OR combination of Relay Word bits 89OIP01 through 89OIP48, and Relay Word bit 89AL is respectively the OR combination of Relay Word bits 89AL01 through 89AL48.

Figure 1.20 shows the intermediate position (Case 1 in *Table 1.2*) in a disconnect open-to-close operation, with both A and B auxiliary contacts open for a period of time. Enter this time duration as the disconnect switch alarm timer setting value (89ALP*nn*). By choosing the auxiliary contacts that will change status as soon as disconnect travel starts and close only near the end of travel, the intermediate position time duration can be accurately measured. Should the disconnect remain in the intermediate position for longer than the 89ALP*nn* (*nn* = 1 though 48) time setting, the disconnect switch alarm timer expires and asserts 89AL*nn*, the disconnect monitor alarm.

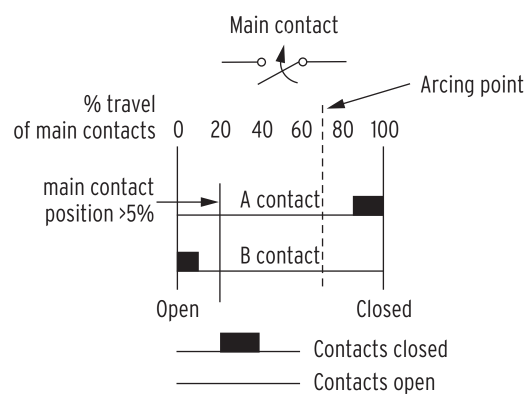


Figure 1.20 Intermediate Position With Both Auxiliary Contacts Open; the Disconnect Is Considered Closed

When auxiliary contact B opens, the disconnect is considered closed (Case 1 in *Table 1.2*). When the disconnect is considered closed, the CT currents are assigned to applicable differential elements, and the disconnect switch alarm timer starts to time. Because disconnect auxiliary contact B opens well in advance of the arcing point, the CT currents are assigned to applicable differential elements before primary current flows.

Auxiliary Contact A Closes

Figure 1.21 shows contact status after auxiliary contact A closes, with the main contact past the arcing point and approaching the end of the close operation.

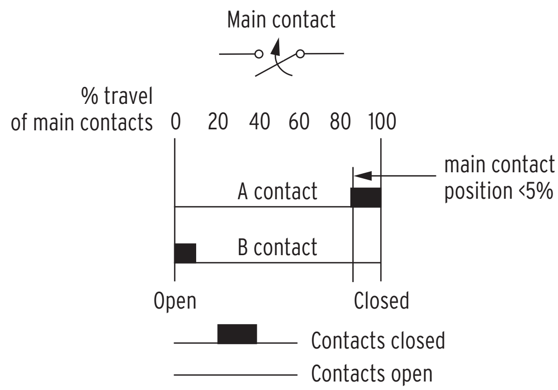


Figure 1.21 The Main Contact Has Completed 95% of Travel; Contact A Is Closed, Contact B Is Open, and the Disconnect Is Considered Closed

When the A contact closes, the disconnect switch alarm timer stops and the Disconnect Monitoring Logic considers the disconnect main contact to be closed.

Disconnect Open and Closed Simultaneously

Case 4 is an illegitimate condition, with the disconnect auxiliary contacts showing the disconnect main contact to be open and closed simultaneously. Timer 89ALP*nn* times for this condition and asserts Relay Word bit 89AL*nn* when the disconnect auxiliary contacts remain in this condition for a period exceeding the timer setting. The relay considers the disconnect main contact closed during this period, and the CTs are considered in the differential calculations.

Close-to-Open Operation

For the close-to-open operation, CT currents must remain assigned to the differential elements for as long as primary current flows. When the auxiliary contact A opens (Case 1), we again enter the intermediate position, as depicted in *Figure 1.20*. In the intermediate position, the CT currents are still assigned to the differential elements, and the disconnect switch alarm timer (89ALnn) starts to time. Only when auxiliary contact B closes (*Figure 1.19*) are the CT currents removed from the differential elements, which are safely past the arcing point.

Many disconnect switches provide only auxiliary contact B. *Table 1.3* shows the two possible disconnect auxiliary contact positions and status interpretations.

Table 1.3 Disconnect Auxiliary Contact Status Interpretation When Only Auxiliary Contact B Is Available

89B01	Disconnect Position
0	Closed
1	Open

Alias Names

Any Relay Word bit, analog quantity, or default terminal name can be renamed with more meaningful names to improve the readability of fault analysis and customized programming. Observe the following restrictions when renaming:

- Maximum of seven digits
- Valid characters are listed below:
  - 0, 1 . . . 9
  - A, B . . . Z (uppercase only)
  - _ (underscore)

No Relay Word bit, analog quantity, or terminal name may appear more than once in the alias settings. Alias names cannot correspond to an already existing Relay Word bit, analog quantity, or terminal name. When an alias is removed, all settings that referenced that alias revert back to the original (primitive) name. For example, assign the alias name OVER to the primitive name 50P01, and then enter OVER into some protection SELOGIC® control equations. When the alias OVER is removed, all protection SELOGIC control equations will revert to the primitive name (50P01) instead of to the alias name (OVER). The torque-control setting for the time-overcurrent element would change from 51P01TC := OVER to 51P01TC := 50P01. However, if 50P01 were set to a new alias, the element would use the new alias name. For example, if alias 50P01,OVER were set and you entered 50P01,O_C, the 50P01 element would use the alias O_C.

Duplicate alias names and blank entries are not allowed. All settings accept aliases, and when an alias exists for an element, the relay displays the alias for that element. Aliases appear in event reports, settings (set and show), and the **TAR** command. *Figure 1.22* shows a feeder called New York that is wired to the analog channel I01. Feeder New York connects to Bus-Zone NORTH when the disconnect auxiliary contact wired to IN205 closes.

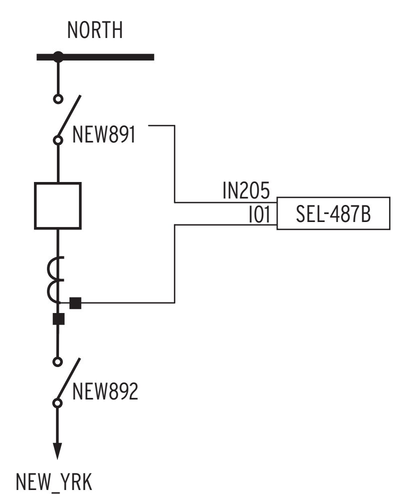


Figure 1.22 Alias Name Example for NEW_YRK Terminal

The following steps describe how to set the I01 and BZ1 aliases:

Step 1. Type **SET T <Enter>** to use the alias function.

The syntax is “existing name” comma “alias name.” For example, the primitive name for the CT input is I01, and we want to change this to the more descriptive feeder name, “New York.” Including the space, the number of characters is eight, one more than the allowable number of seven. Changing the name to “New Yrk” reduces the character count to seven, but the name still contains two types of characters not permitted (a space and four lowercase letters (ew rk)).

Step 2. Type **LIST <Enter>** at the `=>>` prompt to view all existing alias names.

From the display, we see that Terminal I01 and Bus-Zone BZ1 already have alias names.

Step 3. Type **I01,NEW_YRK <Enter>** as shown in *Figure 1.23*.

The prompt shows the existing default value, if any.

Step 4. Type **> 7 <Enter>** after assigning the new alias to Terminal I01 to move to the BZ1 line.

Step 5. Enter **BZ1,NORTH <Enter>** to set the new alias for BZ1.

Step 6. Type **> <Enter>** to move directly to the end of the list.

Step 7. Type Y <Enter> at the `Save Settings (Y,N)?` prompt to save the settings.

Step 8. Type **END <Enter>**.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
.
.
.

68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"

1: I01,"FDR_1"
?  I01,NEW_YRK <Enter>
2: I02,"FDR_2"
?  >7 <Enter>
7: BZ1,"BUS_1"
?  BZ1,NORTH <Enter>
8: BZ2,"BUS_2"
?  > <Enter>
70:
?  END <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"NEW_YRK"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"NORTH"
8: BZ2,"BUS_2"
.
.
.

69: TLED_24,"IRIGLED"

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.23 Assigning Alias Names

Bus-Zone Configurations

Dynamic zone selection is the process the relay uses to assign or remove CT currents from the differential elements as a function of the boolean value (logical 0 or logical 1) of a particular SELOGIC control equation. The SELOGIC control equation is a setting in the form of I*nn*BZ*k*V:= (*nn* = 01 through 18, and *k* = 1 through 6). When setting SELOGIC control equations, use a separate SELOGIC control equation for each busbar to which the terminal can connect.

In general, a terminal can be identified as either a normal terminal (feeders, lines, transformers, etc.) or as a tie breaker (buscoupler). For terminals, typical inputs are disconnect auxiliary contacts and, in some cases, circuit breaker auxiliary contacts. Buscouplers have specific logic and configuration options that require inputs in addition to disconnect and circuit breaker auxiliary contacts to ensure security and dependability.

When configuring bus-zone protection, the goal is to accomplish the following:

➤ Protect the busbars for all operating conditions

➤ Eliminate all dead zones

➤ Open the minimum number of breakers when tripping

➤ Implement the check zone without disconnect supervision, if a check zone is required

When the terminal-to-bus-zone SELOGIC control equation (I*nn*BZ*k*V) is logical 0, differential calculations do not consider the CT inputs from that specific terminal, and no trip outputs from the differential elements are issued to that terminal. Of particular concern are instances when more than one disconnect for any particular terminal are closed at the same time. When this happens, parallel paths form, possibly resulting in the unbalance of multiple zones, as shown in *Figure 1.24* and *Figure 1.25*. Under balanced conditions, the current toward the busbars equals the current away from the busbars, and the differential current in any differential element is practically zero.

In practice, the most popular implementation for preventing misoperation when parallel paths form is to combine the parallel paths into a single zone and route the CTs to a single differential element. Another option is to configure one zone as a check zone by combining all terminals at a specific voltage level into a single zone independent of the terminal-to-bus-zone SELOGIC control equations. Using the check zone as a second trip criterion prevents relay misoperation in the case of parallel paths.

In general, apply the following rules when setting terminal-to-zone SELOGIC control equations:

➤ Observe the correct CT polarity

➤ Avoid parallel operating conditions

➤ When parallel paths are unavoidable, take necessary precautions

Two situations exist where parallel paths are unavoidable: when two disconnects are closed simultaneously and when using inboard (bushing) CTs.

Two Disconnects Closed Simultaneously

Figure 1.24 shows a double busbar layout in which two disconnects can be closed simultaneously. With the tie breaker (TZ) connected in overlap, CT1 and CT2 form Differential Element 1, and CT3 and CT4 form Differential Element 2. There are no parallel paths in *Figure 1.24*, and both differential elements are balanced. Calculate the differential currents with the following expression:

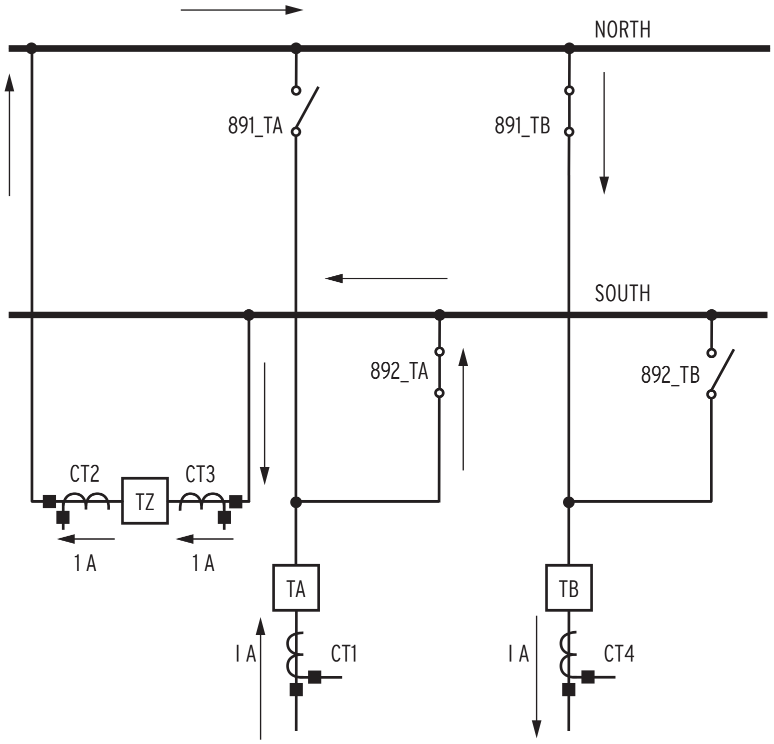
$$I_{DIFF1} = \sum_{1}^{n} I_n$$

Equation 1.1

where:

I_{DIFF1} = The differential current calculated in Differential Element 1

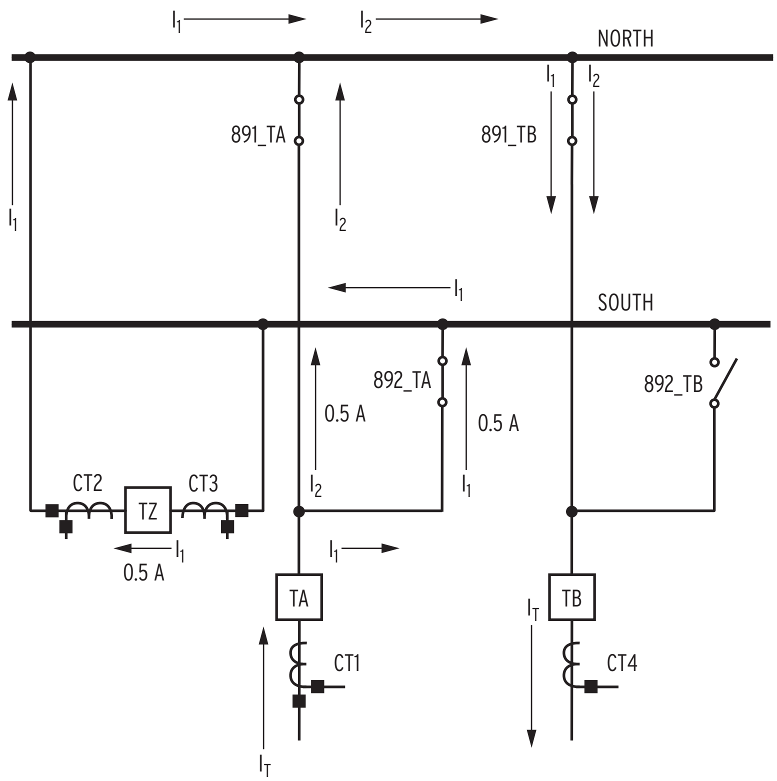
I_n = CT currents from the *n* terminals assigned to Differential Element 1



I_{DIFF1} = CT1 - CT2 = 1 - 1 = 0
I_{DIFF2} = CT3 - CT4 = 1 - 1 = 0

Figure 1.24 Both Differential Elements Balanced

Closing 891_TA in *Figure 1.25* forms a parallel path between the two busbars, and both differential elements are unbalanced.



I_{DIFF1} = CT1 + CT2 = 1 – 0.5 = 0.5
I_{DIFF2} = CT3 + CT4 = 0.5 – 1 = –0.5
$I_1 + I_2 = I_T$

Figure 1.25 Both Differential Elements Unbalanced

To prevent misoperation, combine the two bus-zones by stating the conditions governing the combinations during setting of bus-zones-to-bus-zones connections. When using bushing (inboard) CTs, combining bus-zones involves including a circuit breaker as part of the connection. You can include a circuit breaker provided that the circuit breaker auxiliary contact is wired to the relay and included in the bus-zones-to-bus-zones settings.

Inboard (Bushing) CTs

Figure 1.26 shows an outboard CT, and *Figure 1.27* shows an inboard CT. Defining a CT as inboard or outboard only has meaning when a terminal is on transfer. To define the terms, refer to the area between the circuit breaker and the CT, and determine the connection to the transfer bus.

- Outboard CT: the connection to the transfer bus is between the circuit breaker and the CT (*Figure 1.26*).
- Inboard CT: the connection to the transfer bus is not between the circuit breaker and the CT (*Figure 1.27*).

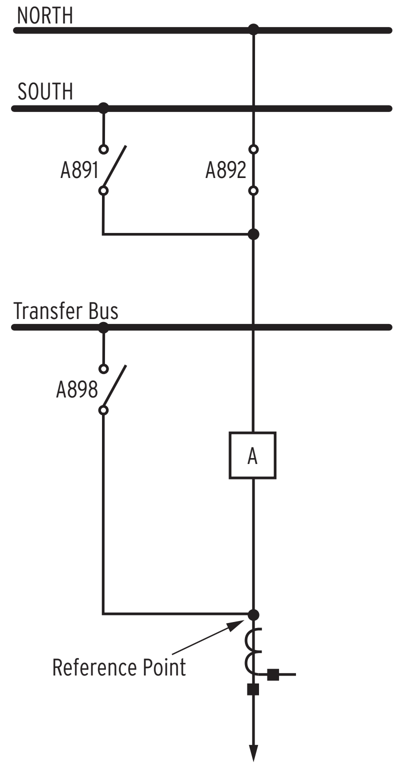


Figure 1.26 Outboard CT

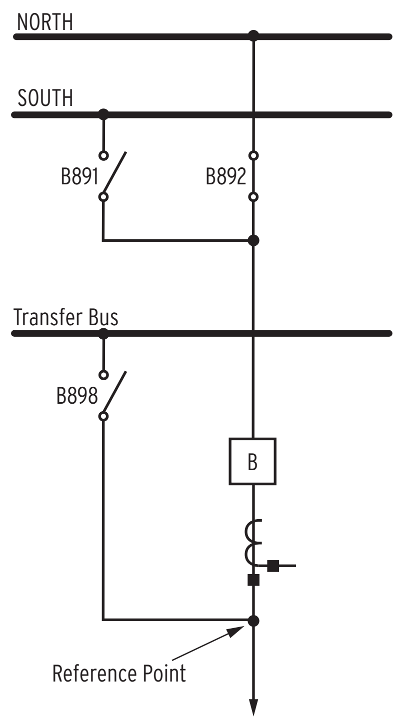


Figure 1.27 Inboard CT

Bushing CTs (typically the source of inboard CTs) present two difficulties to bus protection when a terminal is on transfer:

➤ A transfer differential zone cannot be formed because of a lack of CT inputs.

- The check zone is unbalanced.

Not having a transfer differential zone is not a major problem if it is understood that the transfer busbar becomes part of the line and forms part of the line protection when a terminal is on transfer. However, the unbalanced check zone usually necessitates blocking busbar protection when a terminal is on transfer.

Terminal Configurations

In essence, busbar protection is assigning the correct CT currents to the appropriate differential elements. Disconnect auxiliary contacts provide the information necessary for busbar protection, and breaker auxiliary contacts provide the breaker status for refining the protection. SELOGIC control equations provide the mechanism for declaring the conditions when the currents are assigned to the appropriate differential elements. Entering data in the relay requires two steps. The first identifies the terminal and attributes, the second involves creation of the SELOGIC control equation stating the conditions for the CTs to be considered in the differential calculation. Buscouplers (tie breakers) require more condition information when two or more bus-zones are combined.

Step 1. Identify the terminal, the bus-zone to which the terminal can connect, and the CT polarity when this connection is made.

The following is the relay prompt for the *Step 1* entry:

```
Terminal, Bus-Zone, Polarity (P,N)
?
```

Step 2. State the conditions when **Terminal** will be connected to the **Bus-Zone**:

I01BZ2V :=

Think of **Terminal** as the CT of that particular terminal and **Bus-Zone** as the busbar to which the CT will be connected for differential and restraint current calculations. In other words, assign the CT (**Terminal**) to busbar (**Bus-Zone**) under the following conditions: **I01BZ2V := <conditions>**.

Figure 1.28 shows Terminal NEW_YRK. The differential calculations consider the CT when disconnect NEW891 closes to complete the connection to Bus-Zone NORTH.

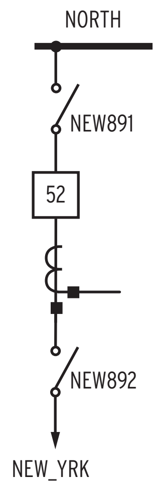


Figure 1.28 Terminal NEW_YRK Disconnects NEW892 and NEW891 and Bus-Zone NORTH

Step 3. Enter the data as follows:

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH,P <Enter>
```

Entering incorrect information may result in relay misoperation. To reduce potential entry of incorrect information, the relay provides a double check to verify that terminal and bus-zone connections are indeed as intended. The next prompt has two parts:

- ➢ The relay states terminal and bus-zone alias names just entered.
- ➢ The relay generates a prompt with the primitive terminal and bus-zone names.

Thus, the prompt now appears as follows:

```
NEW_YRK to NORTH Connection (SELogic Equation)
I01BZ1V :=
```

Step 4. Enter the conditions under which Terminal NEW_YRK is to be assigned to Busbar NORTH by specifying the particular disconnect (89) auxiliary contact that will connect the terminal to the busbar.

For example, when Disconnect NEW891 is closed, Terminal NEW_YRK is connected to Busbar NORTH. A Terminal, Bus-Zone, Polarity (P,N), and I01BZ1V setting is required for each 89 contact that results in a terminal-to-busbar connection. Consider a terminal that can be connected to Busbar 1, Busbar 2, and the transfer bus. Because the terminal connects to three busbars, provide terminal-to-bus-zone (Terminal, Bus-Zone, Polarity) and conditions for consideration in the differential calculations [I01BZ*n*V ($n = 3$)] for each of the three busbars.

Step 5. Enter the following settings for Terminal NEW_YRK:

```
NEW_YORK to NORTH Connection (SELogic Equation)
I01BZ1V := NEW891 <Enter>
```

Entries here assign CT currents to differential elements. Take care to first investigate the position of the CT for each entry. For example, refer to *Figure 1.26*, and observe that regardless of which disconnect closes (A891, A892 or A898), current always flows through the CT. This is not the case with inboard CTs; closing B898 in *Figure 1.27* bypasses the CT, and no current flows in the inboard CT.

Step 6. Follow the guidelines for establishing CT polarity (*Guideline for Establishing CT Polarity on page A.1.14*) to determine the CT polarity. Following the steps (shown in *Figure 1.29*), we determine that the CT polarity is positive.

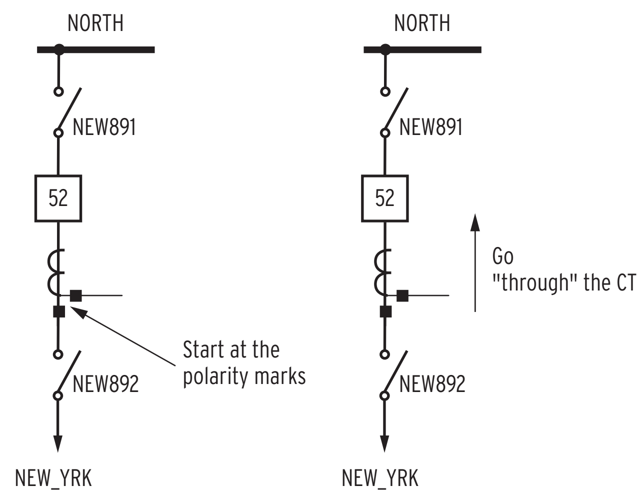


Figure 1.29 Determine the CT Polarity to Select P or N for the Polarity Setting

Step 7. Omit the final argument if the CT polarity is positive.

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH,P <Enter>
```

It has the same meaning as

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH <Enter>
```

Buscoupler (Tie Breaker) Configurations

In general, buscouplers are usually configured according to one of the three cases shown in *Figure 1.30*:

- Case 1: Single CT, single or two cores (two cores shown) with overlap
- Case 2: CT either side of the breaker, configured in overlap
- Case 3: CT either side of the breaker with breaker differential

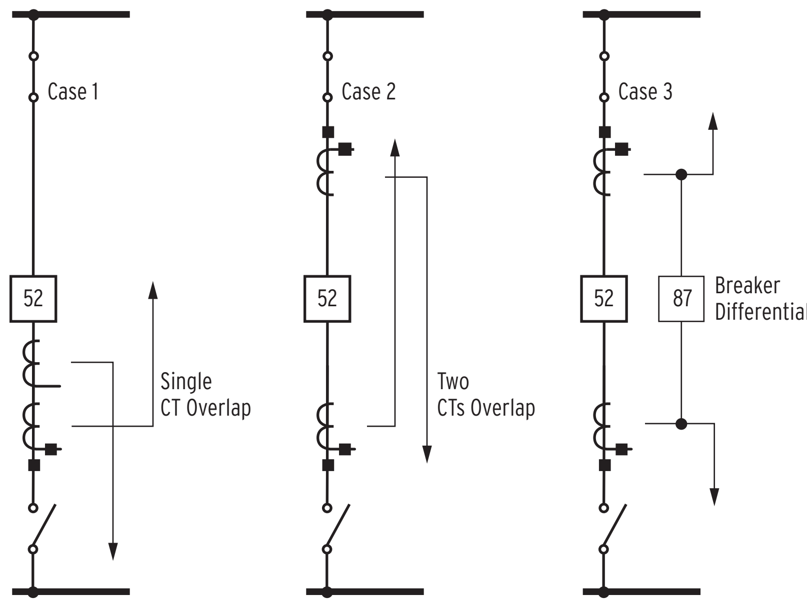


Figure 1.30 Three Typical Cases of Buscoupler Configurations

A discussion on how to set the three configurations follows.

Label all CTs as indicated in *Figure 1.31* (i.e., CPL1 and CPL2) with the understanding that CPL1 is wired to Terminal I01, and CPL2 to Terminal I02 of the SEL-487B.

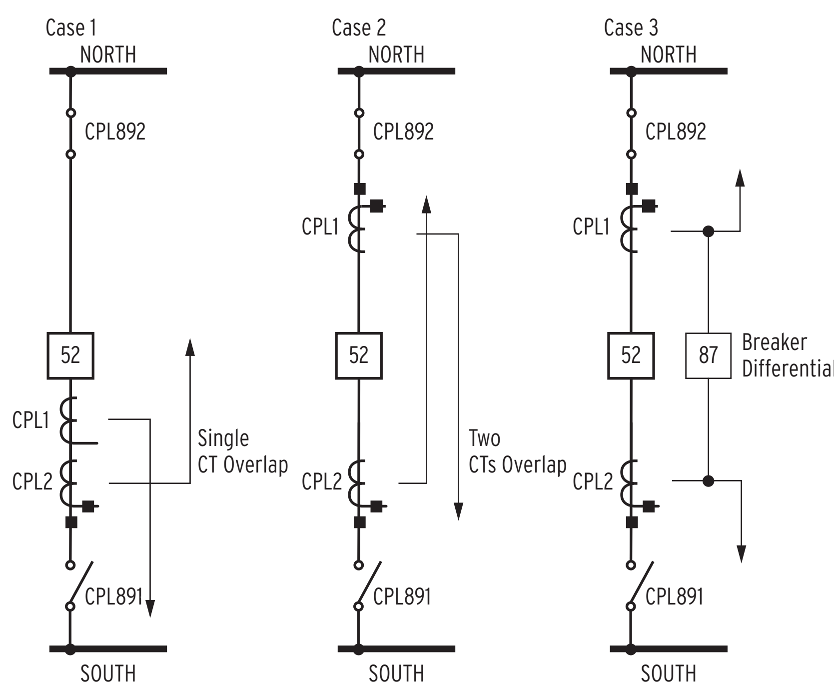


Figure 1.31 General Information Regarding the Three Typical Buscoupler Configurations

Case 1: Single CT, Single or Two Cores (Two Cores Shown) With Overlap

Step 1. For an overlap, establish the following relationships:

- ➢ CPL1 and SOUTH when CPL891 is closed
- ➢ CPL2 and NORTH when CPL892 is closed

Step 2. After applying guidelines for establishing CT polarity (see *Guideline for Establishing CT Polarity on page A.1.14*), we determine that the polarity of Terminal CPL1 is negative, as shown in *Figure 1.32*:

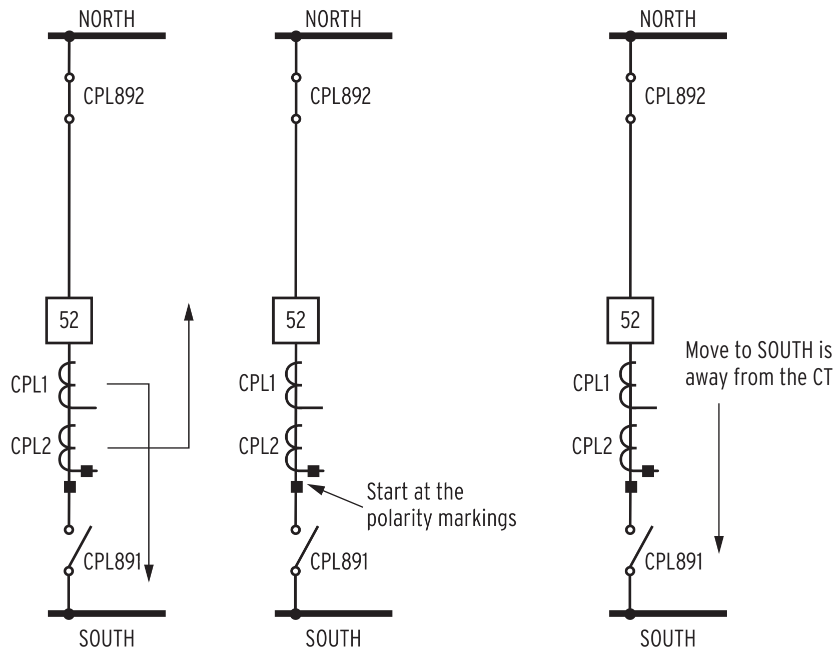


Figure 1.32 Steps in Establishing Negative CT Polarity for Terminal CPL1

Step 3. Similarly, after applying guidelines for establishing CT polarity, we determine that the polarity of Terminal CPL2 is positive, as shown in *Figure 1.33*.

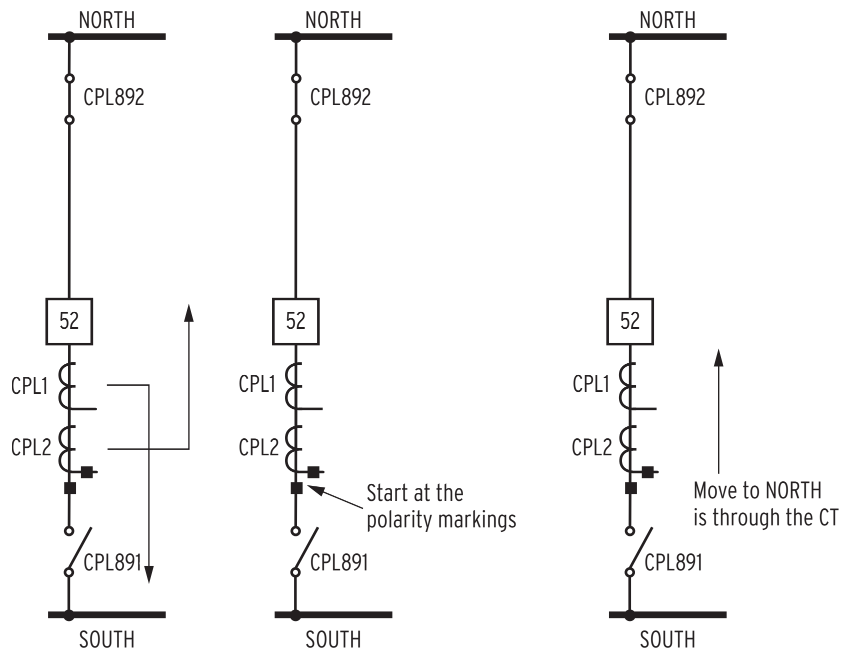


Figure 1.33 Steps in Establishing Positive CT Polarity for Terminal CPL2

Step 4. *Figure 1.34* shows an extract from the **SET Z 1** ASCII command in determining the terminal-to-bus-zone settings in the relay.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,SOUTH,N <Enter>
CPL1 to SOUTH Connection (SELogic Equation)
I01BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  CPL2,NORTH,P <Enter>
CPL2 to NORTH Connection (SELogic Equation)
I02BZ1V := CPL892 <Enter>
```

Figure 1.34 Using the SET Z 1 Command to Determine Terminal-to-Bus-Zone Settings

This concludes the Case 1 configuration.

Case 2: CT Either Side of the Breaker, Configured in Overlap

Step 1. As we did before for an overlap, establish the following relationships:

- ➢ CPL1 and SOUTH when CPL891 is closed
- ➢ CPL2 and NORTH when CPL892 is closed

Step 2. After applying the guidelines for establishing CT polarity (see *Guideline for Establishing CT Polarity on page A.1.14*), we determine the polarities of both Terminals CPL1 and CPL2 to be positive, as shown in *Figure 1.35*.

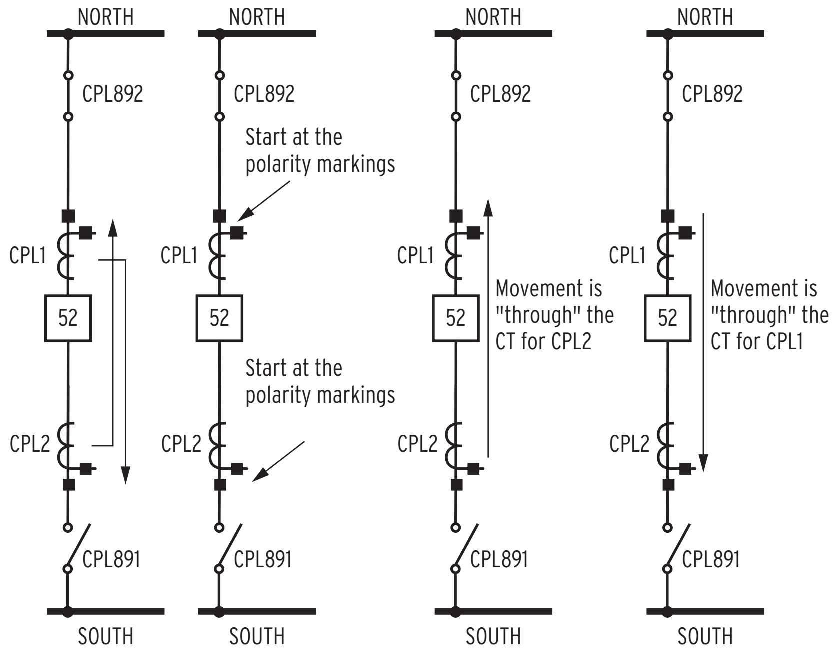


Figure 1.35 Steps in Establishing Positive CT Polarity for Both Terminals CPL1 and CPL2

Figure 1.36 shows an extract from use of the **SET Z 1** ASCII command to set the terminal-to-bus-zone settings in the relay.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,SOUTH,P <Enter>
CPL1 to SOUTH Connection (SELogic Equation)
I01BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,NORTH,P <Enter>
CPL21 to NORTH Connection (SELogic Equation)
I02BZ1V := CPL892 <Enter>
```

Figure 1.36 Using the SET Z 1 Command to Set the Terminal-to-Bus-Zone Settings

This concludes the configuration for Case 2.

Case 3: CT Either Side of the Breaker With Breaker Differential

Step 1. Use one of the six available differential elements to configure the breaker differential.

For the buscoupler in the example, three differential elements are required; the third differential element covers only the common area between the two CTs.

In addition to the breaker differential, configure the same CTs (CPL1 and CPL2) to balance SOUTH and NORTH. For the breaker differential, establish the following relationships:

For balancing SOUTH and NORTH:

- ➢ CPL1 and NORTH when CPL892 is closed
- ➢ CPL2 and SOUTH when CPL891 is closed

For the breaker differential:

- ➢ CPL1 and ZONE3 when CPL891 or CPL892 is closed
- ➢ CPL2 and ZONE3 when CPL891 or CPL892 is closed

Considering both Terminals CPL1 and CPL2, and after we apply the guidelines for establishing CT polarity (see *Guideline for Establishing CT Polarity on page A.1.14*), we determine that both polarities are negative, when we balance SOUTH and NORTH, as shown in *Figure 1.37*.

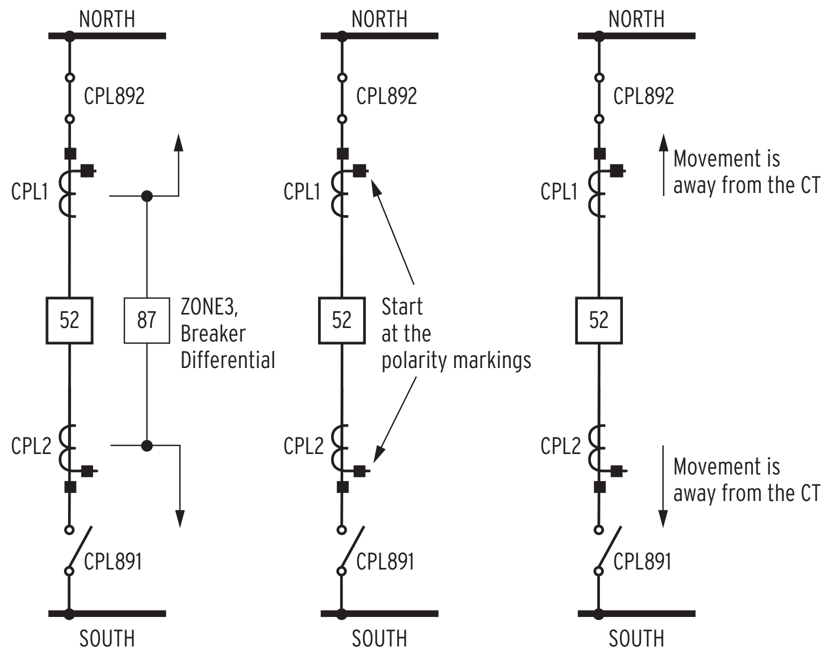


Figure 1.37 Steps in Establishing Negative CT Polarities for Both Terminals CPL1 and CPL2 When Balancing SOUTH and NORTH

Step 2. After applying guidelines for establishing CT polarity (see *Polarity on page A.1.13*), we determine the polarities of both Terminals CPL1 and CPL2 to be positive for the breaker differential (ZONE3), as shown in *Figure 1.38*.

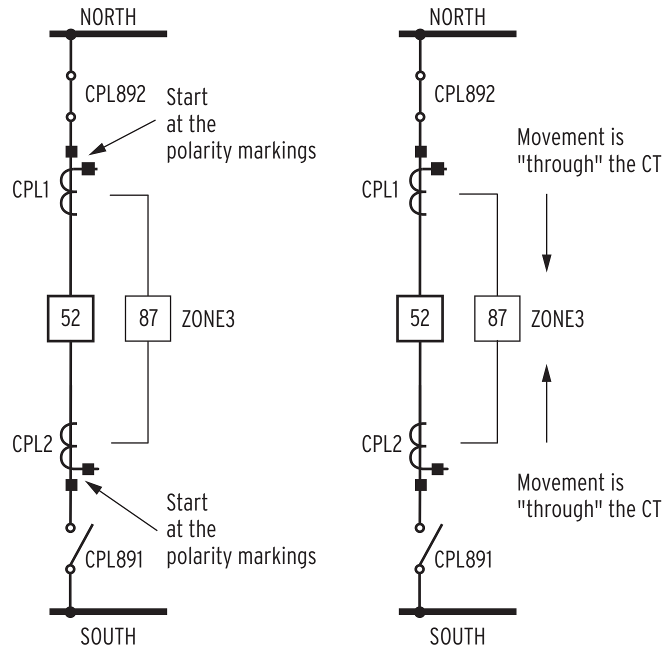


Figure 1.38 Steps in Establishing Positive CT Polarities for Both Terminals CPL1 and CPL2 for the Breaker Differential

Figure 1.39 shows the entries for Terminals CPL1 and CPL2.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,NORTH,N <Enter>
CPL1 to NORTH Connection (SELogic Equation)
I01BZ1V := CPL892 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,ZONE3,P <Enter>
CPL1 to ZONE3 Connection (SELogic Equation)
I01BZ3V := CPL891 OR CPL892 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,SOUTH,N <Enter>
CPL2 to SOUTH Connection (SELogic Equation)
I02BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,ZONE3,P <Enter>
CPL2 to ZONE3 Connection (SELogic Equation)
I02BZ3V := CPL891 OR CPL892 <Enter>
```

Figure 1.39 Entries for Terminals CPL1 and CPL2

Bus-Zone-to-Bus-Zone Connections

Bus-zone-to-bus-zone settings are used only when bus-zone-to-bus-zone connections are formed between two or more busbars, particularly when the connection is formed without a circuit breaker between the busbars. For example, closing disconnects D891 and D892 in *Figure 1.40* forms a solid connection between NORTH and SOUTH, and there is no circuit breaker between the busbars.

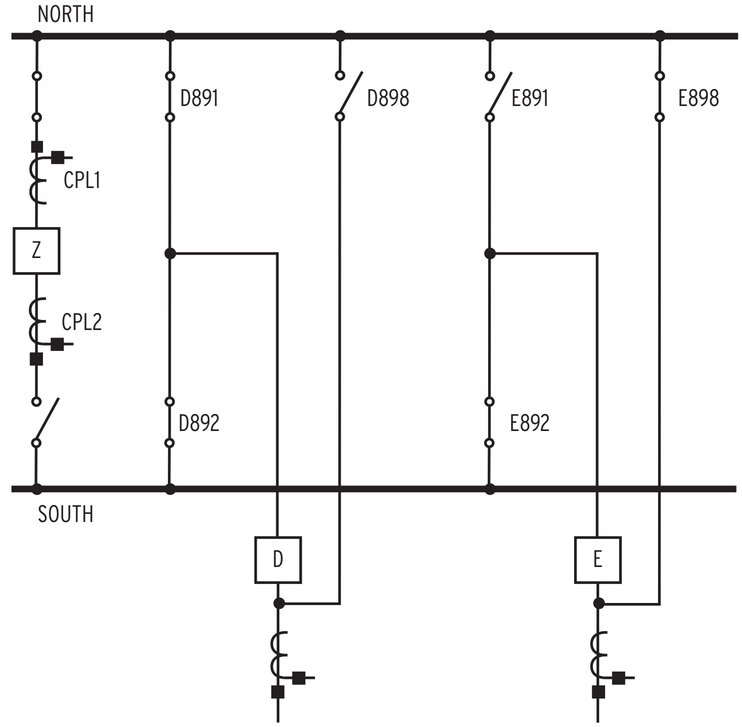


Figure 1.40 Forming Bus-Zone-to-Bus-Zone Connections With and Without a Circuit Breaker

By contrast, closing E892 and E898 or E891, E892, and E898 also forms a connection between Busbar 1 and Busbar 2, but now there exists a circuit breaker between the busbars, namely the Terminal E circuit breaker. The significance of the bus-zone-to-bus-zone connection is twofold.

- Both differential zones (SOUTH and NORTH) must operate when a fault develops on either zone during the time when the two differential zones are connected via disconnects D891 and D892 (or similar connections).
- Parallel paths are formed, and both differential zones may be unbalanced see *Figure 1.25*.

When two bus-zones are combined, buscoupler CTs are redundant and are removed from the differential calculations.

One protection philosophy requires the tripping of only those circuit breakers that can contribute fault current to optimize breaker maintenance. However, there is also the protection philosophy that requires all breakers in the faulted differential zone to be tripped. To satisfy both protection philosophies, the SEL-487B offers the choice of leaving the buscoupler closed or issuing a trip signal. The first prompt in this group asks you for the two busbars that will be combined.

Step 1. From *Figure 1.40*, we see that we would enter SOUTH and NORTH at the prompt (without spaces between the differential zone names or the comma).

```
Bus-Zone,Bus-Zone?
SOUTH,NORTH <Enter>
```

Step 2. Next, the SELOGIC control equation that declares the digital input conditions which must be a logical 1 for the relay to recognize the combination of SOUTH and NORTH. Again, the relay states the names you enter and then generates a prompt with the primitive names as a double check.

List all of the several possible combinations, separating each combination with the OR function. From *Figure 1.40*, NORTH and SOUTH are combined when D891 and D892 are closed, or when E891 and E892 are closed:

```
SOUTH to NORTH Connection (SELogic Equation)
BZ1BZ2V := (D891 AND D892) OR (E891 AND E892) <Enter>
```

NOTE: When the bus-zone-to-bus-zone SELOGIC control equation includes the circuit breaker, be sure to also include the breaker auxiliary contact status (not only the disconnect status) to ensure separate bus-zones when the circuit breaker is open.

This setting identifies the particular differential zones that can be combined and the conditions under which this combination can take place.

Step 3. The next setting allows you to select a subset of the conditions stated in the previous setting. In the present example, there is no subset, and the setting is a repeat of the previous setting.

```
Remove Terminals when NORTH and SOUTH Bus-Zones merge (SELogic Equation)
BZ1BZ2R := NA
?  (D891 AND D892) OR (E891 AND E892) <Enter>
```

Step 4. Next, state the terminals to be removed when the two differential zones are combined. In most cases, these terminals are the buscoupler CTs, as is the case in *Figure 1.40*. You would, therefore, enter the buscoupler terminal names at the prompt.

```
Terminals Removed when NORTH and SOUTH Bus-Zone merge (Ter k,...,Ter n)
BZ1BZ2M :=
?CPL1,CPL2 <Enter>
```

Step 5. To end this group, select whether the buscoupler must be tripped (**Y**) when a fault occurs in the combined protection zone during the time when the two bus-zones are merged, or whether the buscoupler must not be issued a trip signal (**N**). Again, as a double check, the relay states the primitive names of the terminals that must be removed:

```
Trip Terminals CPL1, CPL2 (Y,N)
BZ1BZ2T := N
?  Y <Enter>
```

Zone Supervision

This is the final check before a bus-zone trip (87Z1) is issued for each of the six differential zones. *Figure 1.41* shows the relay logic for this function, where the output from the differential calculations (87R1) is ANDed with the zone supervision conditions. See *Section 1: Protection Functions in the Reference Manual* for more information.

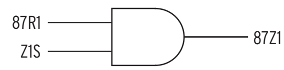


Figure 1.41 Zone Supervision Logic

This is a good place to include the overall check zone differential element output, if one was configured.

Assume Check Zone 1 was configured. Enter the following to include the check zone.

```
Z1S:= 87CZ1 <Enter>
```

Trip Logic

Figure 1.42 shows the steps necessary for assigning protection functions to the trip logic.

Make sure all selected protection functions appear in the trip equation.

For example, having selected the breaker failure protection, assign the output from this logic to the output contact, or the contact will not assert when the breaker failure protection operates. For Terminal I06 wired to OUT201, the following includes differential protection, internal breaker failure protection, and time-overcurrent protection.

```
=>>SET TR06 <Enter>
Group 1

Trip Logic

Trip 06 (SELogic Equation)
TR06 := NA
? 87BTR06 OR SBFTR06 OR 51P01T <Enter>
Unlatch Trip 06 (SELogic Equation)
ULTR06 := NA
?  END <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.42 Assign the Protection Functions to the Trip Logic

Output Assignments

Figure 1.43 shows the steps necessary for assigning the output from the trip logic (TRIP06) to output contact OUT201.

```
=>>SET O OUT201 <Enter>
Output

Interface Board #1

OUT201 := NA
?   TRIP06 <Enter>

OUT202 := NA
?   END <Enter>
Output

Main Board

.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.43 Assigning the Output From the Trip Logic to an Output Contact

Summary

In general, system configuration can be summarized in the four-step approach shown in *Figure 1.44*. Use the worksheets provided on the SEL-487B *Relay Product Literature CD* to collect and organize the data before configuring and setting the relay.

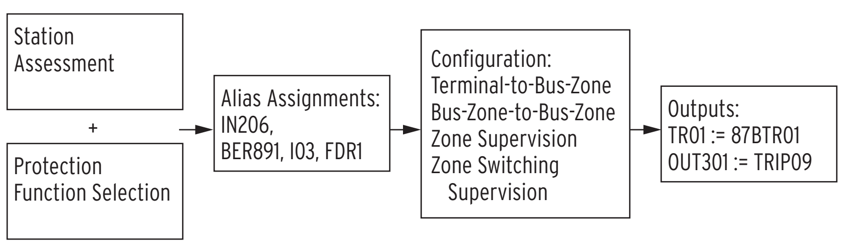


Figure 1.44 Information Flow Diagram

Step 1. Assess your station and select appropriate protection functions.

Inspect the substation layout to make the appropriate selection in terms of number of bus-zones, number of terminals, CT ratio mismatch, I/O count, etc.

As for protection functions, decide whether to use internal or external breaker failure protection, breaker differential, or an overlap coupler CT application (if two sets of CTs are available), etc.

Step 2. Assign alias names.

Because configuration settings use terminal names, assign alias names at this point.

Step 3. Configure your system.

Entries here determine the CT/differential element assignment with the terminal-to-bus-zone and bus-zone-to-bus-zone settings, while zone supervision and zone-switching supervision provide for additional control and information.

Step 4. Assign outputs.

For each terminal, select the relay functions for which the terminal will be issued a trip signal.

Use *Table 1.4* through *Table 1.9* to assist with *Step 1* of the configuration process.

Table 1.4 Primary Plant Data

Items	Requirement for Your Plant
Number of terminals (maximum 18)	
Number of busbars (maximum 6)	
Number of main zones (maximum 6)	
Number of check zones (maximum 1)	
Number of buscouplers or tie breakers (maximum 4)[a]	
Inboard CTs (Y,N)	
Maximum/minimum CT ratio	

[a] Mutually exclusive; sum of buscouplers and bus sections cannot exceed four.

Table 1.5 Data for Buscoupler 1 and Buscoupler 2

Buscoupler 1 Data		Buscoupler 2 Data	
Number of CTs		Number of CTs	
Overlap or differential		Overlap or differential	
Coupler security logic? Y, N[a]		Coupler security logic? Y, N[a]	
Breaker status logic? Y, N[b]		Breaker status logic? Y, N[b]	

[a] Allocate independent optoisolated inputs to the selected logic.
[b] Allocate one grouped optoisolated input to the selected logic for each logic.

Table 1.6 Data for Buscoupler 3 and Buscoupler 4

Buscoupler 3 Data		Buscoupler 4 Data	
Number of CTs		Number of CTs	
Overlap or differential		Overlap or differential	
Coupler security logic? Y, N[a]		Coupler security logic? Y, N[a]	
Breaker status logic? Y, N[b]		Breaker status logic? Y, N[b]	

[a] Allocate independent optoisolated inputs to the selected logic.
[b] Allocate one grouped optoisolated input to the selected logic for each logic.

Table 1.7 Disconnect, Breaker, and Input Data

Items	Requirement for Your Plant
Number of 89A (N/O) contacts?[a]	
Number of 89B (N/C) contacts?[b]	
Disconnect Monitoring Logic? (maximum 48)	
Zone-Switching Supervision Logic?	
Number of 52A contacts	

[a] There are on average (for 18 terminals) three optoisolated inputs available per terminal.
[b] Allocate independent optoisolated inputs to the selected logic.

Table 1.8 Breaker Failure Data

Items	Requirement for Your Plant
Number of internal breaker failure circuits	
Number of external breaker failure circuits	
Additional security?[a]	

[a] Allocate independent optoisolated inputs to the selected logic.

Table 1.9 End-Zone Protection

Items	Requirement for Your Plant
Number of 52A (N/O) contacts?[a]	
Number of communication outputs required?[b]	

[a] Allocate this number of common optoisolated input contacts.
[b] Allocate this number of independent output contacts.

Application 1: Single Bus and Tie Breaker (Three Relays)

This application describes the busbar arrangement shown in *Figure 1.45*, a single bus with bus sectionalizer (tie breaker), three-relay application. The busbar arrangement consists of two busbar sections, four feeders, and a tie breaker. Consider the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection functions selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation and alias name assignment
- ➤ Station layout update
- ➤ Relay setting and configuration

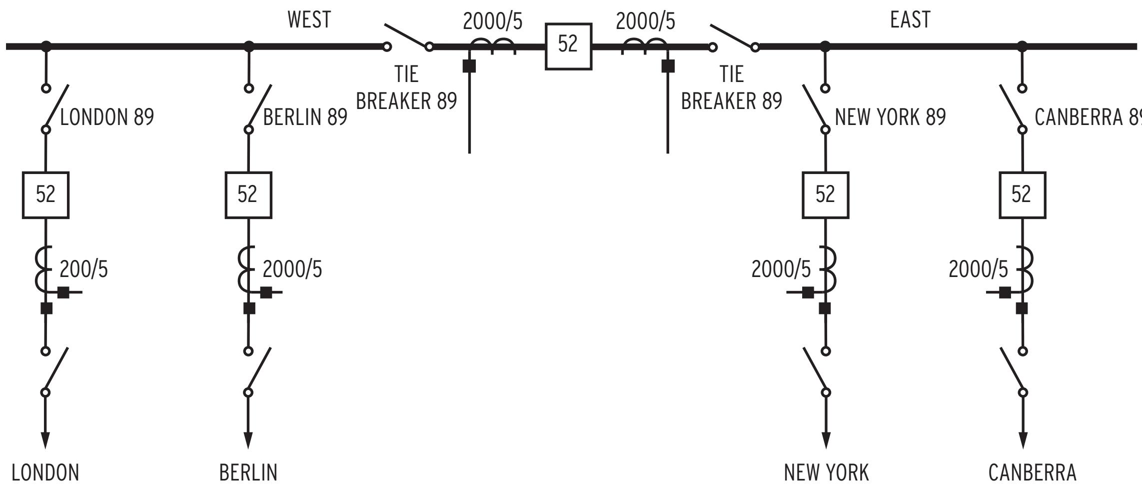


Figure 1.45 Single Bus With Bus Sectionalizer (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information and declares the tie-breaker (buscoupler or sectionalizing breaker) configuration. The classification for this application is as follows:

- Description
  - Single bus with tie breaker
- Current Transformers
  - Outboard (free standing)
- Disconnects
  - Both 89A and 89B disconnect auxiliary contacts are available
- Sectionalizing breaker (tie-breaker) configuration
  - Overlap
- Future expansion
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the 89 disconnect auxiliary contacts to dynamically configure the station.
2. Use the Disconnect Monitoring Logic.
3. Block the busbar protection for an open-circuit CT.
4. Configure check-zone protection.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process, because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for a check zone, but not for breaker failure protection.

The SEL-487B offers a number of protection functions as standard features, but also includes the capability through SELOGIC control equations to create user-configurable functions. Breaker failure protection is a standard function but check-zone protection is not. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- ➤ standard protection functions (available in the relay)
- ➤ user-defined protection functions (created using SELOGIC control equations)

Standard Functions

Refer to *Protection Philosophy* and select the standard functions required for the application. *Table 1.10* shows the selection of the standard functions.

Table 1.10 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection, Check-zone protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Enter the check zone and zone-specific conditions to supervise the zone-specific differential elements
Zone-switching supervision logic	No	89A and 89B disconnect contacts available; therefore, this logic is not required
Coupler security logic	No	Two CTs with overlap configuration do not require the coupler security logic
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Because the SEL-487B includes all protection functions necessary for this application as standard protection functions, we do not need any user-defined functions.

Check-Zone Protection

Figure 1.46 shows a station with check-zone protection. Check-zone protection stems from the philosophy of providing an additional trip criterion before issuing a busbar protection trip signal. This philosophy encompasses additional trip criteria such as directional elements and overcurrent elements.

When using check-zone protection as an additional criterion, the practice is to provide a measurement from a second differential element that is independent of the disconnect auxiliary contact status. Using a measurement independent of the disconnect auxiliary contact status prevents differential element misoperation resulting from disconnect auxiliary contact failure.

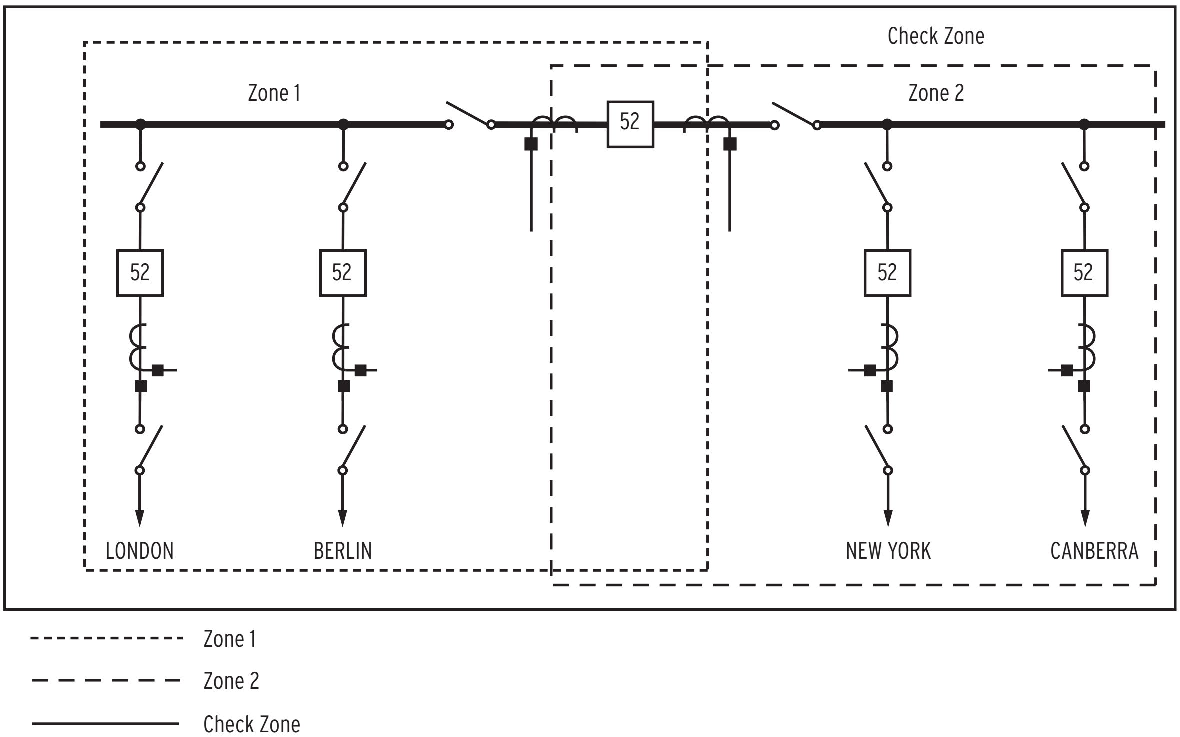


Figure 1.46 Station With Two Zone-Specific Bus-Zones and an Overall Check Zone

Both the Check Zone and either Zone 1 or Zone 2 differential elements must assert before a busbar protection trip output asserts. Use the Differential Element Zone Supervision setting to comply with the requirement for both check zone and zone-specific differential elements to assert. *Figure 1.47* shows the zone supervision logic. Relay Word bit 87R1 is the output from the Zone 1 differential element and Z1S is the SELOGIC control equation where we enter conditions for supervising the Zone 1 differential element. (See *Zone Configuration Group Settings on page A.1.55* for more detail.)

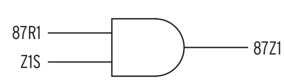


Figure 1.47 Zone Supervision Logic

Create the check-zone protection by configuring the available check zone when entering the zone configuration settings (ECHKZN := Y).

Number of Relays and I/O Boards

Selecting the relay has two parts:

- ➤ the number of relays (single-relay application or three-relay application)
- ➤ the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with as many as 18 CTs (seven 3-phase terminals), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.2* to calculate the number of current channels at the station, and use *Equation 1.3* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.2**

# of bus-zones required = # of per-phase station bus sections **Equation 1.3**

The number of per-phase CTs at the station is 18 and the number of bus-zones required is 2 (Zone 1 and Zone 2). The number of check zones required is 1 (Check Zone 1). One SEL-487B suffices for these requirements, but the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wiring) the input and output contacts to the other two relays. This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (LOND_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding LOND_A setting is LOND_B in the B-phase relay and LOND_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires one disconnect monitoring logic and the tie breaker requires two; therefore, the number of disconnect logics required is six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.4* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

relay inputs required = 2 • # disconnect monitoring logics **Equation 1.4**

Table 1.11 summarizes the input contact required for this application.

Table 1.11 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	6 • 2 = 12
Total number of inputs	12

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts for the disconnect auxiliary contact inputs. From the input contact perspective, we need one interface board. It is not necessary to include I/O for future expansion with the initial order; install additional I/O if and when required.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all breakers are part of the busbar differential protection, we want to trip each breaker upon differential protection operation. *Table 1.12* shows the breakdown and the total number of relay output contacts required.

Table 1.12 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts.

The interface boards may have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can be ordered with an option that provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- the selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- ➤ link specific CT inputs to specific relay analog channels
- ➤ link specific disconnect and circuit breaker inputs to specific relay input contacts
- ➤ link relay element/logic outputs to specific relay output contacts
- ➤ assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- ➤ Relay Word bit
- ➤ Analog quantity
- ➤ Terminal name
- ➤ Bus-Zone name
- ➤ Check-Zone name

Alias names are valid when they consist of a maximum of seven characters and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

Table 1.13 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT1 to relay channel I01, and assign to this CT the alias name SEC1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.13* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left to right from *Figure 1.45*.

Table 1.13 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	SEC1_A
TIE-BREAKER CT2, A-Phase	I02	SEC2_A
LONDON, A-phase	I03	LOND_A
BERLIN, A-phase	I04	BERL_A
NEW YORK, A-phase	I05	NEWY_A
CANBERRA, A-phase	I06	CANB_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.14*.

Table 1.14 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	WEST_A
BZ2	Bus-Zone 2	EAST_A

Check-Zone Alias Assignment

Each SEL-487B provides one check zone. For the A-phase relay, we use the check zone with the alias name as shown in *Table 1.15*.

Table 1.15 Alias Name for the Check Zone

Check-Zone Name	Description	Alias
CZ1	Check Zone	CHECK_A

Input to Logic Allocation and Alias Assignment

Table 1.11 shows that we require 12 digital inputs. We now assign the 12 digital input contacts to the selected logic and assign alias names to the input contacts and logic elements. Because of the functional requirement of this application, we do not need to use any digital inputs on the main board.

Input Contact to Logic Allocation and Alias Assignment, Interface Board 1 (200)

Table 1.16 shows the disconnect auxiliary contact input allocations and the alias names. Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs for breaker failure initiate inputs; these inputs are not used in the present application.

Table 1.16 Alias Names for the Breaker Status Logic Output Relay Word Bits

Input	Description	Alias
IN204	TIE-BREAKER disconnect (WEST) NO contact	ISE891A
IN205	TIE-BREAKER disconnect (WEST) NC contact	ISE891B
IN206	TIE-BREAKER disconnect (EAST) NO contact	ISE892A
IN207	TIE-BREAKER disconnect (EAST) NC contact	ISE892B
IN208	LONDON disconnect N/O contact	ILON89A
IN209	LONDON disconnect N/C contact	ILON89B
IN210	BERLIN disconnect N/O contact	IBER89A
IN211	BERLIN disconnect N/C contact	IBER89B
IN212	NEW YORK disconnect NO contact	INEW89A
IN216	NEW YORK disconnect NC contact	INEW89B
IN217	CANBERRA disconnect NO contact	ICAN89A
IN218	CANBERRA disconnect NC contact	ICAN89B

Assign Alias Names to the Selected Standard Logic

Referring to *Table 1.10*, the following is a discussion on each selected function. Alias name assignments are also included.

Disconnect Monitoring Logic and Disconnect Alias Assignment

Figure 1.48 shows one of the 48 disconnect monitor logic circuits available in the relay. (See *Disconnect Requirements on page A.1.15* for more information on the disconnect auxiliary contact requirements).

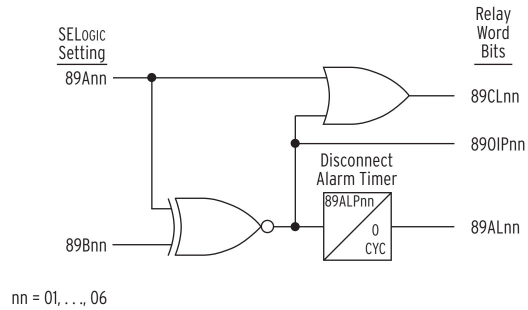


Figure 1.48 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.17 shows the alias names for the disconnect auxiliary contact Relay Word bits.

Table 1.17 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits

Input	Description	Alias
89A01	TIE-BREAKER disconnect (WEST) NO contact	SEC891A
89B01	TIE-BREAKER disconnect (WEST) NC contact	SEC891B
89A02	TIE-BREAKER disconnect (EAST) NO contact	SEC892A
89B02	TIE-BREAKER disconnect (EAST) NC contact	SEC892B
89A03	LONDON disconnect NO contact	LON89A
89B03	LONDON disconnect NC contact	LON89B
89A04	BERLIN disconnect NO contact	BER89A
89B04	BERLIN disconnect NC contact	BER89B
89A05	NEW YORK disconnect NO contact	NEW89A
89B05	NEW YORK disconnect NC contact	NEW89B
89A06	CANBERRA disconnect NO contact	CAN89A
89B06	CANBERRA disconnect NC contact	CAN89B

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets that the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations. We also assign alias names to the alarm Relay Word bits (89AL*nn*). *Table 1.18* shows the alias names.

Table 1.18 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits (Sheet 1 of 2)

Primitive Name	Description	Alias
89CL01	TIE-BREAKER disconnect (WEST) is closed	SEC189C
89CL02	TIE-BREAKER disconnect (EAST) is closed	SEC289C
89CL03	LONDON disconnect is closed	LOND89C
89CL04	BERLIN disconnect is closed	BERL89C
89CL05	NEW YORK disconnect is closed	NEWY89C
89CL06	CANBERRA disconnect is closed	CANB89C
89AL01	TIE-BREAKER disconnect (WEST) alarm	SEC189A

Table 1.18 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits (Sheet 2 of 2)

Primitive Name	Description	Alias
89AL02	TIE-BREAKER disconnect (EAST) alarm	SEC289A
89AL03	LONDON disconnect alarm	LOND89A
89AL04	BERLIN disconnect alarm	BERL89A
89AL05	NEW YORK disconnect alarm	NEWY89A
89AL06	CANBERRA disconnect alarm	CANB89A

Differential Trip Logic and Differential Element Alias Assignment

Figure 1.49 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information). *Table 1.19* shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 1.19 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	WESTA_T
87Z2	Zone 2 differential element trip	EASTA_T
87CZ1	Check Zone differential element trip	CHECA_T

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information).

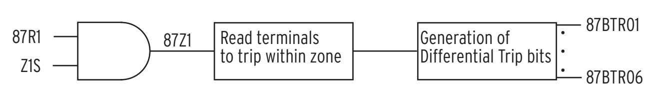


Figure 1.49 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.54* for more information). *Table 1.20* shows the primitive differential trip bit names, the alias names for the differential trip bits, and the terminal with which the relay associates each differential trip bit.

Table 1.20 Primitive Differential Trip Bit Names, Alias Names for the Differential Trip Bits, and Associated Terminals

Differential Trip Bit	Alias	Comments
87BTR01	87SEC1A	Associated with Terminal 01
87BTR02	87SEC2A	Associated with Terminal 02
87BTR03	87LON_A	Associated with Terminal 03
87BTR04	87BER_A	Associated with Terminal 04
87BTR05	87NEW_A	Associated with Terminal 05
87BTR06	87CAN_A	Associated with Terminal 06

Breaker Trip Logic and Trip Alias Assignment

Figure 1.50 shows the general tripping logic in the SEL-487B. (See *Section 1: Protection Functions in the Reference Manual* for more information).

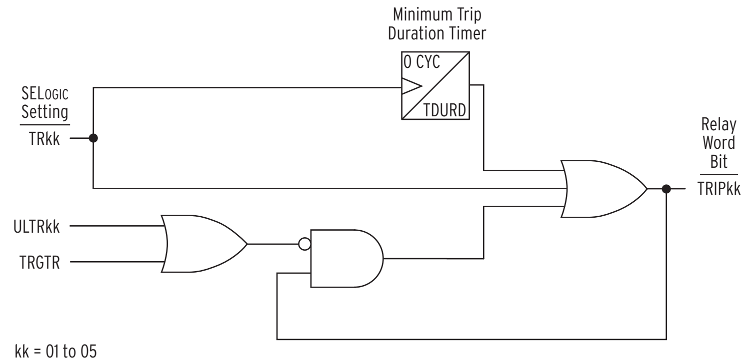


Figure 1.50 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers setting (NUMBK) and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK) setting. *Table 1.21* shows the five primitive and alias names for the trip logic of each terminal.

Table 1.21 Primitive and Alias Names for the Trip Logic of Each Terminal

Primitive Name	Description	Alias Name
TRIP01	Trip output of the sectionalizing breaker asserted	TRSEC_A
TRIP02	Trip output of the LONDON Terminal asserted	TRLON_A
TRIP03	Trip output of the BERLIN Terminal asserted	TRBER_A
TRIP04	Trip output of the NEW YORK Terminal asserted	TRNEW_A
TRIP05	Trip output of the CANBERRA Terminal asserted	TRCAN_A

Assign Alias Names to the User-Defined Logic

This application requires no user-defined logic.

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 1.12* shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts and assign alias names to the relay output contacts. *Table 1.22* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 1.23* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1 and the alias names of the of the interface board output contacts.

Output Alias Assignment, Main Board

This application requires no output contacts from the main board.

Table 1.22 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can be ordered to include six high-speed, high-interrupting output contacts. *Table 1.23* shows the alias assignment for the five terminals of the A-phase relay.

Table 1.23 Alias Assignment for the Five Terminals in Our Example

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	TIE-BREAKER trip logic output	SECTR_A
OUT202[a]	LONDON trip logic output	LONTR_A
OUT203[a]	BERLIN trip logic output	BERTR_A
OUT204[a]	NEW YORK trip logic output	NEWTR_A
OUT205[a]	CANBERRA trip logic output	CANTR_A

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 1.51*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the auxiliary terminal contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals

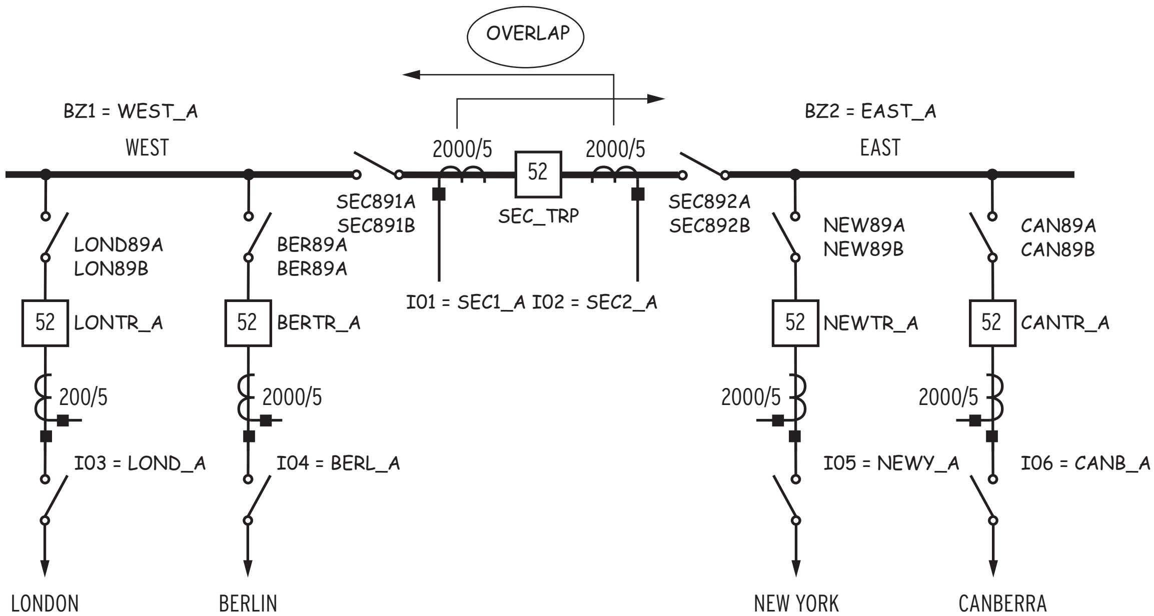


Figure 1.51 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. We set the following settings classes:

- ➤ Alias Settings
- ➤ Global Settings
- ➤ Zone Configuration Group Settings
- ➤ Protection Group Settings
- ➤ Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias settings class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.52*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"

1: I01,"FDR_1"
?
```

Figure 1.52 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.53*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.53 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.54*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  IO1,SEC1_A <Enter>
20:
?  IO2,SEC2_A <Enter>
21:
?  IO3,LOND_A <Enter>
22:
?  IO4,BERL_A <Enter>
23:
?  IO5,NEWY_A <Enter>
24:
?  IO6,CANB_A <Enter>
25:
?  BZ1,WEST_A <Enter>
26:
?  BZ2,EAST_A <Enter>
27:
?  CZ1,CHECK_A <Enter>
28:
?  IN204,ISE891A <Enter>
29:
?  IN205,ISE891B <Enter>
30:
.
.
.
?  OUT204,NEWTR_A <Enter>
92:
?  OUT205,CANTR_A <Enter>
93:
?  END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.54 Analog Quantities and Relay Word Bit Alias Names

This concludes the alias settings. The next settings class is the global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from protection setting Group 1 to protection setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.55* shows the setting changes we need for our example. Because we declared the alias names in the alias settings class, use either alias names or primitive names when entering settings.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01–52A05) and five corresponding trip equations (TR01–TR05) available for setting. Because we do not need circuit breaker auxiliary contacts for this application, set 52A01–52A05 to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need six disconnect logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01 through 06). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 1.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                      NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-48)                   NUMDS   := N      ?6 <Enter>
Nominal System Frequency (50,60 Hz)              NFREQ   := 60     ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                 EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                  GINPU   := 0.17   ?> < Enter>

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
Breaker Inputs
N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  ISE891A <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  ISE891B <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)            89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  ISE892A <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  ISE892B <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)            89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  ILON89A <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
.
.
.

89ALP06 := 300 <Enter>
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.55 Global Settings for Application 1

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information). In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the LONDON feeder, all three phases (LOND_A, LOND_B, and LOND_C) operate together. Because the relay measures the three phases in three separate relays (phase LOND_A in the A-phase relay, phase LOND_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

Because the check zone performs a supervising function, enter the check zone zone configuration settings ahead of the Zone 1 and Zone 2 settings. To configure the Check Zone, declare all terminals, except the tie-breaker (bus sectionalizer) CTs in the Check Zone terminal-to-check-zone SELOGIC control equations. Never include the tie-breaker CTs in the check zone. *Figure 1.59* shows the zone configuration group settings. Use the Differential Element Zone Supervision setting to comply with the requirement for both check zone and zone-specific differential elements to assert before a busbar protection trip output asserts. For this application, we allocated BZ1 for Zone 1, BZ2 for Zone 2, and CZ1 for the overall check zone (see *Table 1.14*). Because the check zone is independent from any other zone, the relay does not follow the differential trip logic shown in *Figure 1.56* when the check zone asserts.

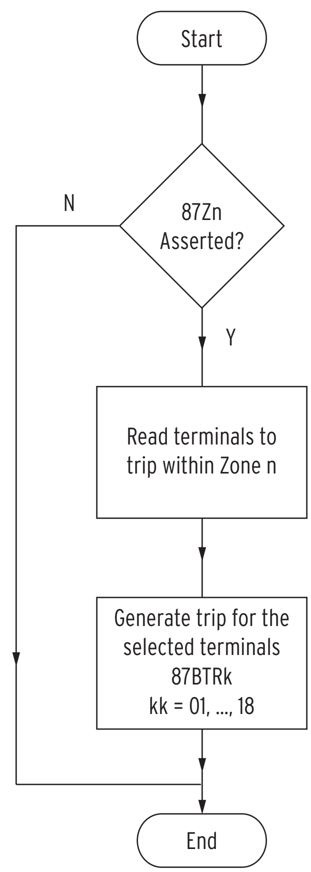


Figure 1.56 Bus Differential Trip Logic

The implication of this independence is that the Check Zone Supervision Logic can be left to its default value of 1 as seen in *Figure 1.57*. The same effect is achieved by setting E87CZSP = N.

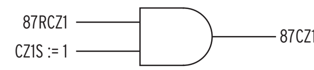


Figure 1.57 Check-Zone Supervision Logic

For the zone-specific elements, enter the Check Zone differential element trip output 87CZ1 as a supervisory condition for each zone, as shown in *Figure 1.58*.

Figure 1.58 Zone Supervision for Zone 1 (a) and Zone 2 (b)

Be sure to include Relay Word bit 87CZ1 as the supervisory condition for all zones encompassed by the Check Zone. Set E87ZSUP = Y to enable the Differential Element Zone Supervision settings, then enter the supervision settings.

For the ease of setting the zone configuration settings for the new substation, delete the existing zone configuration group default settings. With the zone configuration group default settings deleted, the setting prompts no longer reference the default settings. The zone configuration group default settings are for a specific substation with arbitrarily selected alias names, serving only as an example.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?400 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?400 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?40 <Enter>
Current Transformer Ratio -I04 (1-50000)            CTR04   := 600    ?400 <Enter>
Current Transformer Ratio -I05 (1-50000)            CTR05   := 600    ?400 <Enter>
Current Transformer Ratio -I06 (1-50000)            CTR06   := 600    ?400 <Enter>
Current Transformer Ratio -I07 (1-50000)            CTR07   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := SEC1_A, WEST_A, P
?  DELETE 100 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,BZ2,P <Enter>
SEC1_A to EAST_A Connection (SELogic Equation)
I01BZ2V := NA
?  SEC189C AND SEC289C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,BZ1,P <Enter>
SEC2_A to WEST_A Connection (SELogic Equation)
I02BZ1V := NA
?  SEC189C AND SEC289C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,BZ1,P <Enter>
LOND_A to WEST_A Connection (SELogic Equation)
I03BZ1V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,BZ1,P <Enter>
BERL_A to WEST_A Connection (SELogic Equation)
I04BZ1V := NA
?  BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,BZ2,P <Enter>
```

```
NEWY_A to EAST_A Connection (SELogic Equation)
I05BZ2V := NA
?  NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I06,BZ2,P <Enter>
CANB_A to EAST_A Connection (SELogic Equation)
I06BZ2V := NA
?  CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N       ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?  87CZ1 <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  87CZ1 <Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N       ?<Enter>

Reset Zone 1 Open CT Detector (SELogic Equation)
ROCTZ1 := RSTOCT1
?<Enter>
Reset Zone 2 Open CT Detector (SELogic Equation)
ROCTZ2 := RSTOCT2
?<Enter>

Check Zone Configuration

Enable Check Zones at Station (Y,N)                  ECHKZN  := N       ?Y <Enter>

Check Zone Configuration: Terminal to Check Zone Connections

Terminal, Check-Zone, Polarity (P,N)
?  I03,CZ1,P <Enter>
LOND_A to CHECK_A Connection (SELogic Equation)
I03CZ1V := NA
?  1 <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  I04,CZ1,P <Enter>
BERL_A to CHECK_A Connection (SELogic Equation)
I04CZ1V := NA
?  1 <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  I05,CZ1,P <Enter>
NEWY_A to CHECK_A Connection (SELogic Equation)
I05CZ1V := NA
?  1 <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  I06,CZ1,P <Enter>
CANB_A to CHECK_A Connection (SELogic Equation)
I06CZ1V := NA
?  1 <Enter>
Terminal, Check-Zone, Polarity (P,N)
?<Enter>

Check Zone Supervision

Differential Element Check Zone Supervision (Y,N)    E87CZSP := N       ?<Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.59 Zone Configuration Group Settings for Application 1

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y.

With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element by setting E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information). Set ECSL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, and EVOLT := N because we do not use the coupler security logic, terminal out of service, breaker failure protection, overcurrent elements, or voltage elements in this application.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01 through 52A05) and five corresponding trip equations (TR01 through TR05) available for setting. There are five trip equations available, but there are six analog channels (I01 though I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 1.20*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip. Because the tie breaker has two analog channels but only one circuit breaker, include both differential trip bits (87SEC1A and 87SEC2A) in trip equation TR01.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Although each SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting. Set the timer TDURD longer than the clearing time of the slowest circuit breaker at the station. For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element, the Directional Element, and the Trip Duration Timer. *Figure 1.60* shows the group settings.

```
=>>SET <Enter>
Group 1

Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y       ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N       ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5       ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6       ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N       ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N       ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y       ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N       ?> <Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Check Zone Sensitive Differential Element

CZ Sensitive Differential Element Pickup (0.05-1 pu) CZS87P := 0.10     ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Check Zone Restrained Differential Element

CZ Restrained Diff Element Pickup (0.10-4 pu)        CZO87P := 1.00     ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87SEC1A
?  87SEC1A OR 87SEC2A <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
? <Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87SEC2A
?  87LON_A <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
? <Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87LON_A
?  87BER_A <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
Trip 04 (SELogic Equation)
TR04 := SBFTR04 OR 87BER_A
?  87NEW_A <Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87NEW_A OR SBFTR06 OR 87CAN_A
?  87CAN_A <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?> <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.60 Protection Group Settings for Application 1

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the {RELAY TEST MODE} pushbutton disables all output contacts. Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 1.61* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRSEC_A AND NOT PLT03
?   NA <Enter>

OUT102 := TRLON_A AND NOT PLT03
?   NA <Enter>

OUT103 := TRBER_A AND NOT PLT03
?   NA <Enter>

OUT104 := TRNEW_A AND NOT PLT03
?   NA <Enter>

OUT105 := TRCAN_A AND NOT PLT03
?   NA <Enter>

OUT106 := NA
? > <Enter>

Interface Board #1

OUT201 := NA
?   TRSEC_A AND NOT PLT03 <Enter>

OUT202 := NA
?   TRLON_A AND NOT PLT03 <Enter>

OUT203 := NA
?   TRBER_A AND NOT PLT03 <Enter>

OUT204 := NA
?   TRNEW_A AND NOT PLT03 <Enter>

OUT205 := NA
?   TRCAN_A AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>
Output
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.61 Control Output Settings for Application 1

This concludes the settings for Application 1.

Application 2: Single Bus and Tie Breaker (Single Relay)

This application describes the busbar arrangement shown in *Figure 1.62*, a single bus with bus sectionalizer (tie breaker), single-relay application. The busbar arrangement consists of two busbar sections, four feeders, and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

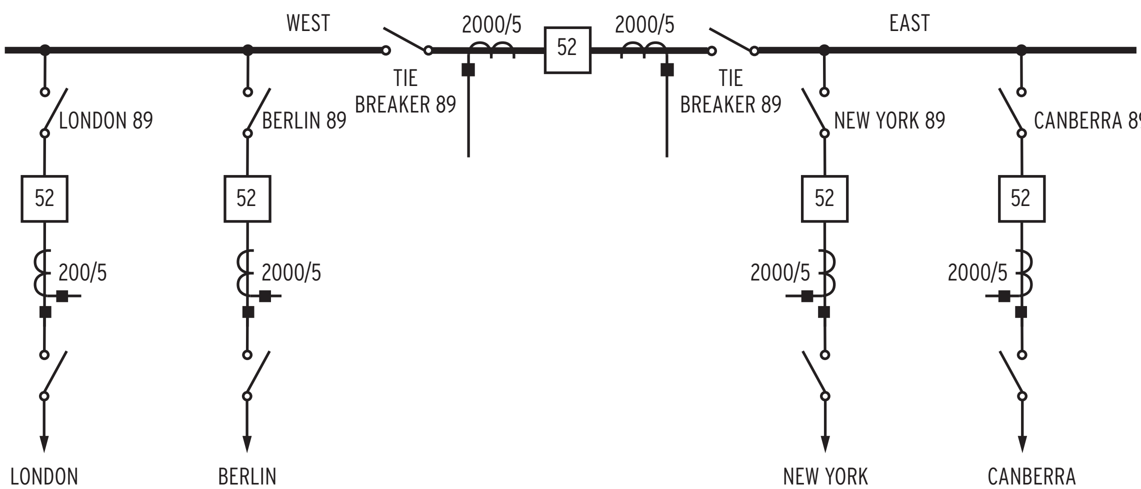


Figure 1.62 Single Bus With Bus Sectionalizer (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie breaker (buscoupler or sectionalizing breaker) configuration.

- Description:
  - Single bus with tie breaker
- Current Transformers:
  - Outboard
- Disconnect:
  - Both 89A and 89B disconnect auxiliary contacts are available
- Sectionalizing breaker (tie-breaker) configuration:
  - Overlap

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the 89 disconnect auxiliary contacts to dynamically configure the station.
2. Block the busbar protection for an open-circuit CT.
3. Use the Disconnect Monitoring Logic.
4. Include end-zone protection with direct transfer tripping for the four feeders.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for end-zone protection, but not for breaker failure protection.

The SEL-487B offers a number of protection functions as standard features, but also includes the capability through SELOGIC control equations to create user-configurable functions. Breaker failure protection is a standard function but end-zone protection is not. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created using SELOGIC control equations)

Standard Functions

Refer to the *Protection Philosophy* and select the standard functions required for the application. *Table 1.24* shows the selection of the standard functions.

Table 1.24 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch.
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available.
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions
Sensitive differential protection	Yes	CT open circuit detection.
Zone supervision logic	No	Not required
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.

Table 1.24 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Function	Selection	Comment
Coupler security logic	No	Two CTs configured in overlap configuration do not require the coupler security logic.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need for the application that are not part of the standard logic in the relay. For this application, end-zone protection for the four feeders is not a standard function; we use SELOGIC control equations to create this logic.

End-Zone Protection

Figure 1.63 shows end-zone fault F1, which is a fault between the feeder CT and circuit breaker. The busbar protection at Busbar S operates for this fault and trips Circuit Breaker 1, but the line still feeds the fault from the source at Busbar R.

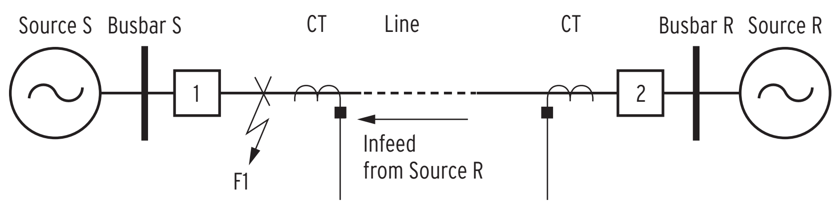


Figure 1.63 Fault Between Circuit Breaker 1 and the CT at Busbar S

Fault F1 is only cleared when Circuit Breaker 2 at Busbar R trips. In step-distance protection schemes, Circuit Breaker 2 trips after a time delay, typically on the order of 400 ms. Using end-zone protection, we can shorten this time by sending a direct transfer trip (DTT) from Station S to Circuit Breaker 2 at Station R to trip Circuit Breaker 2.

This logic detects faults under the following three conditions:

- The differential protection has issued a trip signal to the circuit breaker.
- There is still current flowing in the feeder CT after Circuit Breaker 1 has been open for 5 cycles.
- The busbar disconnect of the feeder is closed.

Create the above-mentioned end-zone logic by programming four protection SELOGIC control variables (PSV01–PSV04) when setting the protection logic, and assign the alias names as described in *Assign Alias Names to the User-Defined Logic on page A.1.74*.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and 3 voltage channels. For stations with as many as 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install 3 SEL-487B relays. Use *Equation 1.5* to calculate the number of current channels at the station, and use *Equation 1.6* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.5**

# of bus-zones required = # of per-phase station bus sections **Equation 1.6**

The number of per-phase CTs at the station is 18 and the number of bus-zones required is 6. Because each SEL-487B has 18 analog input channels and 6 zones, we need only one SEL-487B. This is known as a single-relay application.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires one disconnect monitoring logic and the tie breaker requires two; the number of disconnect logics required is therefore six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.7* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

relay inputs required = 2 • # disconnect monitoring logics **Equation 1.7**

The protection philosophy calls for end-zone protection. Because there are four feeder circuit breakers at the station the number of circuit breaker auxiliary inputs we need is four. *Table 1.25* summarizes the input contact required for this application.

Table 1.25 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 6 = 12
Number of relay inputs required for end-zone protection	4
Total number of inputs	16

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts for the disconnect auxiliary contact inputs; the six independent input contacts are available for breaker failure initiate inputs. Because this application has no circuit breaker failure protection, the independent input contacts are available for circuit breaker auxiliary contact inputs. However, in anticipation of future circuit breaker failure protection installation, instead use the grouped input contacts on the interface board for the circuit breaker auxiliary contact inputs and disconnect contact inputs. From the input contact perspective, we need one interface board.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all breakers are part of the busbar differential protection, we want to trip each breaker upon differential protection operation. We also need direct transfer trip output contacts for the end-zone protection for each of the four feeders. *Table 1.26* shows the breakdown and the total number of relay output contacts required.

Table 1.26 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping	5
Number of relay output contacts required for direct transfer tripping	4
Total number of relay output contacts	9

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). *Table 1.26* shows that we need nine output contacts; the eight main board output contacts are insufficient for our application. Also, the main board contacts are all standard output contacts.

The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign the circuit breaker trip outputs to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. Although the standard output contacts are slightly slower (6 ms for resistive loads) than the high-speed, high-interrupting output contacts, we use the main board output contact for direct transfer tripping. From the output contact perspective, we need one interface board. If you require fast output contacts for direct transfer tripping, add another interface board to the relay.

The conclusion from the preceding analysis is that we need one SEL-487B, equipped with a single interface board, for this application.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- the selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay input contacts
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

NOTE: Alias names cannot exceed seven characters.

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

Table 1.27 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie breaker CT1 to relay channel I01, and assign to this CT the alias name SEC1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.27* shows the assignment taken from *Figure 1.62*.

Table 1.27 CTs to Analog Channel Allocations and Alias Assignments (Sheet 1 of 2)

CTs	Analog Channel	Alias
LONDON, A-phase	I01	LOND_A
LONDON, B-phase	I02	LOND_B
LONDON, C-phase	I03	LOND_C
BERLIN, A-phase	I04	BERL_A
BERLIN, B-phase	I05	BERL_B
BERLIN, C-phase	I06	BERL_C
NEW YORK, A-phase	I07	NEWY_A
NEW YORK, B-phase	I08	NEWY_B
NEW YORK, C-phase	I09	NEWY_C
CANBERRA, A-phase	I10	CANB_A
CANBERRA, B-phase	I11	CANB_B
CANBERRA, C-phase	I12	CANB_C

Table 1.27 CTs to Analog Channel Allocations and Alias Assignments (Sheet 2 of 2)

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I13	SEC1_A
TIE-BREAKER CT1, B-phase	I14	SEC1_B
TIE-BREAKER CT1, C-phase	I15	SEC1_C
TIE-BREAKER CT2, A-phase	I16	SEC2_A
TIE-BREAKER CT2, B-phase	I17	SEC2_B
TIE-BREAKER CT2, C-phase	I18	SEC2_C

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. In this application, we use all six zones with alias names as shown in *Table 1.28*.

Table 1.28 Alias Names for the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	WEST_A
BZ2	Bus-Zone 2	WEST_B
BZ3	Bus-Zone 3	WEST_C
BZ4	Bus-Zone 4	EAST_A
BZ5	Bus-Zone 5	EAST_B
BZ6	Bus-Zone 6	EAST_C

Input-to-Logic Allocation and Alias Assignment

Table 1.25 shows that we require 16 digital inputs. We now assign the digital inputs to the selected logic, and apply alias names to the inputs and logic elements. Because of the functional requirement of this application, we do not need to use any digital inputs on the main board.

Input-to-Logic-Allocation and Alias Assignment, Interface Board 1 (200)

Table 1.29 shows the circuit breaker auxiliary contact input allocations, the disconnect auxiliary contact input allocations, and the alias names. Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs for breaker failure initiate inputs; these inputs are not used in this application.

Table 1.29 Alias Names and Assignment for the Digital Inputs (Sheet 1 of 2)

Input	Description	Alias
IN204	LONDON circuit breaker	ILON52A
IN205	BERLIN circuit breaker	IBER52A
IN206	NEW YORK circuit breaker	INEW52A
IN207	CANBERRA circuit breaker	ICAN52A
IN208	LONDON disconnect NO contact	ILON89A
IN209	LONDON disconnect NC contact	ILON89B
IN210	BERLIN disconnect NO contact	IBER89A

Table 1.29 Alias Names and Assignment for the Digital Inputs (Sheet 2 of 2)

Input	Description	Alias
IN211	BERLIN disconnect NC contact	IBER89B
IN212	NEW YORK disconnect NO contact	INEW89A
IN216	NEW YORK disconnect NC contact	INEW89B
IN217	CANBERRA disconnect NO contact	ICAN89A
IN218	CANBERRA disconnect NC contact	ICAN89B
IN219	TIE-BREAKER disconnect (WEST) NO contact	ISE891A
IN220	TIE-BREAKER disconnect (WEST) NC contact	ISE891B
IN221	TIE-BREAKER disconnect (EAST) NO contact	ISE892A
IN222	TIE-BREAKER disconnect (EAST) NC contact	ISE892B

Assign Alias Names to the Selected Standard Logic

Referring to *Table 1.24*, the following is a discussion on each selected function. Alias name assignments are also included.

Disconnect Monitoring Logic and Disconnect Alias Assignment

Figure 1.64 shows one of the 48 disconnect monitor logic circuits available in the relay. (See *Disconnect Requirements on page A.1.15* for more information on the disconnect auxiliary contact requirements.)

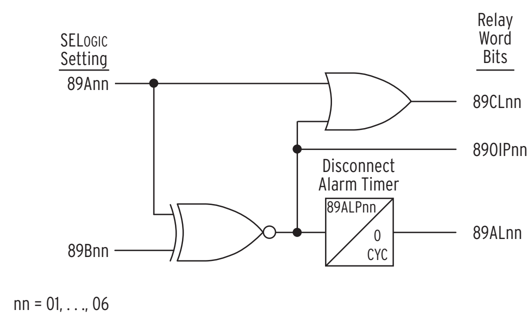


Figure 1.64 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.30 shows the alias names for the disconnect auxiliary contact Relay Word bits.

Table 1.30 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description	Alias
89A01	LONDON disconnect NO contact	LON89A
89B01	LONDON disconnect NC contact	LON89B
89A02	BERLIN disconnect NO contact	BER89A
89B02	BERLIN disconnect NC contact	BER89B
89A03	NEW YORK disconnect NO contact	NEW89A
89B03	NEW YORK disconnect NC contact	NEW89B
89A04	CANBERRA disconnect NO contact	CAN89A
89B04	CANBERRA disconnect NC contact	CAN89B

Table 1.30 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description	Alias
89A05	TIE-BREAKER disconnect (WEST) NO contact	SEC891A
89B05	TIE-BREAKER disconnect (WEST) NC contact	SEC891B
89A06	TIE-BREAKER disconnect (EAST) NO contact	SEC892A
89B06	TIE-BREAKER disconnect (EAST) NC contact	SEC892B

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations. We also assign alias names to the alarm Relay Word bits (89AL*nn*). *Table 1.31* shows the alias names.

Table 1.31 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits

Primitive Name	Description	Alias
89CL01	LONDON disconnect is closed	LOND89C
89CL02	BERLIN disconnect is closed	BERL89C
89CL03	NEW YORK disconnect is closed	NEWY89C
89CL04	CANBERRA disconnect is closed	CANB89C
89CL05	TIE-BREAKER disconnect (WEST) is closed	SEC189C
89CL06	TIE-BREAKER disconnect (EAST) is closed	SEC289C
89AL01	LONDON disconnect alarm	LON89AL
89AL02	BERLIN disconnect alarm	BER89AL
89AL03	NEW YORK disconnect alarm	NEW89AL
89AL04	CANBERRA disconnect alarm	CAN89AL
89AL05	TIE-BREAKER disconnect (WEST) alarm	SE189AL
89AL06	TIE-BREAKER disconnect (EAST) alarm	SE289AL

Breaker Status Logic

Figure 1.65 shows the breaker status logic circuit associated with current channel I01. This logic includes an OPH01 input from the open phase detection logic. Open phase detection logic asserts the OPH01 Relay Word bit when the logic measures no current in that specific phase. Alarm output 52AL01 asserts when the 52A01 and OPH01 inputs are both deasserted for longer than 5 cycles. For example, when the circuit breaker is open (52A01 is logical 0), Relay Word bit OPH01 asserts (changes to logical 1) when current stops flowing. AND Gate 2 in *Figure 1.65* outputs a logical 0 and the timer does not run. However, if current still flows through the CT when the circuit breaker is open (end-zone fault, for example), Relay Word bit OPH01 does not assert (remains at logical 0) and the timer starts.

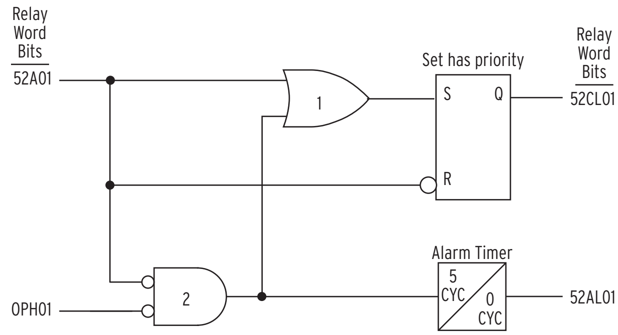


Figure 1.65 Breaker Status Logic

Wire a single, normally open circuit breaker auxiliary contact from each of the four feeder circuit breakers to an individual relay input (IN204, IN205, IN206, and IN207). In this example, we do not assign alias names to the Relay Word bits; we use the primitive names instead. Because this is a single-relay application, the three phases of each terminal are in the same relay. *Table 1.32* shows the breaker status logic input and output Relay Word bits.

Table 1.32 Breaker Status Logic Input and Output Relay Word Bits

Primitive Name	Description
52A01	LONDON A-phase NO contact
52AL01	LONDON A-phase discrepancy alarm
52A02	LONDON B-phase NO contact
52AL02	LONDON B-phase discrepancy alarm
52A03	LONDON C-phase NO contact
52AL03	LONDON C-phase discrepancy alarm
52A04	BERLIN A-phase NO contact
52AL04	BERLIN A-phase discrepancy alarm
52A05	BERLIN B-phase NO contact
52AL05	BERLIN B-phase discrepancy alarm
52A06	BERLIN C-phase NO contact
52AL06	BERLIN C-phase discrepancy alarm
52A07	NEW YORK A-phase NO contact
52AL07	NEW YORK A-phase discrepancy alarm
52A08	NEW YORK B-phase NO contact
52AL08	NEW YORK B-phase discrepancy alarm
52A09	NEW YORK C-phase NO contact
52AL09	NEW YORK C-phase discrepancy alarm
52A10	CANBERRA A-phase NO contact
52AL10	CANBERRA A-phase discrepancy alarm
52A11	CANBERRA B-phase NO contact
52AL11	CANBERRA B-phase discrepancy alarm
52A12	CANBERRA C-phase NO contact
52AL12	CANBERRA C-phase discrepancy alarm

Differential Trip Logic and Differential Element Alias Assignment

Figure 1.66 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information). *Table 1.33* shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 1.33 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	WESTA_T
87Z2	Zone 2 differential element trip	WESTB_T
87Z3	Zone 3 differential element trip	WESTC_T
87Z4	Zone 4 differential element trip	EASTA_T
87Z5	Zone 5 differential element trip	EASTB_T
87Z6	Zone 6 differential element trip	EASTC_T

Differential trip bits 87BTR01 through 87BTR18 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information).

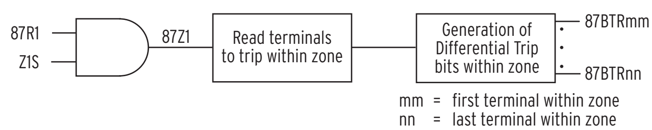


Figure 1.66 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate. In our example, we will use all the 87BTR*mm* (*mm* = 01 through 18) Relay Word bits. *Table 1.34* shows the primitive differential trip bit names, and the alias names for the differential trip bits.

Table 1.34 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits (Sheet 1 of 2)

Differential Trip Bit	Alias	Comments
87BTR01	87LON_A	Associated with Terminal 01
87BTR02	87LON_B	Associated with Terminal 02
87BTR03	87LON_C	Associated with Terminal 03
87BTR04	87BER_A	Associated with Terminal 04
87BTR05	87BER_B	Associated with Terminal 05
87BTR06	87BER_C	Associated with Terminal 06
87BTR07	87NEW_A	Associated with Terminal 07
87BTR08	87NEW_B	Associated with Terminal 08
87BTR09	87NEW_C	Associated with Terminal 09
87BTR10	87CAN_A	Associated with Terminal 10
87BTR11	87CAN_B	Associated with Terminal 11
87BTR12	87CAN_C	Associated with Terminal 12
87BTR13	87SEC1A	Associated with Terminal 13

Table 1.34 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits (Sheet 2 of 2)

Differential Trip Bit	Alias	Comments
87BTR14	87SEC1B	Associated with Terminal 14
87BTR15	87SEC1C	Associated with Terminal 15
87BTR16	87SEC2A	Associated with Terminal 16
87BTR17	87SEC2B	Associated with Terminal 17
87BTR18	87SEC2C	Associated with Terminal 18

Breaker Trip Logic and Trip Alias Assignment

Figure 1.67 shows the general tripping logic for the 15 trip outputs used in this application. (See *Section 1: Protection Functions in the Reference Manual* for more information).

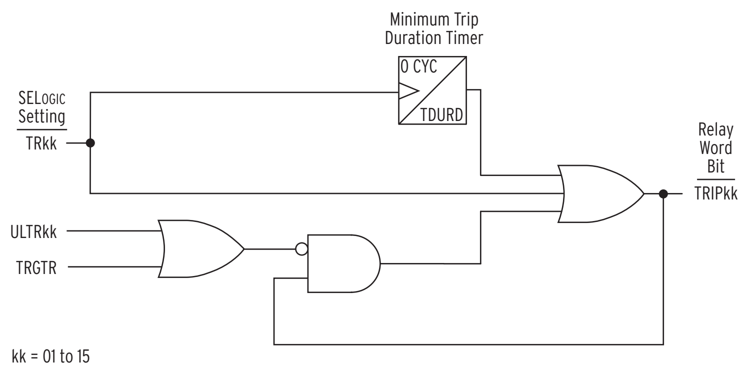


Figure 1.67 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK). Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals 15.

After setting the TR*nn* trip equations, the relay associates each TR*nn* trip equation with a particular circuit breaker pole; we must combine the trip equations in the output settings to form a single output for the tie breaker (see the *Protection Group Settings on page A.1.83*). For example, after setting TR01:= 87BTR01 and TR02:= 87BTR02, the relay associates Trip Equation TR01 with Terminal 01 (LOND_A), Trip Equation TR02 with Terminal 02 (LOND_B), and so on. *Table 1.35* shows the 15 primitive and alias names for the trip logic of each terminal.

Table 1.35 Primitive and Alias Names for the Trip Logic of Each Terminal (Sheet 1 of 2)

Primitive Name	Description	Alias
TRIP01	Trip output of the LONDON Terminal A phase asserted	TRLON_A
TRIP02	Trip output of the LONDON Terminal B phase asserted	TRLON_B
TRIP03	Trip output of the LONDON Terminal C phase asserted	TRLON_C
TRIP04	Trip output of the BERLIN Terminal A phase asserted	TRBER_A
TRIP05	Trip output of the BERLIN Terminal B phase asserted	TRBER_B
TRIP06	Trip output of the BERLIN Terminal C phase asserted	TRBER_C

Table 1.35 Primitive and Alias Names for the Trip Logic of Each Terminal (Sheet 2 of 2)

Primitive Name	Description	Alias
TRIP07	Trip output of the NEW YORK Terminal A phase asserted	TRNEW_A
TRIP08	Trip output of the NEW YORK Terminal B phase asserted	TRNEW_B
TRIP09	Trip output of the NEW YORK Terminal C phase asserted	TRNEW_C
TRIP10	Trip output of the CANBERRA Terminal A phase asserted	TRCAN_A
TRIP11	Trip output of the CANBERRA Terminal B phase asserted	TRCAN_B
TRIP12	Trip output of the CANBERRA Terminal C phase asserted	TRCAN_C
TRIP13	Trip output of the sectionalizing breaker A phase asserted	TRSEC_A
TRIP14	Trip output of the sectionalizing breaker B phase asserted	TRSEC_B
TRIP15	Trip output of the sectionalizing breaker C phase asserted	TRSEC_C

Assign Alias Names to the User-Defined Logic

We created the general end-zone protection logic under *User-Defined Functions on page A.1.64*. We now assign the application-specific alias names to all the appropriate Relay Word bits in the end-zone protection logic.

End-Zone Protection

Table 1.36 shows the alias names for the four protection SELOGIC control equation variables (PSV01–PSV04).

Table 1.36 Alias Names for the End-Zone Protection Logic

Primitive Name	Description	Alias
PSV01	End-zone element for LONDON terminal	LOND_EZ
PSV02	End-zone element for BERLIN terminal	BERL_EZ
PSV03	End-zone element for NEW YORK terminal	NEWY_EZ
PSV04	End-zone element for CANBERRA terminal	CANB_EZ

Figure 1.68 shows the end-zone logic with the alias names instead of the primitive names. The logic declares an end-zone fault when the following three conditions are met:

- A differential trip signal has been issued to the circuit breaker
- Current continues to flow through the feeder CT after a 5-cycle delay
- The busbar disconnect of the feeder is closed.

Notice that the second condition is met by using the built-in 5-cycle delay of 52AL*nn*, which is the alarm timer output of the circuit breaker status logic. Create similar logic for the other three feeders with the protection logic settings.

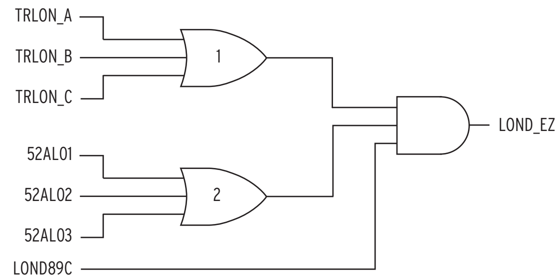


Figure 1.68 End-Zone Logic With the Alias Names for the London Feeder

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 1.26* shows the breakdown of the nine relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts and assign alias names to the relay output contacts. *Table 1.37* shows the linking of the end-zone protection logic to the output contacts of the main board and the alias names of the relay main board output contacts. *Table 1.38* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1 and the alias names of the of the interface board output contacts.

Output Alias Assignment–Main Board

We assign the outputs from the end-zone protection logics as direct transfer trip (DTT) functions to the output contacts of the main board. Wire the direct transfer trip outputs to the communications equipment or terminal panel to transmit the signal to the remote busbar.

Table 1.37 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT101	DTT for an end zone fault on LONDON Feeder	LON_DTT
OUT102	DTT for an end zone fault on BERLIN Feeder	BER_DTT
OUT103	DTT for an end zone fault on NEW YORK Feeder	NEW_DTT
OUT104	DTT for an end zone fault on CANBERRA Feeder	CAN_DTT
OUT105	NA	NA
OUT106	NA	NA
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment–Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.38* shows the alias assignment for the five terminals in our example.

Table 1.38 Alias Assignment for the Five Terminals in Our Example

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	LONDON trip logic output	LON_TRP
OUT202[a]	BERLIN trip logic output	BER_TRP
OUT203[a]	NEW YORK trip logic output	NEW_TRP
OUT204[a]	CANBERRA trip logic output	CAN_TRP
OUT205[a]	TIE-BREAKER trip logic output	SEC_TRP

[a] High-speed, high-interrupting outputs.

Station Layout Update

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 1.69*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminals CTs to the relay input current channels.
4. Allocate the auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

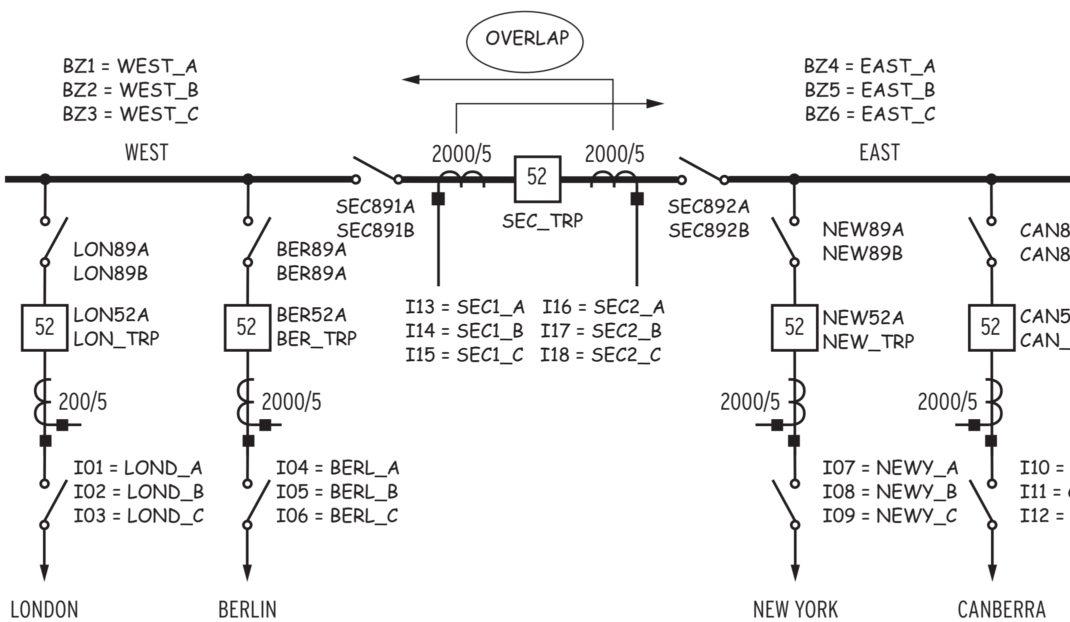


Figure 1.69 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Protection Logic Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.70*.

After inspecting the list, we decide that the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>
1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.70 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.71*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.71 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the 18 analog channels and Relay Word bits, as shown in *Figure 1.72*.

```
1:OUT107,"TEST"
?  <Enter>
19:
?  I01,LOND_A <Enter>
20:
?  I02,LOND_B <Enter>
21:
?  I03,LOND_C <Enter>
22:
?  I04,BERL_A <Enter>
23:
?  I05,BERL_B <Enter>
24:
?  I06,BERL_C <Enter>
.
.
.

133:
?  OUT204,CAN_TRP <Enter>
134:
?  OUT205,SEC_TRP <Enter>
135:
?  END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.72 Analog Quantities and Relay Word Bit Alias Names for Application 2

This concludes the alias settings. The next settings class is the global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Settings Group 1 to Protection Settings Group 2, global settings such as station name and relay name still apply. *Figure 1.73* shows the setting changes we need for our example. Because we declared the alias names in the alias setting class, use either alias names or primitive names when entering settings.

Carefully consider circuit breaker related settings when applying the relay in a single-relay application. The relay considers all applications to be three-relay applications; there is no setting distinguishing a single-relay application from a three-relay application. In particular, the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, not as the number of circuit breakers.

In this single-relay application example, there are 15 circuit breaker poles at the substation, and the value of NUMBK is 15. However, wire only one circuit breaker auxiliary contact from each circuit breaker to the relay; see the TR*kk*, TRIP*kk,* and the output settings for information on how to set the relay for this application.

There exists a direct relationship between the number of circuit breakers and the number of breaker status logics, i.e., the number of breaker input equations (52A*kk*) equals the number of circuit breakers (NUMBK). Enter the number of poles at the station for the NUMBK setting. Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals 15.

Setting NUMBK equal to 15 makes 15 corresponding circuit breaker auxiliary input equations (52A01 through 52A15), and 15 corresponding trip equations (TR01 through TR15) available for setting. Although 15 circuit breaker auxiliary input equations are available, there are only four circuit breaker auxiliary contacts wired to the relay, one contact from each of the four feeder circuit breakers at the station. Group three circuit breaker auxiliary input equations to form an association with a circuit breaker, and enter the same contact name for the three circuit breaker auxiliary input equations. For example, group circuit breaker auxiliary input equations 52A01, 52A02, and 52A03 to form an association with the LONDON circuit breaker.

Table 1.29 shows the allocation of ILON52A, the circuit breaker auxiliary contact to relay input IN204. We use relay input IN204 to monitor the status of the LONDON circuit breaker. All three circuit breaker auxiliary input equations (52A01, 52A02, and 52A03) must assert when ILON52A asserts, so ILON52A must appear in all three circuit breaker auxiliary input equations. Because we do not need a circuit breaker auxiliary contact from the tie breaker, set 52A13–52A15 to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need six disconnect logics although there are 12 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*nn* setting (*nn* = 01 through 06). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 1.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                         NUMBK   := 5      ?15 <Enter>
Number of Disconnects (N,1-48)                      NUMDS   := N      ?6 <Enter>
Nominal System Frequency (50,60 Hz)                 NFREQ   := 60     ?<Enter>
Date Format (MDY,YMD,DMY)                           DATE_F  := MDY    ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                    EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                     GINPU   := 0.17   ?> <Enter>
Settings Group Selection
Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  ILON52A <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
?  ILON52A <Enter>
N/O Contact Input -BK03 (SELogic Equation)
52A03 := NA
?  ILON52A <Enter>
N/O Contact Input -BK04 (SELogic Equation)
52A04 := NA
?  IBER52A <Enter>
N/O Contact Input -BK05 (SELogic Equation)
52A05 := NA
?  IBER52A <Enter>
N/O Contact Input -BK06 (SELogic Equation)
52A06 := NA
?  IBER52A <Enter>
N/O Contact Input -BK07 (SELogic Equation)
.
.
.
52A13 := NA
?  <Enter>
N/O Contact Input -BK13 (SELogic Equation)
52A14 := NA
?  <Enter>
N/O Contact Input -BK14 (SELogic Equation)
52A15 := NA
?  <Enter>
N/O Contact Input -BK15 (SELogic Equation)

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  ILON89A <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  ILON89B <Enter>

DS01 Alarm Pickup Delay (0-99999 cyc)               89ALP01 := 300    ? <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IBER89A <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IBER89B <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)               89ALP02 := 300    ? <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.73 Global Settings for Application 2

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration, and to assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three phases. For example, when we close the busbar disconnect on the LONDON feeder, all three phases (LOND_A, LOND_B, and LOND_C) operate together. Because the relay measures the three phases in three separate differential elements (phase LOND_A in differential element WEST_A, phase LOND_B in differential element WEST_B, etc.), we need to convey the disconnect status to all three differential elements. *Table 1.31* shows the alias names of the disconnect status Relay Word bits; *Figure 1.74* shows the zone configuration group settings.

The zone configuration group default settings are for a specific substation with arbitrarily selected alias names, serving only as an example. For the ease of setting the zone configuration group settings for the new substation, delete the existing zone configuration default settings. With the zone configuration group default settings deleted, the setting prompts no longer reference the default settings.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>
Current Transformer Ratio
Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?40 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?40 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?40 <Enter>
Current Transformer Ratio -I04 (1-50000)            CTR04   := 600    ?400 <Enter>
Current Transformer Ratio -I05 (1-50000)            CTR05   := 600    ?400 <Enter>
Current Transformer Ratio -I06 (1-50000)            CTR06   := 600    ?400 <Enter>
Current Transformer Ratio -I07 (1-50000)            CTR07   := 600    ?400 <Enter>
Current Transformer Ratio -I08 (1-50000)            CTR08   := 600    ?400 <Enter>
Current Transformer Ratio -I09 (1-50000)            CTR09   := 600    ?400 <Enter>
Current Transformer Ratio -I10 (1-50000)            CTR10   := 600    ?400 <Enter>
Current Transformer Ratio -I11 (1-50000)            CTR11   := 600    ?400 <Enter>
.
.
.
Current Transformer Ratio -I18 (1-50000)            CTR18   := 600    ?400 <Enter>
Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := SEC1_A, WEST_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,BZ1,P <Enter>
LOND_A to WEST_A Connection (SELogic Equation)
I01BZ1V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,BZ2,P <Enter>
```

```
LOND_B to WEST_B Connection (SELogic Equation)
I02BZ2V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,BZ3,P <Enter>
LOND_C to WEST_C Connection (SELogic Equation)
I03BZ3V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,BZ1,P <Enter>
BERL_A to WEST_A Connection (SELogic Equation)
I04BZ1V := NA
?  BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,BZ2,P <Enter>
BERL_B to WEST_B Connection (SELogic Equation)
I05BZ2V := NA
?  BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I06,BZ3,P <Enter>
BERL_C to WEST_C Connection (SELogic Equation)
I06BZ3V := NA
?  BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I07,BZ4,P <Enter>
NEWY_A to EAST_A Connection (SELogic Equation)
I07BZ4V := NA
?  NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I08,BZ5,P <Enter>
NEWY_B to EAST_B Connection (SELogic Equation)
I08BZ5V := NA
?  NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I09,BZ6,P <Enter>
NEWY_C to EAST_C Connection (SELogic Equation)
I09BZ6V := NA
?  NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I10,BZ4,P <Enter>
CANB_A to EAST_A Connection (SELogic Equation)
I10BZ4V := NA
?  CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I11,BZ5,P <Enter>
CANB_B to EAST_B Connection (SELogic Equation)
I11BZ5V := NA
?  CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I12,BZ6,P <Enter>
CANB_C to EAST_C Connection (SELogic Equation)
I12BZ6V := NA
?  CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I13,BZ4,P <Enter>
SEC1_A to EAST_A Connection (SELogic Equation)
I13BZ4V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I14,BZ5,P <Enter>
SEC1_B to EAST_B Connection (SELogic Equation)
I14BZ5V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I15,BZ6,P <Enter>
SEC1_C to EAST_C Connection (SELogic Equation)
I15BZ6V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I16,BZ1,P <Enter>
SEC2_A to WEST_A Connection (SELogic Equation)
I16BZ1V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I17,BZ2,P <Enter>
SEC2_B to WEST_B Connection (SELogic Equation)
I17BZ2V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I18,BZ3,P <Enter>
SEC2_C to WEST_C Connection (SELogic Equation)
I18BZ3V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>
```

```
Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?<Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.74 Zone Configuration Group Settings for Application 2

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information) to use the sensitive differential element for this requirement. Set ECSL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, and EVOLT := N because we do not use the Coupler Security Logic, terminal out of service, breaker failure protection, overcurrent elements, or voltage elements in this application. Pay close attention to the trip logic (TR01 through TR15) settings.

Because we use one SEL-487B, CTs from the three phases (A-phase, B-phase, and C-phase) from each terminal are assigned to three different differential elements (see *Single-Relay Application on page A.1.3*).

Setting NUMBK (Global Settings) equal to 15 also makes 15 corresponding trip equations (TR01 through TR15) available for setting. *Table 1.34* shows the 18 differential trip bits that assert when the differential protection operates. Setting the trip equations involves assigning the 18 differential trip bits to the correct 15 trip equations. There are six differential elements in the relay, and because there are six bus-zones at the station, we use all six differential elements.

For the per-phase differential calculations, the relay assigns the individual phases of each terminal to three separate differential elements. (Strictly speaking, the relay assigns the phases according to the zone configuration group settings. However, correct zone configuration group settings cause the relay to assign the individual phases of each terminal to three separate differential elements.) The tie breaker has six CTs; one CT assigned to each of the six differential elements. Because the tie breaker has only one circuit breaker, operation of any one of the six differential elements must trip the tie-breaker circuit breaker. For this reason, we include the two A-phase differential trip bits (87SEC1A and 87SEC2A) in the same trip equation, the two B-phase differential trip bits (87SEC1B and 87SEC2B) in the same trip equation, and so on.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. Press the **{TARGET RESET}** pushbutton on the front panel to deassert the trip outputs. Alternatively, enter specific reset conditions at the ULTR*kk* settings.

Although the SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting. Set the timer TDURD longer than the clearing time of the slowest circuit breaker at the station.

For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element, the Directional Element, and the Trip Duration Timer. *Figure 1.75* shows the group settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y       ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N       ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5       ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6       ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N       ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N       ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y       ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N       ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>
Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87LON_A
?  87LON_A <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87LON_B
?  87LON_B <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87LON_C
?  87LON_C <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.
Trip 12 (SELogic Equation)
TR12 := NA
?  87CAN_C <Enter>
Unlatch Trip 12 (SELogic Equation)
ULTR12 := NA
?<Enter>
Trip 13 (SELogic Equation)
TR13 := NA
?  87SEC1A OR 87SEC2A <Enter>
Unlatch Trip 13 (SELogic Equation)
ULTR13 := NA
?<Enter>
Trip 14 (SELogic Equation)
TR14 := NA
?  87SEC1B OR 87SEC2B <Enter>
Unlatch Trip 14 (SELogic Equation)
ULTR14 := NA
?<Enter>
Trip 15 (SELogic Equation)
TR15 := NA
?  87SEC1C AND 87SEC2C <Enter>
```

```
Unlatch Trip 15 (SELogic Equation)
ULTR15 := NA
?  <Enter>

Trip Logic
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?> <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.75 Protection Group Settings for Application 2

This concludes the protection group settings. The next settings class is the protection logic settings.

Protection Logic Settings

Use the protection logic settings to create logics in the relay. *Figure 1.76* shows the settings in our example. Protection Latch Bit PLT01 constitutes the differential enable function on the front-panel pushbutton labeled **{87(DIFF) ENABLED}**. Because we do not require breaker failure protection or voltage elements for this application, we remove the settings associated with these functions. Lines 5 through 9 show the programming for the end-zone protection. *Figure 1.76* shows the protection logic settings.

```
=>>SET L <Enter>
Protection 1

1: PLT01S := PCT02Q AND NOT PLT01 # DIFFERENTIAL ENABLED
?<Enter>
2: PLT01R := PB1_PUL AND PLT01
?<Enter>
3: PLT02S := PCT03Q AND NOT PLT02 # BREAKER FAILURE ENABLED
?  DELETE <Enter>
3: PLT02R := PB2_PUL AND PLT02
?  DELETE <Enter>
3: PLT03S := PCT04Q AND NOT PLT03 # RELAY TEST MODE
?<Enter>
4: PLT03R := PB4_PUL AND PLT03
?<Enter>
5: PCT01PU := 240.000000
?  DELETE 12 <Enter>
5:
?  # END-ZONE PROTECTION FOR THE LONDON FEEDER <Enter>
6:
?  LOND_EZ:=(TRLON_A OR TRLON_B OR TRLON_C) AND (52AL01 OR 52AL02 OR 52AL03) AND LOND89C <Enter>
7:
?  # END-ZONE PROTECTION FOR THE BERLIN FEEDER <Enter>
8:
?  BERL_EZ:=(TRBER_A OR TRBER_B OR TRBER_C) AND (52AL04 OR 52AL05 or 52AL06) AND BERL89C <Enter>
9:
?  # END-ZONE PROTECTION FOR THE NEW YORK FEEDER <Enter>
10:
?  NEWY_EZ:=(TRNEW_A OR TRNEW_B OR TRNEW_C) AND (52AL07 or 52AL08 or 52AL09)\
AND NEWY89C <Enter>
11:
?  # END-ZONE PROTECTION FOR THE CANBERRA FEEDER <Enter>
12:
?  CANB_EZ:=(TRCAN_A OR TRCAN_B OR TRCAN_C) AND (52AL10 OR 52AL11 OR 52AL12)\
AND CANB89C <Enter>
13:
?  END <Enter>

Protection 1
.
.
.
```

```
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.76 Protection Logic Settings for Application 2

This concludes the protection logic settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need nine output contacts for our example:

- ➤ four for the direct transfer trip outputs
- ➤ five for the bus-bar protection trip outputs

Although not specifically called for in the protection philosophy, it is good practice to also include the TEST and ALARM outputs in the relay settings.

Because the relay interprets the NUMBK setting as the number of poles, there are 15 trip equations for this application. There is, of course, only one circuit breaker for each terminal. We, therefore, combine the appropriate trip outputs from the breaker trip logic (TRIP01 through TRIP15, see *Figure 1.67*) to provide a single trip output for each circuit breaker. For example, we set the trip equations (*Protection Group Settings on page A.1.83*) for the London terminal to TR01:= 87LON_A, TR02:= 87LON_B, and TR03:= 87LON_C, with the corresponding breaker trip logic output alias names of TRLON_A, TRLON_B, and TRLON_C. Because Terminal LONDON has only one circuit breaker, we assign only one trip output contact (OUT201) to trip the circuit breaker. Therefore, assertion of any one of the three breaker trip logic outputs (TRLON_A, TRLON_B, or TRLON_C) must trip the circuit breaker of the London terminal. To achieve this tripping, set Output OUT201 equal to the OR combination of the three breaker trip logic outputs.

NOTE: The tie-breaker trip equations (TR13 through TR15) already include the combination of two differential elements (87SEC1A OR 87SEC2A, etc.).

Figure 1.77 shows the settings. We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts. We assign the direct transfer trip outputs to the main board contacts and the bus-zone protection to the trip outputs of the interface board. *Figure 1.77* shows the output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRSEC_A AND NOT PLT03
?   LOND_EZ AND NOT PLT03 <Enter>

OUT102 := TRSEC_B AND NOT PLT03
?   BERL_EZ AND NOT PLT03 <Enter>

OUT103 := TRSEC_C AND NOT PLT03
?   NEWY_EZ AND NOT PLT03 <Enter>

OUT104 := TRLON_A AND NOT PLT03
?   CANB_EZ AND NOT PLT03 <Enter>

OUT105 := TRLON_B AND NOT PLT03
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   (TRLON_A OR TRLON_B OR TRLON_C) AND NOT PLT03 <Enter>
```

```
OUT202 := NA
?   (TRBER_A OR TRBER_B OR TRBER_C) AND NOT PLT03 <Enter>

OUT203 := NA
?   (TRNEW_A OR TRNEW_B OR TRNEW_C) AND NOT PLT03 <Enter>

OUT204 := NA
?   (TRCAN_A OR TRCAN_B OR TRCAN_C) AND NOT PLT03 <Enter>

OUT205 := NA
?   (TRSEC_A OR TRSEC_B OR TRSEC_C) AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 1.77 Control Output Settings for Application 2

This concludes the settings for Application 2.

Application 3: Breaker-and-a-Half

This application describes the breaker-and-a-half busbar arrangement shown in *Figure 1.78*. Consider the following to set and configure the relay:

➤ Busbar classification
➤ Protection philosophy
➤ Protection functions selection
➤ Number of SEL-487B relays and I/O boards
➤ Input, logic, and output allocation and alias name assignment
➤ Station layout update
➤ Relay setting and configuration

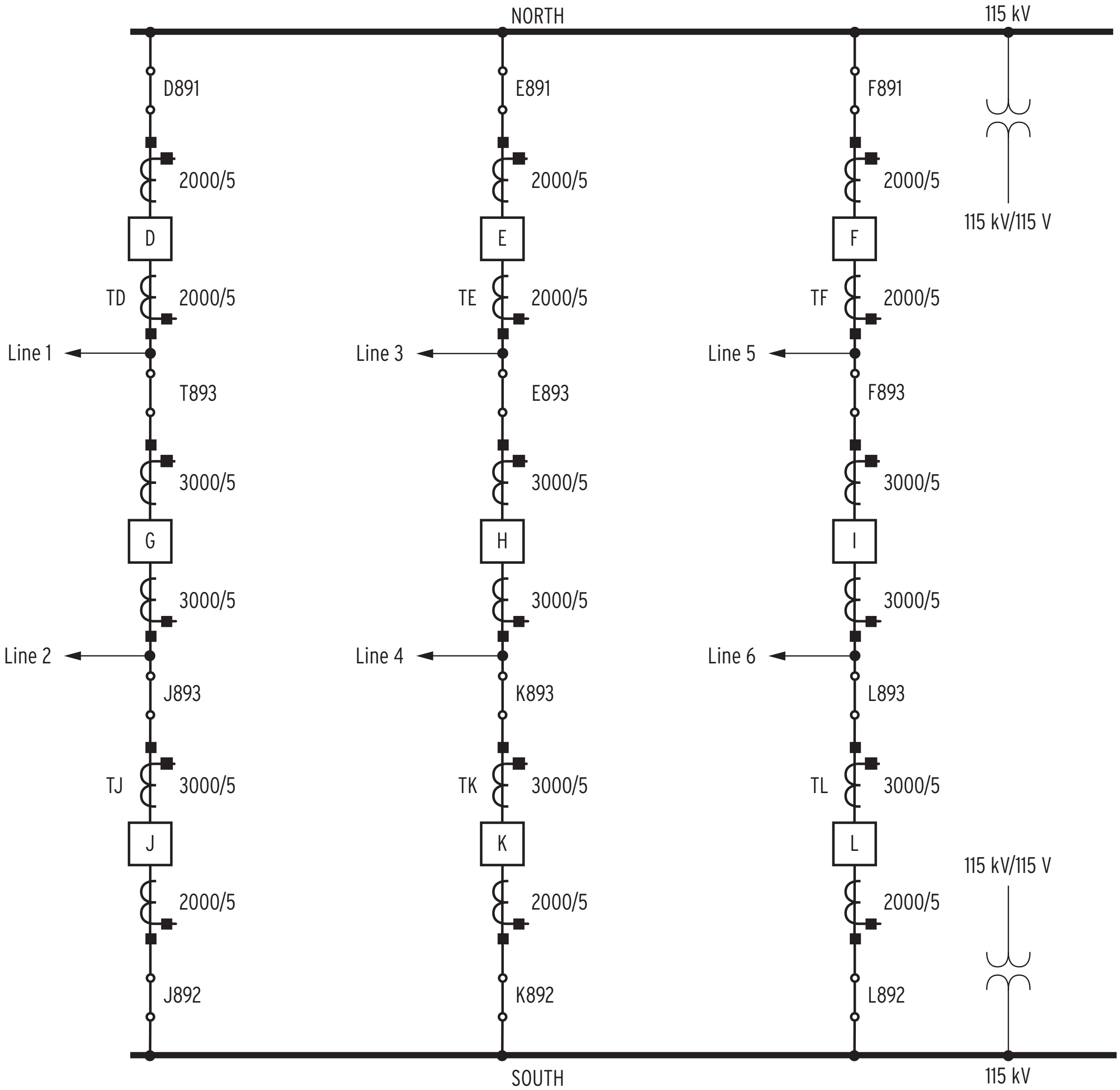


Figure 1.78 Breaker-and-a-Half Busbar Layout

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information.

- Description:
  - Breaker-and-a-half
- Current Transformers:
  - Outboard (free standing)
- Disconnects:
  - No disconnect auxiliary contacts are available
- Future expansion:
  - One feeder

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every substation uses all of these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the terminal-out-of service function.
2. Use the voltage elements as an additional trip criterion, and generate an event report when the voltage elements assert.
3. Block the busbar protection for an open-circuit CT.
4. Use the internal breaker failure protection in the relay for Terminals TD, TE, and TF and include retrip for each terminal.
5. Protect the two busbars with separate relays.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. The SEL-487B offers a number of protection functions as standard features, but it also includes the capability through SELOGIC control equations to create user-configurable functions. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

➤ standard protection functions (available in the relay)

➤ user-defined protection functions (created with SELOGIC control equations)

Standard Functions

Refer to the protection philosophy and select the standard functions necessary for the application. *Table 1.39* shows the selection of the standard functions.

Table 1.39 Section of Standard Protection Functions (Sheet 1 of 2)

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	No	No disconnect auxiliary contacts available
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	No	No disconnect auxiliary contacts available
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Supervise tripping with the under-voltage elements as well as the negative- and zero-sequence over-voltage elements
Zone-switching supervision logic	No	No disconnect auxiliary contacts available
Coupler security logic	No	Breaker-and-a-half busbar layout does not require this function
Circuit breaker failure protection	Yes	Use the internal circuit breaker failure protection

Table 1.39 Section of Standard Protection Functions (Sheet 2 of 2)

Protection Function	Selection	Comment
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	Yes	Use these elements as an additional trip criterion
Zero- or negative-sequence voltage elements	Yes	Use these elements as an additional trip criterion

User-Defined Functions

Because the SEL-487B includes all protection functions necessary for this application as standard protection functions, we do not need any user-defined functions.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with as many as 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.8* to calculate the number of current channels at the station, and use *Equation 1.9* to calculate the number of zones at the station.

# of current channels required # of per-phase station CTs **Equation 1.8**

# of bus-zones required = # of per-phase station bus sections **Equation 1.9**

The protection philosophy calls for a separate relay for each busbar. There are three terminals in each zone, for a total of nine analog channels. Because of future expansion, however, add 3 more channels for a total of 12. Each SEL-487B has 18 analog channels, so that one relay has enough analog inputs to protect one of the busbars; we need 2 relays to protect both busbars.

Therefore, an SEL-487B protects busbar NORTH, and a separate SEL-487B protects the SOUTH busbar. This is known as a single-relay application. The following discussion describes setting the relay that protects the NORTH busbar. Configuration settings for the relay protecting the SOUTH busbar are the same, except for the alias names. System settings such as CT ratios may be different.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application. The protection philosophy calls for breaker failure protection. We, therefore, need a breaker failure initiate input contact for each of the three terminals. *Table 1.40* summarizes the input contact requirement for this application.

Table 1.40 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for circuit breaker failure protection	3
Total number of inputs	3

The relay main board has seven input contacts, sufficient for our application. From the input contact perspective, we only need the main board; we do not need an interface board.

Number of Relay Output Contacts

Circuit breakers TD, TE, and TF each need a trip output contact as well as a direct transfer trip (DTT). *Table 1.41* shows the breakdown and the total number of relay output contacts required.

Table 1.41 Breakdown and the Total Number of Relay Outputs Required

Output description	Outputs
Number of relay output contacts required for differential, breaker failure tripping, and direct transfer trip	3
Number of relay output contacts required for direct transfer tripping	3
Total number of relay output contacts	6

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). There are enough output contacts on the main board, but these contacts are all standard output contacts. The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need one SEL-487B per busbar, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B relays necessary for the application
- the number of input contacts
- the number of output contacts
- the selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation, and CT Alias Assignment

Table 1.42 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase CT from Terminal TD to relay channel I01, and assign to this CT the alias name TD_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.42* shows the assignment starting with Terminal TD, followed by Terminal TE, and Terminal TF, taken left-to-right from *Figure 1.78*.

Table 1.42 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
Terminal TD, A-phase	I01	TD_A
Terminal TD, B-phase	I02	TD_B
Terminal TD, C-phase	I03	TD_C
Terminal TE, A-phase	I04	TE_A
Terminal TE, B-phase	I05	TE_B
Terminal TE, C-phase	I06	TE_C
Terminal TF, A-phase	I07	TF_A
Terminal TF, B-phase	I08	TF_B
Terminal TF, C-phase	I09	TF_C

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. In this application, we use three of the six zones with alias names as shown in *Table 1.43*.

Table 1.43 Alias Names for the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	NORTH_A
BZ2	Bus-Zone 2	NORTH_B
BZ3	Bus-Zone 3	NORTH_C

Input-to-Logic Allocation and Alias Assignment

Table 1.40 shows that we require three digital inputs. We now assign the digital inputs to the selected logic and apply alias names to the inputs and logic elements. Because we installed an interface board, we use the independent inputs on the interface board for the breaker failure initiate inputs, instead of the inputs on the main board.

Input-to-Logic Allocation and Alias Assignment, Interface Board 1 (200)

Table 1.44 shows the breaker failure initiate input allocations.

Table 1.44 Alias Names for the Breaker Failure Input Contacts

Input	Description	Alias
IN201	Terminal TD breaker failure initiate	ITD_BFI
IN202	Terminal TE breaker failure initiate	ITE_BFI
IN203	Terminal TF breaker failure initiate	ITF_BFI

Assign Alias Names to the Selected Standard Logic

The following explains each selected function in reference to *Table 1.39*. Alias name assignments are also included.

Breaker Failure

This application is a breaker-and-a-half busbar layout. For such busbar layouts, two circuit breakers must operate to clear a fault. *Figure 1.79* shows fault F1, for which both Circuit Breaker TD and Circuit Breaker TG must operate to clear the fault. For certain faults, the current distribution may be such that Circuit Breaker TD carries the bulk of the fault current, as shown in *Figure 1.79*.

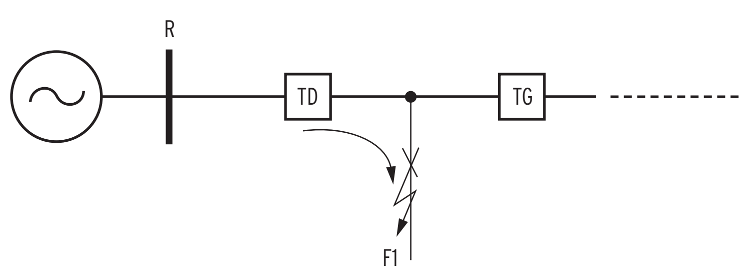


Figure 1.79 Current Distribution for Fault F1 With Circuit Breaker TD and Circuit Breaker TG Closed

Because of the current distribution, Terminal TG may only have enough current to assert the breaker failure current element threshold (50F*nn*) when Circuit Breaker TD opens, as shown in *Figure 1.80*.

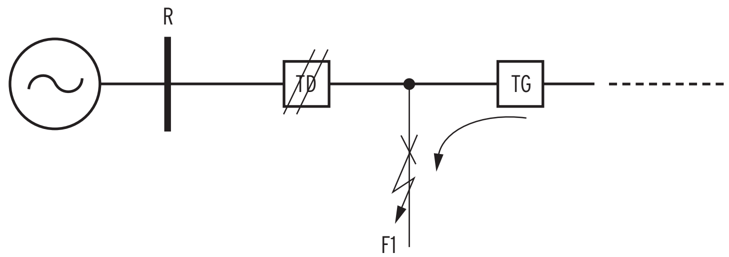


Figure 1.80 Current Flow for Fault F1 After Circuit Breaker TD Opened

This situation delays initiation of the breaker failure protection of Terminal TG until Circuit Breaker TD interrupts the current. However, both circuit breakers receive the trip signal at the same time and are expected to operate at the same time. Use breaker failure protection Scheme 2 to prevent this delay. See *Circuit Breaker Failure Protection on page R.1.37* for more information.

Because the protection philosophy calls for use of the internal breaker failure protection, wire a breaker failure initiate contact from each feeder panel to an independent relay input contact. *Table 1.45* shows the primitive names and the alias names of the breaker failure initiate Relay Word bits (see the *Protection Group Settings on page A.1.104* for more information).

Table 1.45 Alias Names for the Breaker Failure Initiate Relay Word Bits

Logic Name	Description	Alias
ATBFI01	Terminal TD A-phase breaker failure protection initiate input	TDA_BFI
ATBFI02	Terminal TD B-phase breaker failure protection initiate input	TDB_BFI
ATBFI03	Terminal TD C-phase breaker failure protection initiate input	TDC_BFI
ATBFI04	Terminal TE A-phase breaker failure protection initiate input	TEA_BFI
ATBFI05	Terminal TE B-phase breaker failure protection initiate input	TEB_BFI
ATBFI06	Terminal TE C-phase breaker failure protection initiate input	TEC_BFI
ATBFI07	Terminal TF A-phase breaker failure protection initiate input	TFA_BFI
ATBFI08	Terminal TF B-phase breaker failure protection initiate input	TFB_BFI
ATBFI09	Terminal TF C-phase breaker failure protection initiate input	TFC_BFI

We also assign alias names to breaker failure logic output Relay Word bits. *Table 1.46* shows the primitive names and the alias names.

Table 1.46 Alias Names for the Breaker Failure Logic Output Relay Word Bits

Logic Name	Description	Alias
FBF01	Terminal TD A-phase breaker failure protection asserted	TDA_BF
FBF02	Terminal TD B-phase breaker failure protection asserted	TDB_BF
FBF03	Terminal TD C-phase breaker failure protection asserted	TDC_BF
FBF04	Terminal TE A-phase breaker failure protection asserted	TEA_BF
FBF05	Terminal TE B-phase breaker failure protection asserted	TEB_BF
FBF06	Terminal TE C-phase breaker failure protection asserted	TEC_BF
FBF07	Terminal TF A-phase breaker failure protection asserted	TFA_BF

Table 1.46 Alias Names for the Breaker Failure Logic Output Relay Word Bits

Logic Name	Description	Alias
FBF08	Terminal TF B-phase breaker failure protection asserted	TFB_BF
FBF09	Terminal TF C-phase breaker failure protection asserted	TFC_BF

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Alias Assignment

Figure 1.81 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF09 are the inputs to the station breaker failure trip logic; Relay Word bits SBFTR01–SBFTR09 are the outputs from the station breaker failure trip logic. Relay Breaker failure trip bits SBFTR01–SBFTR09 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

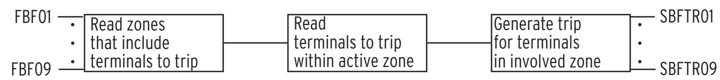


Figure 1.81 Station Breaker Failure Trip Logic

Table 1.47 shows the station breaker failure Relay Word bits and the alias names for the breaker failure protection outputs.

Table 1.47 Primitive Terminal and Station Breaker Failure Trip Relay Word Bit Names and the Alias Names for the Breaker Failure Trip Bits

Primitive Name	Description	Alias Names
SBFTR01	Terminal TD A-phase station breaker failure protection asserted	TDA_SBF
SBFTR02	Terminal TD B-phase station breaker failure protection asserted	TDB_SBF
SBFTR03	Terminal TD C-phase station breaker failure protection asserted	TDC_SBF
SBFTR04	Terminal TE A-phase station breaker failure protection asserted	TEA_SBF
SBFTR05	Terminal TE B-phase station breaker failure protection asserted	TEB_SBF
SBFTR06	Terminal TE C-phase station breaker failure protection asserted	TEC_SBF
SBFTR07	Terminal TF A-phase station breaker failure protection asserted	TFA_SBF
SBFTR08	Terminal TF B-phase station breaker failure protection asserted	TFB_SBF
SBFTR09	Terminal TF C-phase station breaker failure protection asserted	TFC_SBF

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection (see the *Control Output Settings on page A.1.115* for more information).

Differential Trip Logic and Differential Element Alias Assignment

Figure 1.82 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

Differential trip bits 87BTR01 through 87BTR09 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

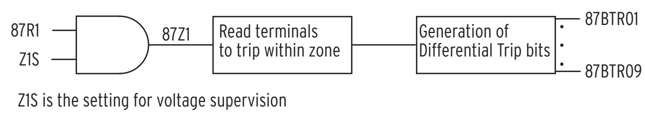


Figure 1.82 Differential Trip Logic for Differential Element 1

Table 1.48 shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 1.48 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	NORTA_T
87Z2	Zone 2 differential element trip	NORTB_T
87Z3	Zone 3 differential element trip	NORTC_T

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate. In our example, we want to trip three terminals. *Table 1.49* shows the primitive terminal names, the differential trip bit names, and the alias names for the differential trip bits.

Table 1.49 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits

Primitive Name	Description	Alias
87BTR01	Terminal TD A-phase differential protection trip asserted	TD_TA
87BTR02	Terminal TD B-phase differential protection trip asserted	TD_TB
87BTR03	Terminal TD C-phase differential protection trip asserted	TD_TC
87BTR04	Terminal TE A-phase differential protection trip asserted	TE_TA
87BTR05	Terminal TE B-phase differential protection trip asserted	TE_TB
87BTR06	Terminal TE C-phase differential protection trip asserted	TE_TC
87BTR07	Terminal TF A-phase differential protection trip asserted	TF_TA
87BTR08	Terminal TF B-phase differential protection trip asserted	TF_TB
87BTR09	Terminal TF C-phase differential protection trip asserted	TF_TC

Breaker Trip Logic and Trip Alias Assignment

Figure 1.83 shows the general tripping logic in the SEL-487B. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

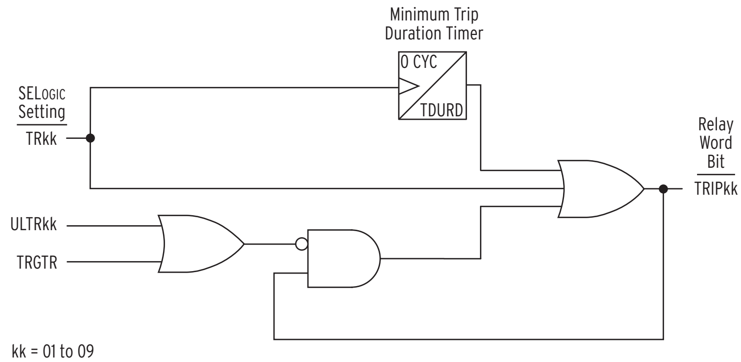


Figure 1.83 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK). Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals nine. After setting the TR*kk* trip equations, the relay associates each TR*kk* trip equation with a particular circuit breaker pole; we must combine the trip equations in the output settings to form a single output for the circuit breaker (see *Control Output Settings on page A.1.115* for more information). For example, after setting TR01:= 87BTR01 OR SBFTR01 and TR02:= 87BTR02 OR SBFTR02, the relay associates Trip Equation TR01 with Terminal 01 (TD_A), Trip Equation TR02 with Terminal 02 (TD_B), and so on. *Table 1.50* shows the primitive and alias names for the trip logic of each terminal.

Table 1.50 Primitive and Alias Names for the Trip Logic of Each Terminal

Primitive Name	Description	Alias Name
TRIP01	Terminal TD A-phase trip output asserted	TRTD_A
TRIP02	Terminal TD B-phase trip output asserted	TRTD_B
TRIP03	Terminal TD C-phase trip output asserted	TRTD_C
TRIP04	Terminal TE A-phase trip output asserted	TRTE_A
TRIP05	Terminal TE B-phase trip output asserted	TRTE_B
TRIP06	Terminal TE C-phase trip output asserted	TRTE_C
TRIP07	Terminal TF A-phase trip output asserted	TRTF_A
TRIP08	Terminal TF B-phase trip output asserted	TRTF_B
TRIP09	Terminal TF C-phase trip output asserted	TRTF_C

Assign Alias Names to the User-Defined Logic

This application requires no user-defined logic.

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 1.41* shows the breakdown of the relay outputs that we need for this application. We now assign specific relay output contacts to the relay functions and assign alias names to the relay output contacts. *Table 1.51* shows the main board assignments and alias names.

Output Alias Assignment, Main Board

This application requires no main board output contacts.

Table 1.51 Alias Assignment for the Trip Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.52* shows the assignments and alias names for Interface Board 1.

Table 1.52 Alias Assignments for the Output Contacts of Interface Board 1

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	Terminal TD trip output	TD_TRIP
OUT202[a]	Terminal TE trip output	TE_TRIP
OUT203[a]	Terminal TF trip output	TF_TRIP
OUT204[a]	Terminal TD direct transfer trip output	TD_DTT
OUT205[a]	Terminal TE direct transfer trip output	TE_DTT
OUT206[a]	Terminal TF direct transfer trip output	TF_DTT

[a] High-speed, high-interrupting outputs.

Station Layout Update

We are now ready to set and configure the relay. Write down all the relevant information onto the station diagram, as shown in *Figure 1.84*. *Figure 1.84* shows the updated station layout for both relays.

1. Write down the bus-zone, terminal, and disconnect names.
2. Allocate the terminals CTs to the relay input current channels.
3. Allocate the auxiliary contacts to the relay digital inputs.
4. Allocate the digital outputs from the relay to the station terminals.

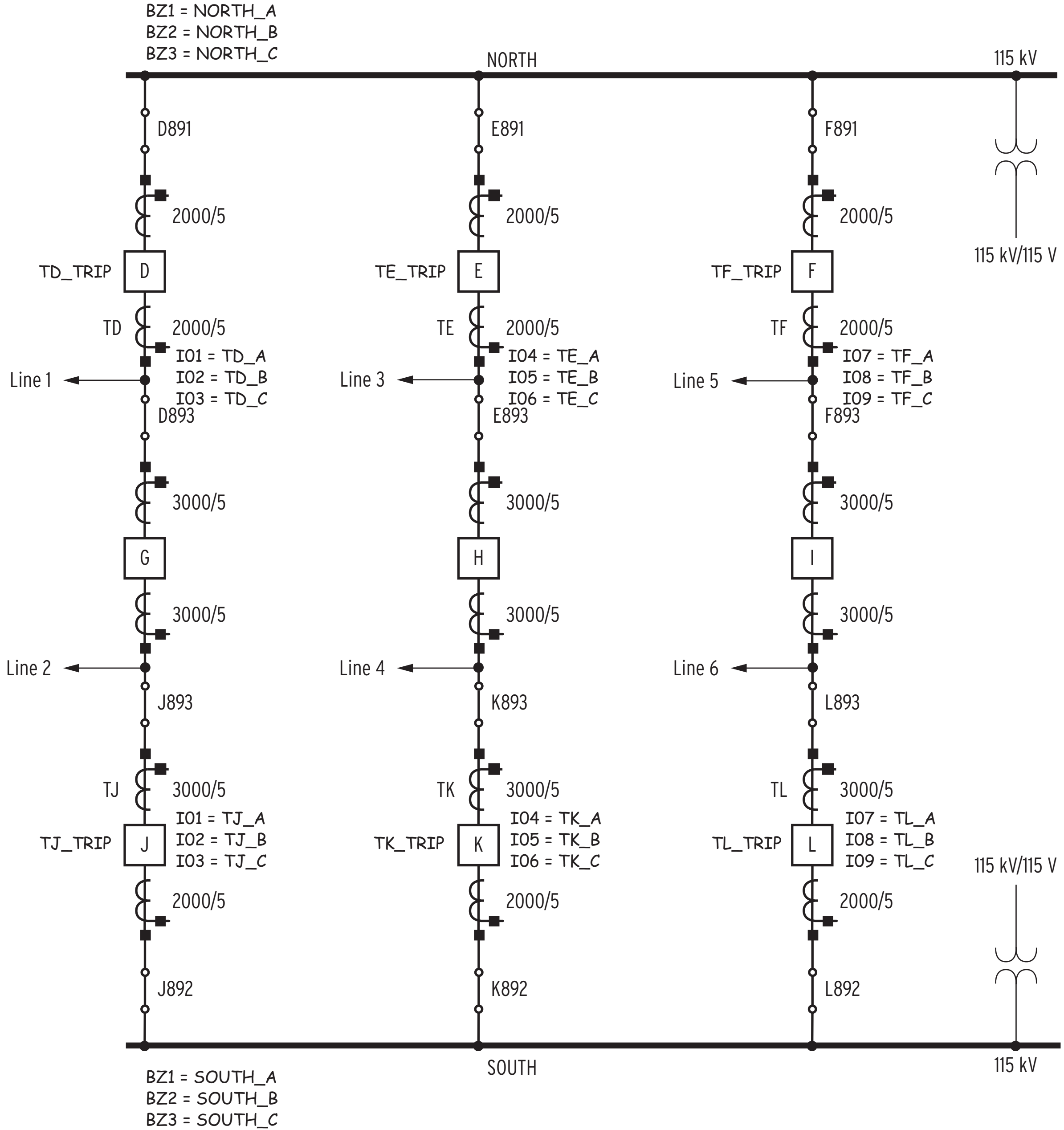


Figure 1.84 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Front Panel Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.85*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.85 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.86*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.86 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the analog channels and Relay Word bits, as shown in *Figure 1.87*.

We include the alias names for the three protection latch bits (PLT01, PLT02, and PLT03). We use these protection latch bits for local control of the differential elements (PLT01), the breaker fail protection (PLT02), and the relay test mode (PLT03). Because the protection logic default settings include these three protection latch bits as default settings, we did not select these protection latch bits as user-defined logic.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TD_A <Enter>
20:
?  I02,TD_B <Enter>
21:
?  I03,TD_C <Enter>
22:
?  I04,TE_A <Enter>
23:
?  I05,TE_B <Enter>
24:
?  I06,TE_C <Enter>
.
.
.
136:
?  PLT01,DIFF_EN <Enter>
137:
?  PLT02,BF_EN <Enter>
138:
?  PLT03,TNS_SW <Enter>
139:
?  END <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.87 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is the global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.88* shows the setting changes we need for our example. Because we declared the alias names in the alias settings class, use either the alias names or the primitive names when entering settings.

Enter the number of poles at the station for the NUMBK settings. There are three terminals in the differential equation, each with three poles. The total number of poles, therefore, equals nine poles, and we set NUMBK to 9.

Setting NUMBK to 9 makes 9 corresponding circuit breaker auxiliary input equations (52A01 through 52A09) and nine corresponding trip equations (TR01 through TR09) available for setting. Because we do not need circuit breaker auxiliary inputs for this example, we need not enter values for the circuit breaker auxiliary input equations. For this example, the only Global setting change is the number of circuit breakers; all other settings remain at default settings.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                         NUMBK   := 5      ?9 <Enter>
Number of Disconnects (N,1-48)                      NUMDS   := N      ?END <Enter>
Global
.
.
.
52A08 := NA
52A09 := NA

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.88 Global Settings for Application 3

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. In this application, there are no disconnect auxiliary contacts available, and we permanently assign analog channels to the appropriate differential elements. All 18 channels are available for setting, but only the first 9 are part of the differential protection. We, therefore, assign only the first nine analog channels to the differential elements. The protection philosophy calls for the use of the voltage elements as an additional trip criterion.

Calculate the ratio settings as follows:

$$\begin{aligned} \text{PTR} &= \frac{\text{Primary Nominal Voltage}}{\text{Secondary Nominal Voltage}} \\ &= \frac{115000}{115} \\ &= 1000 \end{aligned}$$

Equation 1.10

Figure 1.89 shows the zone configuration settings.

Because there are no disconnects available at this station, we cannot use the dynamic zone selection logic. Because we cannot use the dynamic zone selection logic, the CTs are always considered in the differential equations.

When we consider only the disconnect auxiliary contacts as conditions in the terminal-to-bus-zone connection settings, we would have entered a 1 for each of the terminal-to-bus-zone connection settings.

This example, however, also includes two other conditions that must be a logical 1 before the relay considers the CTs in the differential equations. The two conditions are

- the differential enable switch (Alias DIFF_EN)
- and the terminal-out-of-service switch (TOS*nn*, where *nn* is the terminal number)

Front-panel pushbutton **{PB1}** controls DIFF_EN. The function of DIFF_EN is to remove all the terminals from the differential equations with a single command. Enter **DIFF_EN** at every terminal-to-bus-zone variable.

The terminal out-of-service switch, which removes individual terminals from the differential calculations, is part of the front panel local controls. Include an individual terminal out-of-service (TOS*nn*) for each terminal.

The zone configuration default settings are for a specific substation with arbitrarily selected alias names, serving only as an example. Delete the terminal-to-bus-zone default settings for ease of setting zone configuration settings for the new substation. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone settings. *Figure 1.89* shows the Zone configuration settings for this application. Instead of entering **1 AND DIFF_EN AND NOT TOS*nn***, we omit the 1, and enter only **DIFF_EN AND NOT TOS*nn*** for each setting.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000    ?1000 <Enter>
Potential Transformer Ratio -V02 (1-10000)          PTR2    := 2000    ?1000 <Enter>
Potential Transformer Ratio -V03 (1-10000)          PTR3    := 2000    ?1000 <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600     ?400 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600     ?400 <Enter>
.
.
.

Current Transformer Ratio -I09 (1-50000)            CTR09   := 600     ?400 <Enter>
Current Transformer Ratio -I10 (1-50000)            CTR10   := 600     ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TD_A, NORTH_A, P
?   DELETE 100 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I01,BZ1,P <Enter>
TD_A to NORTH_A Connection (SELogic Equation)
I01BZ1V := NA
?   PLT01 AND NOT TOS01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I02,BZ2,P <Enter>
TD_B to NORTH_B Connection (SELogic Equation)
I02BZ2V := NA
?   PLT01 AND NOT TOS01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,BZ3,P <Enter>
TD_C to NORTH_C Connection (SELogic Equation)
I03BZ3V := NA
?   PLT01 AND NOT TOS01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,BZ1,P <Enter>
TE_A to NORTH_A Connection (SELogic Equation)
I04BZ1V := NA
?   PLT01 AND NOT TOS02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,BZ2,P <Enter>
```

```
TE_B to NORTH_B Connection (SELogic Equation)
I05BZ2V := NA
?   PLT01 AND NOT TOS02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,BZ3,P <Enter>
TE_C to NORTH_C Connection (SELogic Equation)
I06BZ3V := NA
?   PLT01 AND NOT TOS02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I07,BZ1,P <Enter>
TF_A to NORTH_A Connection (SELogic Equation)
I07BZ1V := NA
?   PLT01 AND NOT TOS03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I08,BZ2,P <Enter>
TF_B to NORTH_B Connection (SELogic Equation)
I08BZ2V := NA
?   PLT01 AND NOT TOS03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I09,BZ3,P <Enter>
TF_C to NORTH_C Connection (SELogic Equation)
I09BZ3V := NA
?   PLT01 AND NOT TOS03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
? DELETE 100 <Enter>
Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N       ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?   59Q1 OR 59N1 OR 27P11 <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?   59Q1 OR 59N1 OR 27P21 <Enter>
Zone 3 Supervision (SELogic Equation)
Z3S := 1
?   59Q1 OR 59N1 OR 27P31 <Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N       ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.89 Zone Configuration Group Settings for Application 3

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, beginning with the function enable settings.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information) to use the sensitive differential element for this requirement. Set ECSL := N because we do not use the Coupler Security Logic.

Terminal out of service is a local bit (local bits provide programming capabilities for functions available on the front-panel screen under LOCAL CONTROL). Include the terminal out of service in the trip equations to disable the outputs from individual terminals.

This local control selectively takes a terminal out of service, whereas the **{87(DIFF) ENABLED}** pushbutton disables all the trip outputs. Set ETOS := 3 because there are three breakers in the bus-zone differential protection.

There are nine breaker poles (NUMBK := 9), all of which need relay breaker failure protection. Set EBFL := 9 to enable nine breaker failure logics. Set E50 := N and E51 := N because we do not need overcurrent protection for this application.

The protection philosophy calls for undervoltage as an additional trip criterion. Because the voltage elements are enabled in the default settings, leave EVOLT := Y.

Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. Enable the advance settings by setting EADVS := Y to change the slope setting.

With EADVS := Y, the slope settings and incremental restrained and operating current settings become available. For this application, we use the default values for the sensitive differential element, the restrained differential element, and the directional element.

The protection philosophy calls for breaker failure protection. This application shows an example of how to calculate breaker failure settings for the Terminal TD circuit breaker. In this example, we apply the settings calculated for Terminal TD to all the terminals at the station. Because network parameters are different, be sure to calculate values for the other terminals; do not assume that settings for one terminal apply to all other terminals at the same station.

EBFL, Enable Breaker Fail Setting

Enter the number of per-pole breaker fail logics you want to enable.

In this single-relay application, we need nine per-pole breaker fail logics, because we must provide breaker failure protection for three breakers.

EBFL := **9** Enable breaker fail

Figure 1.90 shows the components of breaker failure protection for line protection. Do not consider remote terminal information when considering breaker failure protection for equipment such as capacitor banks, transformers, etc.

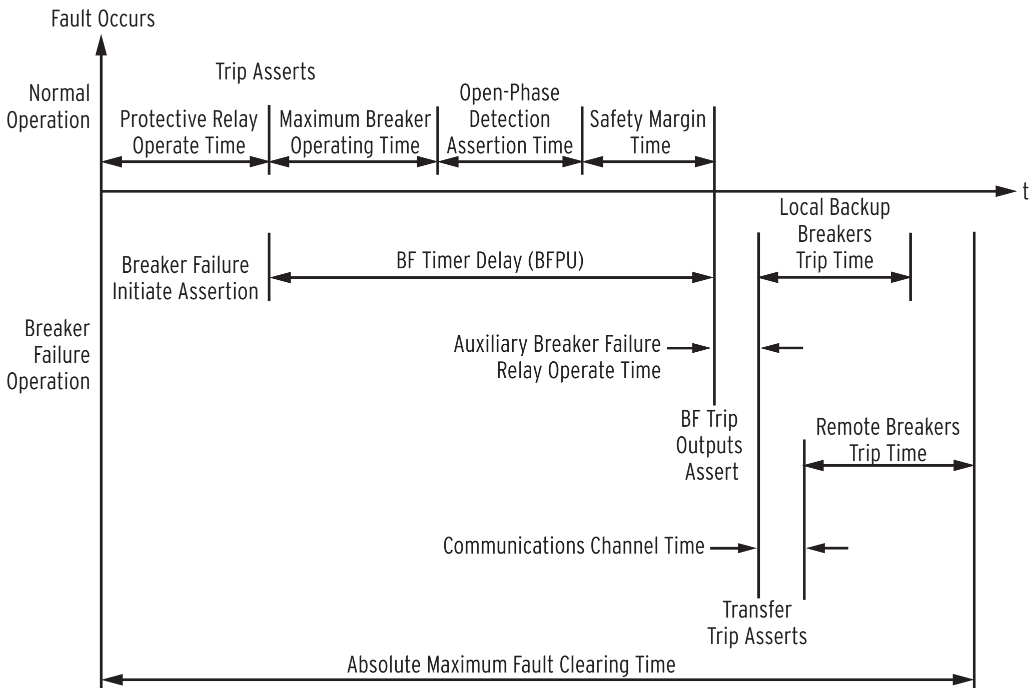


Figure 1.90 Breaker Failure Timing Diagram

Use the SEL-487B to provide circuit breaker failure protection for Circuit Breaker TD in *Figure 1.91*.

Figure 1.91 shows the power system for this example. Line 1 and Line 2 connect Station S and Station R. We set the breaker failure protection in the SEL-487B to detect circuit breaker failures for Terminal TD at Station S. This example uses a line with three-pole tripping, but the relay provides the flexibility to also apply circuit breaker failure for single-pole trip circuit breakers. This flexibility is possible because the current measurement and timers are available on a per-phase basis.

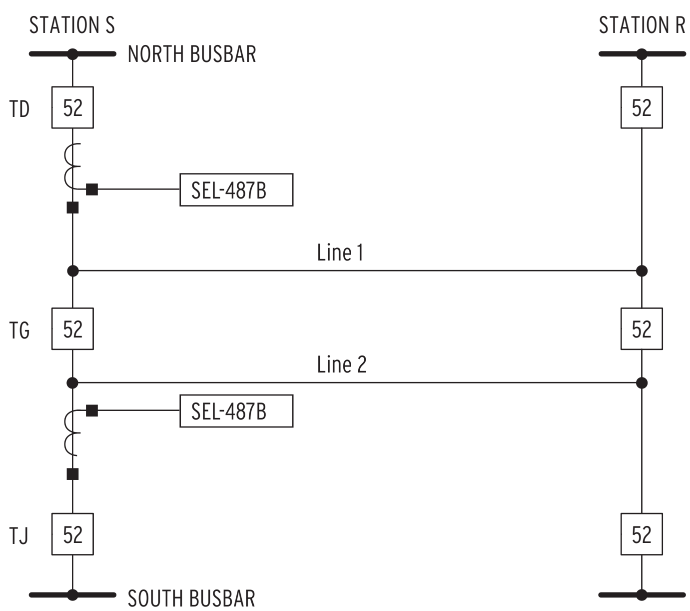


Figure 1.91 Power System for Circuit Breaker Failure Scheme 2

50FP01, Phase Current Level Detector Setting

NOTE: This is one method for calculating setting 50FP01. Use your company's practices and policies for determining the pickup setting for your particular application.

Set the current pickup (50FP01) greater than maximum load and less than the fault current that flows through Terminal TD. Assume that the total load current (I_S) is 3.25 A secondary, supplied from Substation S. Calculate setting 50FP01 with all the load current I_S through Terminal TD.

$$\begin{aligned} 50FP01 &= 120\%(\text{Percent Current} \bullet I_S) \\ &= 120\%(100\%\ \text{Current} \bullet 3.25\ \text{A}) \\ &= 3.91\ \text{A secondary} \end{aligned}$$

Equation 1.11

A fault study shows that the minimum ground fault current, $I_{\text{fault minimum}}$, is 4.2 A secondary when the parallel line is in service at minimum generation. Calculate the 50FP01 setting for dependability at half the minimum fault current.

$$\begin{aligned} 50FP01 &= 0.5(\text{Percent Current} \bullet I_{\text{fault minimum}}) \\ &= 0.5(100\%\ \text{Current} \bullet 4.20\text{A}) \\ &= 2.10\ \text{A secondary} \end{aligned}$$

Equation 1.12

Although the result of this setting calculation is less than maximum load, obtain greater dependability by using this calculation to set the 50FP01 element to 2.10 A.

BFPU01, Circuit Breaker Failure Time Delay Setting

BFPU01 (Breaker Failure Time Delay-Terminal TD) is the time for which the input (BFI01) to Timer BFPU01 must be continuously present to result in a circuit breaker failure trip operation. The recommended setting for BFPU1 is the sum of the following:

- Maximum circuit breaker operating time
- OPH01 maximum dropout time
- Safety margin

Figure 1.92 shows the timing diagram for setting Timer BFPU01.

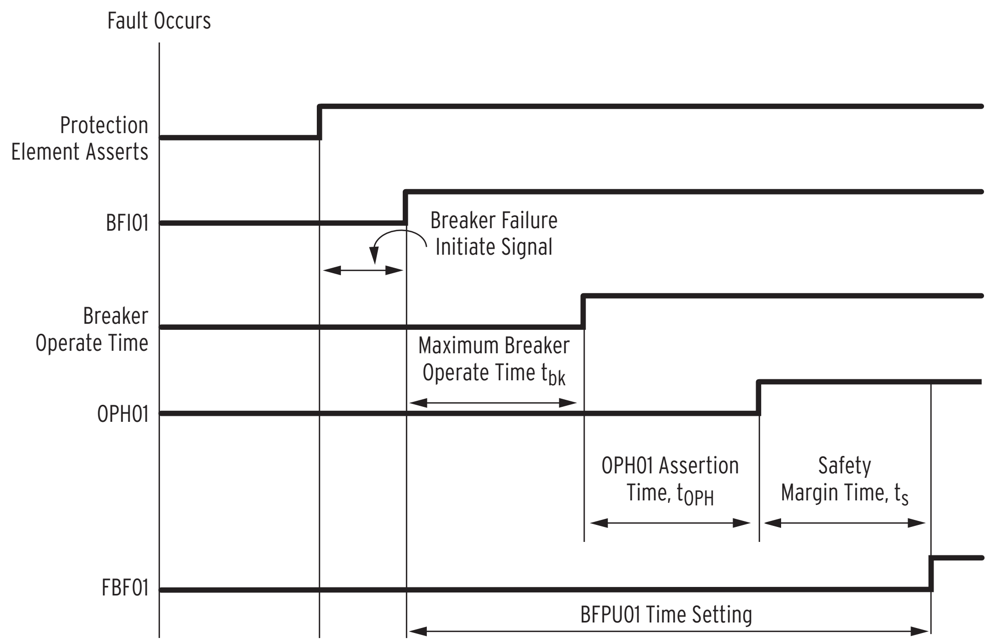


Figure 1.92 Timing Diagram for Setting BFPU01-Scheme 2

To maintain system stability, you must clear the fault within the total clearing time, assumed to be 17 cycles for this example. Use the maximum operating time of the local and remote circuit breakers. The maximum circuit breaker operating time, t_{bk}, is 3 cycles for this example.

Use 0.75 cycle for t_{OPH}, the maximum assertion time of the open-phase detector, OPH01. You must also include the communications channel time, t_{ch}, for remote circuit breaker tripping. To determine setting BFPU1, you must find the safety margin, t_s. Use *Equation 1.13* to calculate the safety margin:

$$\begin{aligned} t_s &= tt - (t_{1r} + t_{1bk} + t_{OPH} + t_{86} + t_{ch} + t_{rbk}) \\ &= 17 - (2 + 3 + 0.75 + 1 + 1 + 3) \\ &= 5.75 \text{ cycles} \end{aligned}$$

Equation 1.13

where:

t_s = safety margin
tt = total clearing time (17 cycles)
t_{1r} = line protection maximum operating time (2 cycles)
t_{1bk} = local circuit breaker maximum operating time (3 cycles)
t_{OPH} = open-phase detection OPH01 maximum assertion time (0.75 cycle)
t_{86} = auxiliary breaker failure relay operating time (1 cycle)
t_{ch} = communications channel maximum operating time (1 cycle)
t_{rbk} = remote circuit breaker maximum operating time (3 cycles)

Use the safety margin result from *Equation 1.13* to calculate BFPU01:

$$\begin{aligned} \text{BFPU01} &= t_{1bk} + t_{OPH} + t_s \\ &= 3 + 0.75 + 5.75 \\ &= 9.5 \text{ cycles} \end{aligned}$$

Equation 1.14

BFPU01 := **9.50** cycles Breaker Failure Time Delay

RTPU01, Retrip Time Delay Setting

If the circuit breaker is equipped with two trip coils, the relay should attempt to retrip the protected circuit breaker before a circuit breaker failure trip asserts. In this example, local circuit breaker maximum operating time is 3 cycles, and the open phase detection assertion is 0.75 cycle. Wait 4 cycles for the retrip.

RTPU01 := **4.00** Retrip Time Delay

BFI01 and ABFI01, Circuit Breaker Initiation Settings

Figure 1.93 shows the breaker failure initiate contact for Terminal TD. Wire similar contacts for Terminal TE and Terminal TF into the SEL-487B.

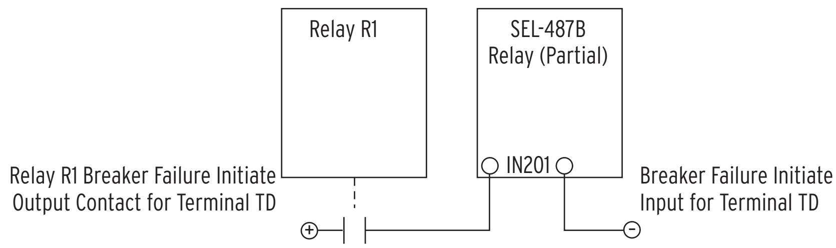


Figure 1.93 Breaker Failure Protection Wiring for Terminal TD

For this example, assume the breaker failure initiate signal is continuous. Because this is a breaker-and-a-half busbar layout, use the input extension option of *Alternate Breaker Failure Initiating Input With Extension and/or Seal In Logic on page R.1.38* (see *Circuit Breaker Failure Protection on page R.1.37* for more information).

Figure 1.94 shows the circuit breaker failure initiation extension and seal-in logic, and *Figure 1.95* shows the circuit breaker failure logic.

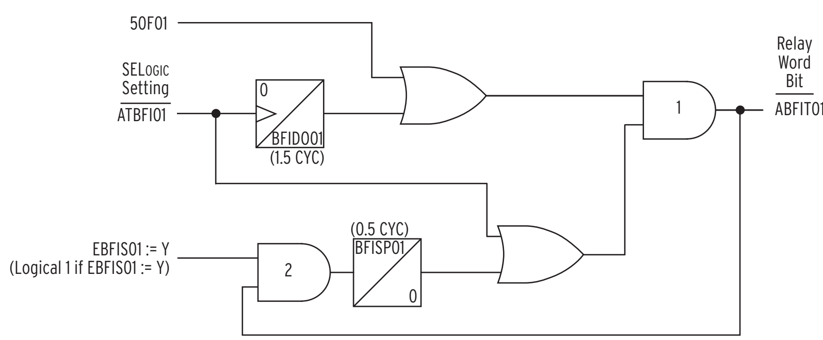


Figure 1.94 Circuit Breaker Failure Initiation Extension and Seal-In Logic

Scheme 2 uses a combination of the logic in *Figure 1.94* and *Figure 1.95* by setting the output from the circuit breaker failure initiation extension and seal-in logic (ABFIT01, *Figure 1.94*) as the breaker failure initiate input of the breaker failure logic (BFI01, *Figure 1.95*).

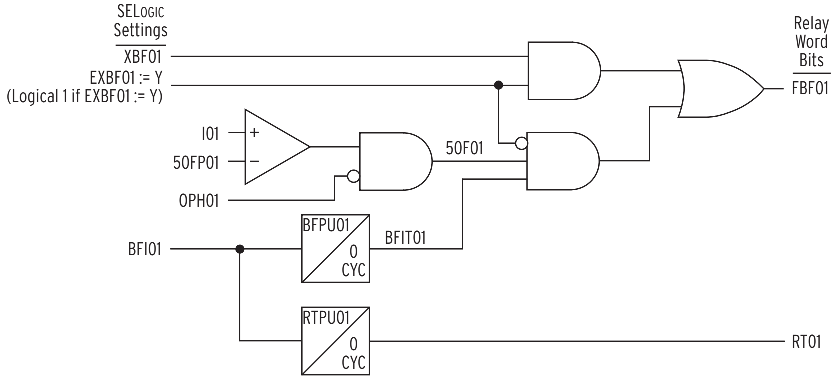


Figure 1.95 Circuit Breaker Failure Logic

Because this is an example of a three-pole circuit breaker, enter the same breaker failure initiate input (IN201) for all three phases (ATBFI01 through ATBFI03) for Terminal TD.

Table 1.53 shows the breaker failure initiate input (IN201) and the assignment and setting to combine the logic for Terminal TD, stating the alias names where applicable. Settings for the remaining terminals are similar.

Table 1.53 Input and Relay Word Bit Assignments and Settings for the Combined Logic

Assignment	Setting to Achieve the Assignment
IN201 to ATBFI01	TDA_BFI := ITD_BFI
IN201 to ATBFI02	TDB_BFI := ITD_BFI
IN201 to ATBFI03	TDC_BFI := ITD_BFI
ABFIT01 to BFI01	BFI01 := ABFIT01
ABFIT02 to BFI02	BFI02 := ABFIT02
ABFIT03 to BFI03	BFI03 := ABFIT03

BFIDO01, Circuit Breaker Failure Protection Initiation Dropout Delay Setting

Setting EBFIS01 applies to the case where the breaker failure initiate signal is not continuous. Because the breaker failure initiate signal is continuous in this example, leave EBFIS01 at the default value of N. Consider the case where the entire fault current initially flows through Terminal TG, and no current flows through Terminal TD. Timer BFIDO01 replaces the current input 50FI01 (*Figure 1.94*) for the period when the entire fault current flows through Circuit Breaker TG. During this period, not enough current is available to assert Relay Word bit 50FI01 to turn AND Gate 1 on (*Figure 1.94*). Timer BFIDO01 extends the breaker failure initiate signal, waiting for Terminal TD to interrupt the fault current. The maximum circuit breaker operating time for Terminal TG is 3 cycles; allow a short safety margin and set Timer BFIDO01 to 4 cycles.

BFID01 := **4.00** Breaker Failure Initiate Dropout Delay-BK1

59QP1 and 59NP1, Negative- and Zero-Sequence Overvoltage, Thresholds and Phase Undervoltage Settings

Conduct fault studies to obtain appropriate settings for the negative-sequence and zero-sequence overvoltage elements.

For this example, assume a setting of 15 V for both negative-sequence and zero-sequence overvoltage elements and 45 V for the undervoltage elements.

59Q1P := **15** Negative-sequence overvoltage element

59N1P := **15** Zero-sequence overvoltage element

27P11P := **45** undervoltage element

TR01–TR09, Trip Equations Settings

Pay close attention to the trip logic (TR01–TR09) settings. Because this is a single-relay application, CTs from the three phases (A-phase, B-phase, and C-phase) from each terminal are assigned to three different differential elements (see *Single-Relay Application on page A.1.3*). Setting NUMBK (Global settings) to 9 also makes 9 corresponding trip equations (TR01 through TR09) available for setting. All nine channels are part of the breaker failure protection, as well as part of the bus-zone protection. Therefore, we include the differential trip outputs as well as the station breaker fail trip outputs in the trip equation of each terminal. Setting the trip equations involves assigning the nine differential trip bits to the correct nine trip equations, and assigning the nine station breaker failure trip bits to the correct nine trip equations.

TDURD, Minimum Trip Duration Time Delay Setting

Although the SEL-487B includes nine trip logics, there is only one Minimum Trip Duration Time Delay setting. Set the timer TDURD longer than the operating time of the slowest circuit breaker at the station, using the default value of 12 cycles.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. Press the **{TARGET RESET}** pushbutton on the front panel to deassert the trip outputs. Alternatively, enter specific reset conditions at the ULTR*kk* settings.

The SEL-487B triggers an event report when any one of the following Relay Word bits asserts:

- 87BTR (any one of the nine differential trip bit)
- SBFTR (any one of the nine station breaker failure trip bit)
- TRIP (any one of the nine trip logic outputs)
- ER (user-defined functions)
- **TRIG** (ASCII command)

The protection philosophy calls for the relay to generate an event report when the negative-sequence and zero-sequence overvoltage elements assert. To achieve this, enter Relay Word bit 59Q1 and 59N1 at the ER prompt.

ER := **59Q1 OR 59N1 OR 87S1 OR 87S2 OR 87S3**

Protection Latch bit PLT02 enables/disables the breaker failure protection in the default settings. Include PLT02 in each breaker failure initiate setting for the **{BKR FAIL ENABLE}** pushbutton to control the breaker failure protection. *Figure 1.96* shows the group settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y       ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N       ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5       ?3 <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6       ?9 <Enter>

Definite Time Overcurrent Elements (N,1-18)          E50     := N       ?> <Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>

Terminal Out-of-Service

Terminal 01 Out-of-Service (SELogic Equation)
TOS01 := LB01
?  > <Enter>

Breaker 01 Failure Logic

External Breaker Fail -BK01 (Y,N)                    EXBF01  := N       ?<Enter>
Fault Current Pickup -BK01 (0.50-50 amps,sec)        50FP01  := 3.00    ?2.1 <Enter>
Brkr Fail Init Pickup Delay -BK01 (0.00-6000 cyc)    BFPU01  := 6.00    ?9.5 <Enter>
Retrip Delay -BK01 (0.00-6000 cyc)                   RTPU01  := 3.00    ?4 <Enter>
Breaker Fail Initiate -BK01 (SELogic Equation)
BFI01 := IN101 AND BF_EN
?  ABFIT01 <Enter>
Alt Breaker Fail Initiate -BK01 (SELogic Equation)
ATBFI01 := NA
?  IN201 AND PLT02 <Enter>
Breaker Fail Initiate Seal-In -BK01 (Y,N)            EBFIS01 := N       ?<Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFIDO01 := 1.50    ?4 <Enter>

Breaker 02 Failure Logic

External Breaker Fail -BK02 (Y,N)                    EXBF02  := N       ?<Enter>
Fault Current Pickup -BK02 (0.50-50 amps,sec)        50FP02  := 3.00    ?2.1 <Enter>
Brkr Fail Init Pickup Delay -BK02 (0.00-6000 cyc)    BFPU02  := 6.00    ?9.5 <Enter>
Retrip Delay -BK02 (0.00-6000 cyc)                   RTPU02  := 3.00    ?4 <Enter>
Breaker Fail Initiate -BK02 (SELogic Equation)
BFI02 := IN102 AND BF_EN
?  ABFIT02 <Enter>
Alt Breaker Fail Initiate -BK02 (SELogic Equation)
ATBFI02 := NA
?  IN201 AND PLT02 <Enter>
Breaker Fail Initiate Seal-In -BK02 (Y,N)            EBFIS02 := N       ?<Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFIDO02 := 1.50    ?4 <Enter>
.
.
.
Phase Inst Under/Over Voltage Elements

Voltage 1 Level 1 U/V Pickup (OFF, 1.0-200 volts)    27P11P  := OFF     ?45 <Enter>
Voltage 1 Level 2 U/V Pickup (OFF, 1.0-200 volts)    27P12P  := OFF     ?
Voltage 1 Level 1 O/V Pickup (OFF, 1.0-200 volts)    59P11P  := OFF     ?
Voltage 1 Level 2 O/V Pickup (OFF, 1.0-200 volts)    59P12P  := OFF     ?
Voltage 2 Level 1 U/V Pickup (OFF, 1.0-200 volts)    27P21P  := OFF     ?45 <Enter>
Voltage 2 Level 2 U/V Pickup (OFF, 1.0-200 volts)    27P22P  := OFF     ?
Voltage 2 Level 1 O/V Pickup (OFF, 1.0-200 volts)    59P21P  := OFF     ?
Voltage 2 Level 2 O/V Pickup (OFF, 1.0-200 volts)    59P22P  := OFF     ?
Voltage 3 Level 1 U/V Pickup (OFF, 1.0-200 volts)    27P31P  := OFF     ?45 <Enter>
Voltage 3 Level 2 U/V Pickup (OFF, 1.0-200 volts)    27P32P  := OFF     ?
Voltage 3 Level 1 O/V Pickup (OFF, 1.0-200 volts)    59P31P  := OFF     ?
Voltage 3 Level 2 O/V Pickup (OFF, 1.0-200 volts)    59P32P  := OFF     ?

Sequence Over Voltage Elements

Neg.-Seq. Level 1 O/V Pickup (OFF, 1.0-200 volts)    59Q1P   := 20.0    ?15 <Enter>
Neg.-Seq. Level 2 O/V Pickup (OFF, 1.0-200 volts)    59Q2P   := 40.0    ?OFF <Enter>
Zero-Seq. Level 1 O/V Pickup (OFF, 1.0-200 volts)    59N1P   := 20.0    ?15 <Enter>
Zero-Seq. Level 2 O/V Pickup (OFF, 1.0-200 volts)    59N2P   := 40.0    ?OFF <Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := TDA_SBF OR TD_TA
?<Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
```

```
Trip 02 (SELogic Equation)
TR02 := TDB_SBF OR TD_TB
?<Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := TDC_SBF OR TD_TC
?<Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
Trip 04 (SELogic Equation)
TR04 := TEA_SBF OR TE_TA
?<Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
Trip 05 (SELogic Equation)
TR05 := TEB_SBF OR TE_TB OR TEC_SBF OR TE_TC
?  TEB_SBF OR TE_TB <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Trip 06 (SELogic Equation)
TR06 := NA
?  TEC_SBF OR TE_TC
Unlatch Trip 06 (SELogic Equation)
ULTR06 := NA
?<Enter>
.
.
.
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000  ? <Enter>
Event Report Trigger Equation (SELogic Equation)
ER := R_TRIG 87ST
?  59Q1 OR 59N1 OR 87S1 OR 87S2 OR 87S3 <Enter>
Group 1
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.96 Protection Group Settings for Application 3

This concludes the protection group settings. The next settings class is the front-panel settings.

Front-Panel Settings

The front-panel settings class is where we set functions visible and accessible from the front panel. Settings include LEDs, pushbuttons, front-panel screen selection, display point, and local control. All of these functions have default settings, except five pushbuttons and the display points.

Because not all functions are required in this application, change the settings according to the protection philosophy. Remove the following LED settings:

- ZONE 4 trip indication (LED 6)
- ZONE 5 trip indication (LED 7)
- ZONE 6 trip indication (LED 8)
- 50 indication (LED 9)
- 51 indication (LED 10)
- 89 IN PROG (LED 14)
- 89 ALARM (LED 15)

Also, change the number of Local bits for the TOS (Terminal Out of Service) function to the correct number, 3. *Figure 1.97* shows the settings.

```
=>>SET F <Enter>
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF, 1-60 mins)        FP_TO   := 15      ?<Enter>
Pushbutton LED 1 (SELogic Equation)
PB1_LED := DIFF_EN # Differential Protection Enabled
?<Enter>
Pushbutton LED 2 (SELogic Equation)
PB2_LED := BF_EN # Breaker Failure Enabled
?<Enter>
Pushbutton LED 3 (SELogic Equation)
PB3_LED := NA
?<Enter>
Pushbutton LED 4 (SELogic Equation)
PB4_LED := TNS_SW # Test normal Switch Enabled
?<Enter>
Pushbutton LED 5 (SELogic Equation)
PB5_LED := NA
?<Enter>
Pushbutton LED 6 (SELogic Equation)
PB6_LED := NA
?<Enter>
Pushbutton LED 7 (SELogic Equation)
PB7_LED := NA
?<Enter>
Pushbutton LED 8 (SELogic Equation)
PB8_LED := NA
?<Enter>
Target LED 1 (SELogic Equation)
T1_LED := 87BTR
?<Enter>
Target LED 1 Latch (Y,N)                             T1LEDL  := Y       ?<Enter>
Target LED 2 (SELogic Equation)
T2_LED := SBFTR
?<Enter>
Target LED 2 Latch (Y,N)                             T2LEDL  := Y       ?<Enter>
Target LED 3 (SELogic Equation)
T3_LED := NORTA_T
?<Enter>
Target LED 3 Latch (Y,N)                             T3LEDL  := Y       ?<Enter>
Target LED 4 (SELogic Equation)
T4_LED := NORTB_T
?<Enter>
Target LED 4 Latch (Y,N)                             T4LEDL  := Y       ?<Enter>
Target LED 5 (SELogic Equation)
T5_LED := NORTC_T
?<Enter>
Target LED 5 Latch (Y,N)                             T5LEDL  := Y       ?<Enter>
Target LED 6 (SELogic Equation)
T6_LED := 87Z4
?  NA <Enter>
Target LED 6 Latch (Y,N)                             T6LEDL  := Y       ?N <Enter>
Target LED 7 (SELogic Equation)
T7_LED := 87Z5
?  NA <Enter>
Target LED 7 Latch (Y,N)                             T7LEDL  := Y       ?N <Enter>
Target LED 8 (SELogic Equation)
T8_LED := 87Z6
?  NA <Enter>
Target LED 8 Latch (Y,N)                             T8LEDL  := Y       ?N <Enter>
Target LED 9 (SELogic Equation)
T9_LED  := 50P01T OR 50P02T OR 50P03T OR 50P04T OR 50P05T OR 50P06T OR \
           50P07T OR 50P08T OR 50P09T OR 50P10T OR 50P11T OR 50P12T OR \
           50P13T OR 50P14T OR 50P15T OR 50P16T OR 50P17T OR 50P18T
?  NA <Enter>
Target LED 9 Latch (Y,N)                             T9LEDL  := Y       ?N <Enter>
Target LED 10 (SELogic Equation)
T10_LED := 51P01T OR 51P02T OR 51P03T OR 51P04T OR 51P05T OR 51P06T OR \
           51P07T OR 51P08T OR 51P09T OR 51P10T OR 51P11T OR 51P12T OR \
           51P13T OR 51P14T OR 51P15T OR 51P16T OR 51P17T OR 51P18T
?  NA <Enter>
Target LED 10 Latch (Y,N)                            T10LEDL := Y       ?N <Enter>
Target LED 11 (SELogic Equation)
T11_LED := 87ST
?<Enter>
Target LED 11 Latch (Y,N)                            T11LEDL := N       ?<Enter>
Target LED 12 (SELogic Equation)
T12_LED := NOT (Z1S AND Z2S AND Z3S AND Z4S AND Z5S AND Z6S)
?  NOT (Z1S AND Z2S AND Z3S) <Enter>
Target LED 12 Latch (Y,N)                            T12LEDL := Y       ?<Enter>
```

```
Target LED 13 (SELogic Equation)
T13_LED := TOS01 OR TOS02 OR TOS03 OR TOS04 OR TOS05 OR TOS06 OR \
           TOS07 OR TOS08 OR TOS09 OR TOS10 OR TOS11 OR TOS12 OR \
           TOS13 OR TOS14 OR TOS15 OR TOS16 OR TOS17 OR TOS18
?  TOS01 OR TOS02 OR TOS03 <Enter>
Target LED 13 Latch (Y,N)                          T13LEDL := N      ?<Enter>
Target LED 14 (SELogic Equation)
T14_LED := 89OIP
?  NA <Enter>
Target LED 14 Latch (Y,N)                          T14LEDL := N      ?<Enter>
Target LED 15 (SELogic Equation)
T15_LED := 89AL
?  NA <Enter>
Target LED 15 Latch (Y,N)                          T15LEDL := N      ?<Enter>
Target LED 16 (SELogic Equation)
T16_LED := PCT01Q
?<Enter>
Target LED 16 Latch (Y,N)                          T16LEDL := Y      ?<Enter>

Selectable Screens for the Front Panel

Station Battery Screen (Y,N)                       STA_BAT := N      ?<Enter>
Fundamental Voltage and Current Screen (Y,N)       FUND_VI := Y      ?<Enter>
Differential Metering (Y,N)                        DIFF    := Y      ?<Enter>
Terminals Associated with Zones (Y,N)              ZONECFG := Y      ?<Enter>

Display Points
(Relay Word Bit, Display Name, Display Set State, Display Clear State)

1:
? <Enter>

Local Control
(Local Bit, Local Name, Local Set State, Local Clear State, Pulse Enable)

1: LB01,"TB1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  LB01,"Terminal TD","OUT OF SERVICE","IN SERVICE",N <Enter>
2: LB02,"F1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  LB02,"Terminal TE","OUT OF SERVICE","IN SERVICE",N <Enter>
3: LB03,"F2 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  LB03,"Terminal TF","OUT OF SERVICE","IN SERVICE",N <Enter>
4: LB04,"T1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  DELETE <Enter>
4: LB05,"F3 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  DELETE <Enter>
4:
?  END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.97 Front-Panel Settings for Application 3

This concludes the front-panel settings. The next settings class is the control output settings.

Control Output Settings

In this setting class, we assign the logic or Relay Word bits in the relay to output contacts. We need six output contacts for our example:

- three for the differential and breaker failure trip outputs
- three for direct transfer trip outputs

Although not specifically called for in the protection philosophy, it is good practice to also include the TEST and ALARM outputs in the relay settings.

Because the relay interprets the NUMBK setting as the number of poles, there are nine trip equations for this application. There is, of course, only one circuit breaker for each terminal. We therefore combine the appropriate trip outputs from the breaker trip logic (TRIP01–TRIP09, see *Figure 1.83*) to provide a single trip output for each circuit breaker. For example, we set (Group settings) the trip equations for Terminal TD to TR01 := TDA_SBF OR

TD_TA, TR02 := TDB_SBF OR TD_TB TR03 := TDC_SBF OR TD_TC, with the corresponding breaker trip logic output alias names of TRTD_A, TRTD_B, and TRTD_C. Because Terminal TD has only one circuit breaker, assertion of any one of the three breaker trip logic outputs (TRTD_A, TRTD_B, or TRTD_C) must trip the circuit breaker of Terminal TD. To achieve this combination, enter all three of the breaker trip logic output Relay Word bits in the output equation of the circuit breaker of Terminal TD. We assign the output Relay Word bits of the breaker failure logic to output contacts OUT204, OUT205, and OUT206 for direct transfer tripping.

Figure 1.98 shows the output settings. We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the {RELAY TEST MODE} pushbutton disables all output contacts.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRTD_A AND NOT TNS_SW
?   NA <Enter>

OUT102 := TRTD_B AND NOT TNS_SW
?   NA <Enter>

OUT103 := TRTD_C AND NOT TNS_SW
?   NA <Enter>

OUT104 := TRTE_A AND NOT TNS_SW
?   NA <Enter>

OUT105 := TRTE_B AND NOT TNS_SW
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   (TRTD_A OR TRTD_B OR TRTD_C) AND NOT PLT03 <Enter>

OUT202 := NA
?   (TRTE_A OR TRTE_B OR TRTE_C) AND NOT PLT03 <Enter>

OUT203 := NA
?   (TRTF_A OR TRTF_B OR TRTF_C) AND NOT PLT03 <Enter>

OUT204 := NA
?   (TDA_SBF OR TDB_SBF OR TDC_SBF) AND NOT PLT03 <Enter>

OUT205 := NA
?   (TEA_SBF OR TEB_SBF OR TEC_SBF) AND NOT PLT03 <Enter>

OUT206 := NA
?   TFA_SBF OR TFB_SBF OR TFC_SBF AND NOT PLT03 <Enter>

OUT207 := NA
?   END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.98 Output Settings for Application 3

This concludes the settings for Application 3.

Application 4: Single Bus and Transfer Bus With Buscoupler

This application describes the busbar arrangement shown in *Figure 1.99*, single bus and transfer bus with tie breaker (buscoupler). The busbar arrangement consists of two busbars (main busbar and transfer busbar), four feeders and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

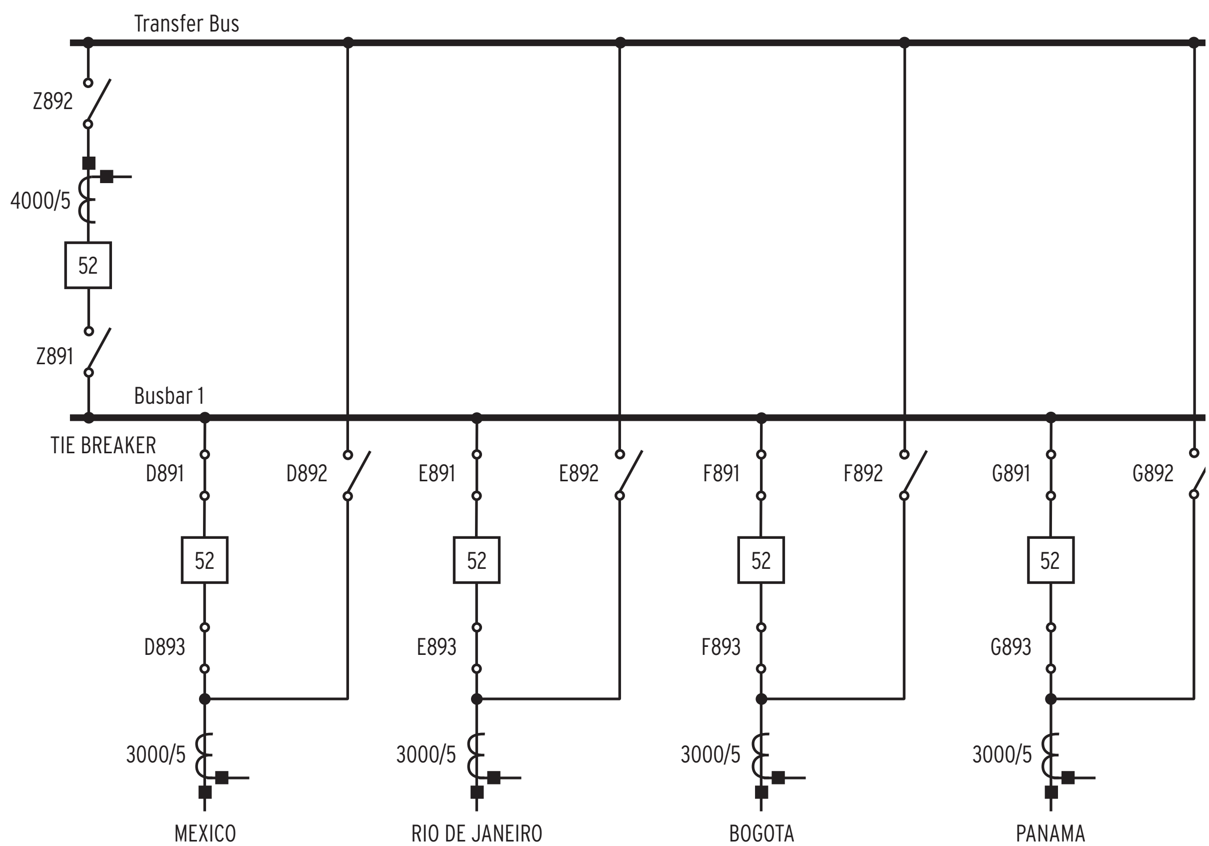


Figure 1.99 Single Bus and Transfer Bus With Buscoupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (buscoupler) configuration.

- Description:
  - Single bus and transfer bus with tie breaker
- Current transformers:
  - Outboard (free standing)
- Disconnects:
  - Only 89A disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Single CT with one CT core for busbar protection
- Future expansion:
  - Five feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every substation uses all of these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the 89B disconnect auxiliary contacts to dynamically configure the station.
4. Use the zone-switching supervision logic.
5. Prevent the loss of Busbar 1 for a fault between the tie breaker and tie-breaker CT.
6. Ensure bus-zone protection stability for all operating conditions.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for the use of the zone-switching supervision, but not for breaker failure protection. The SEL-487B offers a number of protection functions as standard features, but it also includes the capability through SELOGIC control equations to create user-configurable functions.

To prevent tripping of Busbar 1 when there is a fault between the tie breaker and tie-breaker CT, we can delay tripping of Busbar 1 and trip the tie breaker first (see *Protection Group Settings on page A.1.133*). We then remove the tie-breaker currents from the differential calculations. To remove the tie-breaker currents from the differential calculations, we use the breaker auxiliary contact from the tie breaker and a combination of the coupler security logic and zone supervision.

To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created with SELOGIC control equations)

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 1.54* shows the selection of the standard functions.

Table 1.54 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	No	We need both 89A and 89B disconnect; only the 89A contact is available.
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Use the zone supervision logic as part of preventing the loss of Busbar 1 for a fault between the tie breaker and the tie-breaker CT.
Zone-switching supervision logic	Yes	Use this logic when only one (either 89A or 89B) disconnect contact is available.
Coupler security logic	Yes	Use the coupler security logic in a single CT application for enhanced protection for faults between the tie-breaker CT and circuit breaker.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

This application requires no user-defined functions.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- and the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with as many as 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.15* to calculate the number of current channels at the station, and use *Equation 1.16* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.15**

# of bus-zones required = # of per-phase station bus sections **Equation 1.16**

The number of per-phase CTs at the station is 15 (the tie breaker has three CT cores), and one SEL-487B suffices. However, the requirement for 5 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, identified with an appended letter A (MEXCO_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MEXCO_A setting is MEXCO_B in the B-phase relay, and MEXCO_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The protection philosophy calls for disconnect auxiliary contacts to dynamically configure the station. Because each terminal provides only one disconnect auxiliary contact, we cannot use the disconnect monitoring logic. Each feeder has two busbar disconnects (891 and 892), and the tie breaker also has two disconnects (891 and 892). Each feeder therefore requires 2 inputs, and the tie breaker requires 2 inputs, for a total number of 10 disconnect logics.

The protection philosophy also calls for zone-switching supervision logic, and we will use the coupler security logic to prevent tripping of Busbar 1 when there is a fault between the tie breaker and tie-breaker CT. For the zone-switching supervision logic, connect the close and open signals from each disconnect in parallel, and wire the parallel combination as a single input into the relay (see *Zone Configuration Group Settings on page A.1.128*).

The coupler security logic requires three inputs:

- ➤ a close signal
- ➤ a circuit breaker 52A auxiliary contact
- ➤ an input for the accelerated tripping function (see *Figure 1.108* for more information)

We need one input for the circuit breaker 52A auxiliary contact and one input for the closing signal. For the accelerated tripping input (ACTRP1), we use the output from the BZ1 differential element (87R1). *Table 1.55* summarizes the input contacts necessary for this application.

Table 1.55 Number of Required Relay Inputs

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	(4 • 2) + 2 = 10
Number of relay inputs required for disconnect open/close signal	1
Number of relay inputs required for the coupler security logic on the tie breaker	2 (one closing signal and one circuit breaker auxiliary contact)
Total number of inputs	13

The relay main board has seven inputs, insufficient inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs; the six independent inputs are available for breaker failure initiate inputs. Because this application has no circuit breaker failure protection, and the circuit breaker closing signals are best suited for independent inputs, use the independent inputs on the interface board for the circuit breaker closing signal. From the input perspective, we need one interface board. It is not necessary to include I/O for future expansion with the initial order; install additional I/O if and when required.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.56* shows the breakdown and the total number of relay output contacts required for tripping.

Table 1.56 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping the circuit breakers	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the **{RELAY TEST MODE}** pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B relays necessary for the application
- the number of inputs
- the number of output contacts
- the selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay input contacts
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation, and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.57* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.57* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.99*.

Table 1.57 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT, A-phase	I01	TIE_A
MEXICO terminal, A-phase	I02	MEXCO_A
RIO DE JANEIRO terminal, A-phase	I03	RIODJ_A
BOGOTA terminal, A-phase	I04	BOGOT_A
PANAMA terminal, A-phase	I05	PANAM_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.58*.

Table 1.58 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	BUS_A
BZ2	Bus-Zone 2	TRANS_A

Input-to-Logic Allocation

Table 1.55 shows that we require 13 digital inputs. We now assign the 13 digital input contacts to the selected logic. There are 18 grouped and 6 independent input contacts on the interface board. We assign the 10 disconnect inputs to the grouped terminals and the remaining 3 inputs to the independent relay inputs on the interface board.

Input Contact to Logic Allocation, Main Board

This application requires no main board inputs.

Input Contact-to-Logic Allocation, Interface Board 1 (200)

Table 1.59 shows the disconnect and circuit breaker auxiliary contact input allocations. Because inputs IN201–IN203 and IN213–IN215 are independent inputs, assign the inputs for the coupler security logic and the open/closing signals to these relay inputs.

Table 1.59 Relay Input-to-Relay Logic Assignment (Sheet 1 of 2)

Input	Description
IN201	TIE-BREAKER circuit breaker 52A auxiliary contact
IN202	TIE-BREAKER circuit breaker closing signal
IN203	Disconnect open/closing signal
IN204	TIE-BREAKER disconnect (BUS_A) NO contact
IN205	TIE-BREAKER disconnect (TRANS_A) NO contact
IN206	MEXICO terminal disconnect (BUS_A) NO contact
IN207	MEXICO terminal disconnect (TRANS_A) NO contact
IN208	RIO DE JANEIRO terminal disconnect (BUS_A) NO contact
IN209	RIO DE JANEIRO terminal disconnect (TRANS_A) NO contact
IN210	BOGOTA terminal disconnect (BUS_A) NO contact

Table 1.59 Relay Input-to-Relay Logic Assignment (Sheet 2 of 2)

Input	Description
IN211	BOGOTA terminal disconnect (TRANS_A) NO contact
IN212	PANAMA terminal disconnect (BUS_A) NO contact
IN216	PANAMA terminal disconnect (TRANS_A) NO contact

Identification of the Selected Standard Logic

The following explains each selected function in reference to *Table 1.54*. Alias name assignments are also included.

Differential Trip Logic Identification

Figure 1.100 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.60* shows the Relay Word bits and description for the zone differential protection outputs.

Table 1.60 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR05 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

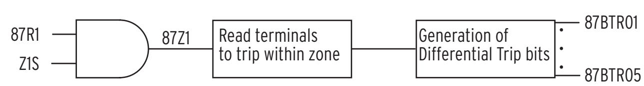


Figure 1.100 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.128* for more information). *Table 1.61* shows the differential trip bit and the associated terminals.

Table 1.61 Differential Trip Bit and Associated Terminals

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05

Relay Logic-to-Output Contact Allocation

Table 1.56 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.62* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 1.63* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Contact Allocation, Main Board

This application requires only the TEST and ALARM output contacts from the main board.

Table 1.62 Alias Names and Contact Allocation of the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Contact Allocation, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.63* shows the assignment for the five terminals of the A-phase relay.

Table 1.63 Allocation of the Interface Board Output Contacts

Output Contact Assignment	Description
OUT201[a]	Tie-breaker trip logic output
OUT202[a]	MEXICO trip logic output
OUT203[a]	RIO DE JANERO trip logic output
OUT204[a]	BOGOTA trip logic output
OUT205[a]	PANAMA trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 1.101*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the terminal digital inputs to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

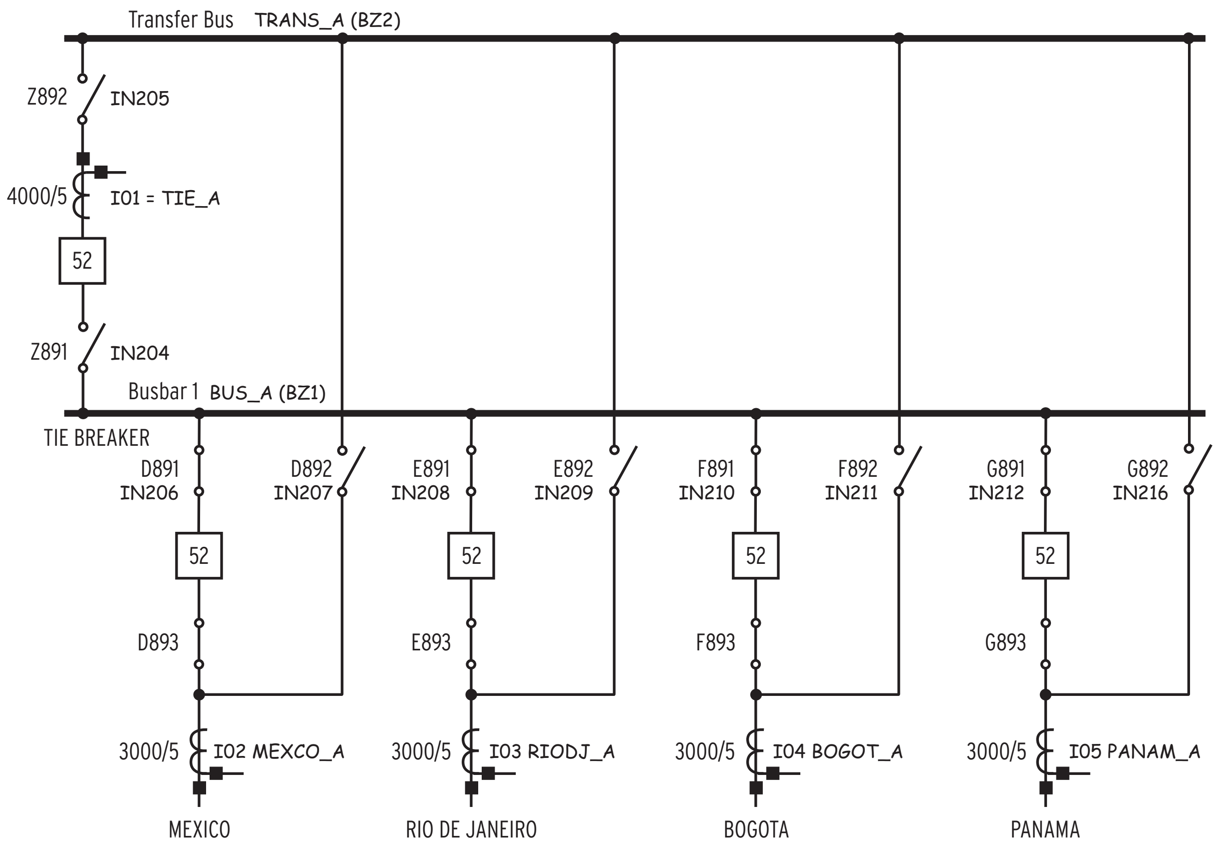


Figure 1.101 Substation Layout With Specific Information

Setting the Relay

The following describes the settings for this application. For this application example, we set the following setting classes:

- ➤ Alias Settings
- ➤ Global Settings
- ➤ Zone Configuration Group Settings
- ➤ Protection Group Settings
- ➤ Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay.

Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.102*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?   LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.102 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.103*.

```
1: I01,"FDR_1"
?   DELETE 43 <Enter>
```

Figure 1.103 Deletion of the First 43 Alias Names

Type > <Enter> to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.104*.

```
1: OUT107,"TEST"
?   > <Enter>
19:
?   I01,TIE_A <Enter>
20:
?   I02,MEXCO_A <Enter>
21:
?   I03,RIODJ_A <Enter>
22:
?   I04,BOGOT_A <Enter>
23:
?   I05,PANAM_A <Enter>
24:
?   BZ1,BUS_A <Enter>
25:
?   BZ2,TRANS_A <Enter>
26:
?   PLT01,DIFF_EN <Enter>
27:
? PLT03,TNS_SW <Enter>
28:
? END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.104 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.105* shows the setting changes we need for our example.

Because there are five circuit breakers at the station, set NUMBK to 5. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01 through 52A05), and five corresponding trip equations (TR01 through TR05) available for setting.

Declare here the input contact for the tie-breaker auxiliary contact (52A01 := IN201). Set the remaining four circuit breaker auxiliary input equations (52A02–52A05) to NA.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                          NUMBK   := 5      ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                     EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                      GINPU   := 0.17   ?> <Enter>

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
? IN201 <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
? <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.105 Global Settings for Application 4

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contact status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the Mexico feeder, all three phases (MEXCO_A, MEXCO_B, and MEXCO_C) operate together. Because the relay measures the three phases in three separate relays (phase MEXCO_A in the A-phase relay, phase MEXCO_B in B-phase relay, etc.), we must convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- Transfer busbar: the busbar to which the terminal on transfer is connected
- Transfer disconnect: the disconnect that connects the terminal to the transfer busbar (disconnect G892 on the Panama Feeder)

Although the relay is flexible enough to accept settings for many disconnect combinations, we will configure the relay according to the following operating conditions:

- Only one feeder will be on transfer at any given time, i.e., the tie-breaker disconnects and the feeder transfer disconnect (*n*892, *n* = D, E, F, G) of only one of the four feeders can be closed simultaneously.
- Only Busbar 1 can be the source busbar.
- The operating sequence to put a feeder on transfer is fixed.

Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone settings for each step.

Table 1.64 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Refer to *Figure 1.101* and consider a case in which we put the PANAMA Feeder on transfer.

Assume the tie breaker is open and both tie-breaker disconnects are open.

Table 1.64 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Close tie-breaker disconnects Z892 and Z891. Close the tie-breaker circuit breaker.	Feeder Disconnects D891, E891, F891, and G891 as well as D893, E893, F893, and G893 are now closed. Feeder Disconnects D892, E892, F892, and G892 are open. Closing the tie breaker brings both busbars to the same potential.
2	Close the Panama G892 disconnect.	Closing Disconnect G892 forms a bus-zone-to-bus-zone connection, resulting in a parallel path between the tie breaker and the Panama Feeder. Merge the two zones to prevent possible relay misoperation.
3	Open the Panama circuit breaker.	Although the current distribution is known at this point, the feeder is still considered in the intermediate position and the two zones are still merged.
4	Open the line disconnect (G893) of the Panama feeder. Open the Busbar 1 (G891) disconnect.	Opening G891 removes the bus-zone-to-bus-zone connection, forming two independent zones. The Panama feeder is now on transfer.

Because the operating sequence prevents connections that could result in relay misoperation, we must merge the zones during the intermediate position (Step 2 in *Table 1.64*). We define this intermediate position as the time when disconnects *n*891 and *n*892 of any feeder are closed simultaneously.

Enter this state to merge the zones in the bus-zone-to-bus-zone connections:

BZ1BZ2V := **(IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN216)**

We use a combination of the zone supervision and coupler security logics to prevent tripping Busbar 1 for a fault between the tie-breaker circuit breaker and CT. For the zone supervision setting, we supervise the BZ1 differential element output by the negated coupler security output (ZS1 := NOT CSL1) (see *Protection Group Settings on page A.1.133* for more information).

I01BZ1V and I01BZ2V, the tie-breaker terminal-to-bus-zone settings, comprise the disconnect auxiliary contacts (IN204 and IN205), the circuit breaker auxiliary contact (CB52A1), the circuit breaker closing signal (CBCLST1), and the coupler status timed-out bit (CB52T1). (See *Figure 1.108* and *Protection Group Settings on page A.1.133* for more detail.)

In this application, the disconnect provides only one (89B) disconnect auxiliary contact. We cannot use the disconnect monitoring logic because the disconnect monitoring logic requires two disconnect auxiliary contacts. For installations with only one disconnect auxiliary contact, use the zone-switching supervision logic. (See *Section 1: Protection Functions in the Reference Manual* for more information.) Enable the zone switching supervision by setting EZSWSUP := Y. Connect the open and close signals from the disconnects in parallel (see *Figure 1.106*).

In this application, we assign this parallel connection to relay input IN203. Set ZSWO := IN203.

Alarm ZSWOAL stays asserted indefinitely in the event of the disconnect auxiliary contact failing to change status. Use pushbutton {PB5} to reset Alarm ZSWOAL when a disconnect auxiliary contact fails to change status. Set RZSWOAL := PB5.

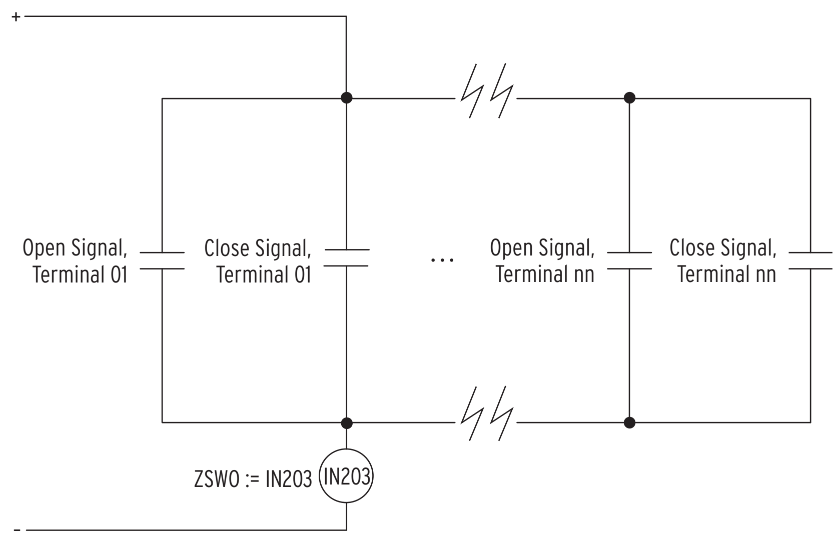


Figure 1.106 External Wiring and Initiation Input for Zone-Switching Supervision

Measure each disconnect travel time.

Set the zone-switching operation pickup delay (ZSWOPU) to a value longer than the time necessary for the slowest disconnect to complete an open-to-close, or close-to-open operation. Based on previous experience with similar equipment, we set the ZSWOPU to 3600 cycles in this example. *Figure 1.107* shows the zone configuration settings for this application.

The zone configuration default settings are for a specific substation with arbitrarily selected alias names, serving only as an example.

For ease of setting zone configuration settings for the new substation, delete the terminal-to-bus-zone connections default settings. With the terminal-to-bus-zone connections default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 1.107* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?600 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE_A, BUS_A, P
?   DELETE 100 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I01,BZ1,P <Enter>
```

```
TIE_A to BUS_A Connection (SELogic Equation)
I01BZ1V := NA
?   IN204 AND IN205 AND (CB52A1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I01,BZ2,N <Enter>
TIE_A to TRANS_A Connection (SELogic Equation)
I01BZ2V := NA
?   IN204 AND IN205 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I02,BZ1,P <Enter>
MEXCO_A to BUS_A Connection (SELogic Equation)
I02BZ1V := NA
?   IN206 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I02,BZ2,P <Enter>
MEXCO_A to TRANS_A Connection (SELogic Equation)
I02BZ2V := NA
?   IN207 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,BZ1,P <Enter>
RIODJ_A to BUS_A Connection (SELogic Equation)
I03BZ1V := NA
?   IN208 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,BZ2,P <Enter>
RIODJ_A to TRANS_A Connection (SELogic Equation)
I03BZ2V := NA
?   IN209 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,BZ1,P <Enter>
BOGOT_A to BUS_A Connection (SELogic Equation)
I04BZ1V := NA
?   IN210 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,BZ2,P <Enter>
BOGOT_A to TRANS_A Connection (SELogic Equation)
I04BZ2V := NA
?   IN211 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,BZ1,P <Enter>
PANAM_A to BUS_A Connection (SELogic Equation)
I05BZ1V := NA
?   IN212 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,BZ2,P <Enter>
PANAM_A to TRANS_A Connection (SELogic Equation)
I05BZ2V := NA
?   IN216 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?   BZ1,BZ2 <Enter>
BUS_A to TRANS_A Connection (SELogic Equation)
BZ1BZ2V := NA
?   (IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN\
216) <Enter>
Connection to Remove Terminals when BUS_A and TRANS_A merge (SELogic Equation)
BZ1BZ2R := NA
?   (IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN\
216) <Enter>
Terminals Removed when BUS_A and TRANS_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?   I01 <Enter>
Trip Terminals TIE_A (Y,N)
BZ1BZ2T := N
?   Y <Enter>
Bus-Zone, Bus-Zone
?

Zone Supervision

Differential Element Zone Supervision (Y,N)         E87ZSUP := N       ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?   NOT CSL1 <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?   > <Enter>
Zone Switching Supervision (Y,N)                    EZSWSUP := N       ?Y <Enter>
Zone Switching Operation (SELogic Equation)
ZSWO := NA
?   IN203 <Enter>
Reset Zone Switching Op Alarm (SELogic Equation)
RZSWOAL := NA
?   PB5 <Enter>
Zone Switching Op Pickup Delay (0-99999 cyc)        ZSWOPU  := 1800    ?3600 <Enter>
```

```
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.107 Zone Configuration Group Settings for Application 4

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, beginning with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available. For this application, we use the default values for the sensitive differential element, the restrained differential element and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information).

We need one coupler security logic for this application. Set ECSL := 1. Set ETOS := N, EBFL := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N because we do not use the terminal out of service function, breaker failure protection, overcurrent elements, voltage elements, or advance settings in this application.

Setting NUMBK to 5 (Global settings) makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. Each of the five analog channels has a corresponding differential trip bit that asserts (*Table 1.61*) when the differential element asserts.

Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip. When applying the coupler security logic as in this example, include the differential element trip output (87R1) and the 87BTR01 differential trip bit in the tie-breaker trip logic.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Figure 1.108 shows the combination of the coupler security logic and the zone supervision with the input settings applied. Notice that Gate 1 and Gate 2 represent the tie-breaker terminal-to-bus-zone connection settings; they are not part of the fixed logic.

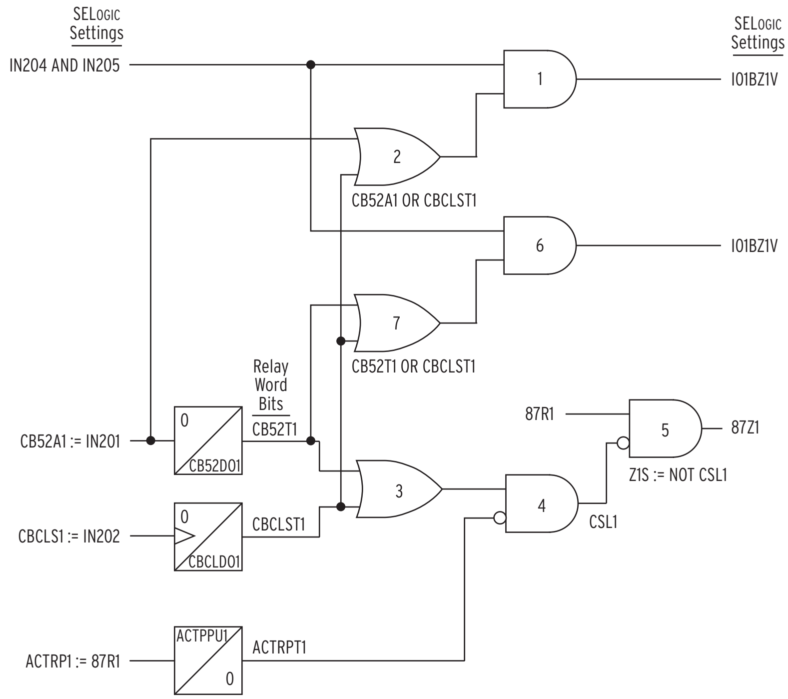


Figure 1.108 Coupler Security Logic With Applied Input Settings

The protection philosophy calls for the loss of only one zone when a fault between the tie-breaker CT and circuit breaker occurs. Use the coupler security logic to prevent the loss of Busbar 1 for a fault between the tie-breaker CT and circuit breaker. Be aware, however, that using this logic delays relay operation for all busbar faults on Busbar 1.

Assume for this application that the maximum circuit breaker tripping time is 2 cycles and that the maximum closing time is 4 cycles. Refer to *Figure 1.108*, and notice the difference in the CB52A1 and CBCLS1 inputs from the regular coupler security application. Input CBCLS1 provides the closing signal information to the relay. For an open-to-close operation, Input CBCLS1 asserts when the operator issues a closing signal to the circuit breaker, asserting Relay Word bits I01BZ1V and I01BZ2V. When Relay Word bits I01BZ1V and I01BZ2V assert, the relay considers the CT in the differential equations. Inserting the CTs in the differential equations before primary current flows emulates the early make, late break timing requirement for the disconnect auxiliary contacts. Set the timer dropout time (CBCLDO1) to a value longer than the maximum breaker closing time. In this example, allow a short safety margin and set CBCLDO1 to 5 cycles (default value). A setting of 5 cycles allows the circuit breaker ample time to change state, during which time Relay Word bit CB52A1 asserts.

When opening the circuit breaker, the inverse applies. For a close-to-open circuit breaker operation, we must guard against prematurely removing the CTs from the differential equations due to circuit breaker auxiliary contact misalignment. We use CB52T1 in the tie-breaker terminal-to-bus-zone connection settings to accomplish this for Zone 2. However, because we supervise all Zone 1 faults, premature removal of the CTs does not adversely affect Zone 1 differential elements.

Figure 1.109 shows just the tie breaker and two terminals of the application. The single CT on the tie breaker has one core, providing CT information to both differential elements. The challenge to the coupler security logic is to trip BZ2 and not BZ1 for Fault F1. This requirement contradicts the existing configuration, for it calls for the coupler security logic to prevent BZ1 from operating for an in-zone fault (fault on Busbar 1) and for BZ2 to operate for an out-of-zone fault (fault on Busbar 1).

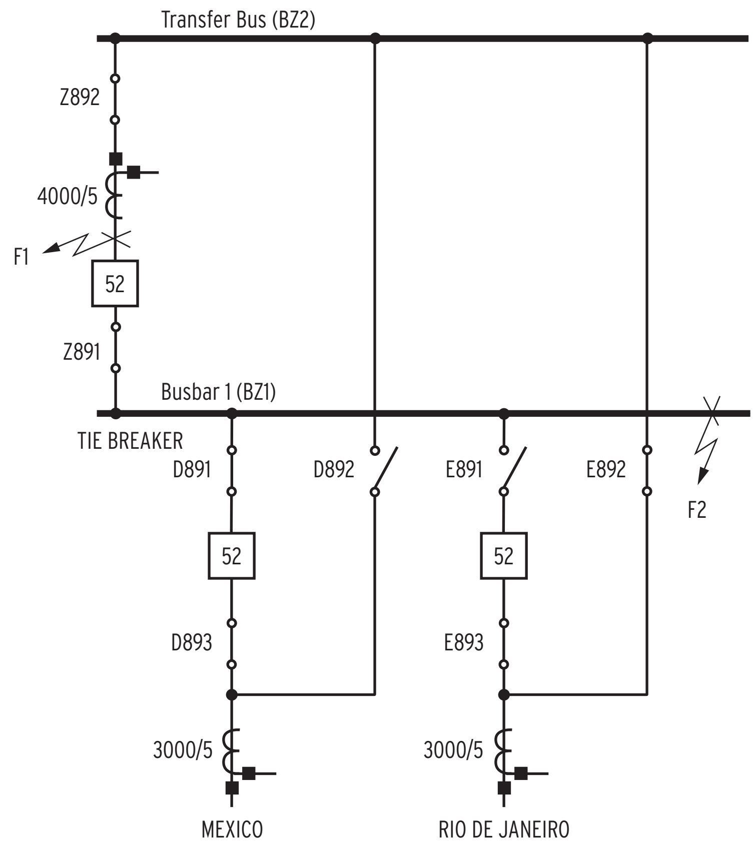


Figure 1.109 Single CT Application With Faults Between the Circuit Breaker and Tie-Breaker CT

Consider the operation when Fault F1 occurs without the coupler security logic. Differential protection BZ2 is stable, and differential protection BZ1 immediately trips the Mexico circuit breaker and the tie-breaker circuit breaker. However, tripping the Mexico circuit breaker and the tie-breaker circuit breaker does not clear Fault F1. Fault current still flows from the Rio de Janeiro Feeder, through the transfer bus, and into the fault. Although breaker failure protection will operate to trip the Rio de Janeiro circuit breaker, this operation takes place after the breaker failure time delay. After the tie-breaker breaker failure timer times out, all circuit breakers in BZ2 zone trip, resulting in both BZ1 and BZ2 tripping to clear Fault F1.

If a delay in bus-zone protection operation is in order, implement the coupler security logic in such a way that tripping of the BZ1 bus-zone is only permitted when the tie-breaker circuit breaker is open. To prevent tripping BZ1, configure the relay to achieve the following:

- ➤ Check if the tie-breaker circuit breaker is closed.
- ➤ If the tie-breaker circuit breaker is closed, trip only the tie breaker to interrupt the fault current from BZ1; trip no other circuit breakers.

- If the tie breaker is open, allow normal busbar protection tripping.
- When the tie breaker is open, remove the tie-breaker CT from the differential calculations of BZ1 and eventually BZ2.

To check the tie-breaker status and remove the CT from the supervised zone when the tie breaker is open, use the tie-breaker auxiliary contact in the tie-breaker terminal-to-bus-zone connection settings. To remove the CT from the unsupervised zone, use the coupler status timed-out bit (CB52T1) in the tie-breaker terminal-to-bus-zone connection settings. To trip only the tie breaker for a fault on Busbar 1 requires the following two settings:

- supervising the BZ1 differential element
- issuing a trip signal to the tie breaker first

Supervise the BZ1 differential element output with the negated output from the coupler security logic (Z1S := NOT CSL1). We assign 87R1, the unsupervised output from the BZ1 differential element, to ACTRP1, the accelerated trip input of the coupler security logic. When accelerated trip timer output (ACTRPT1) asserts, Gate 4 in *Figure 1.108* turns off and Relay Word bit CSL1 deasserts. When Relay Word bit CSL1 deasserts, Relay Word bit Z1S asserts, removing the supervision from the BZ1 differential element.

Supervising the BZ1 differential element in this way prevents the tripping of all terminals in BZ1, including the tie breaker. To trip the tie breaker, include 87R1, the unsupervised output from Differential Element 1 in the trip equation of the tie breaker.

After the tie breaker opens (2 cycles), we remove the tie-breaker CT from the differential calculations of BZ1 but not the BZ1 supervision. Maintain the BZ1 supervision for at least another 1.25 cycles (add a safety margin of 0.75 cycle) to allow the differential element to reset. Achieve this delay by setting ACTPPU1 to at least 4 cycles.

For Fault F1, BZ1 operates, asserting Relay Word bit 87R1. When Relay Word bit 87R1 asserts, the accelerated trip timer starts timing. Because of the BZ1 zone supervision (NOT CSL1), 87Z1 cannot assert, and only the bus tie breaker receives a trip signal.

Two cycles later, the tie-breaker trips, interrupting the fault current contribution from BZ1. Assume the circuit breaker auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ1V and eventually I01BZ2V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. For Fault F1, the tie breaker is open, but fault current still flows through the CT. Removing the tie-breaker CTs from all differential calculations does not trip BZ1 (no fault current contribution from BZ1) but causes BZ2 to operate (BZ2 balancing tie-breaker CT removed), tripping all circuit breakers on the transfer bus. Removing the bus sectionalizer CTs also deasserts Relay Word bit 87R1, causing the accelerated trip timer to stop timing. Fault F1 is now cleared, although there is a time delay.

For Fault F2, the initial tripping is the same as for Fault F1: BZ1 operates, asserting Relay Word bit 87R1. When Relay Word bit 87R1 asserts, the accelerated trip timer starts timing. Because of the BZ1 zone supervision (NOT CSL1), 87Z1 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie-breaker circuit breaker trips, and the auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ1V and eventually I01BZ2V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. Because the circuit breaker is open, terminals from BZ2 no longer contribute to the fault, and BZ2 is stable. However, the BZ1 zone supervision (NOT CSL1) still supervises the BZ1 trip output for another two cycles. Two cycles later, Accelerate Trip Timer ACTRP1 times out, causing CSL1 to deassert. When Relay Word bit CSL1 deasserts, Relay Word bit Z1S asserts, removing the zone supervision from BZ1, issuing a trip signal to all circuit breakers on Busbar 1.

Although each SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 1.110* shows the group settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?1 <Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6      ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N      ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>

Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Coupler 1 Security Logic
Coupler 1 Status (SELogic Equation)
CB52A1 := NA
?  IN201 <Enter>
Coupler 1 Status Dropout Delay (0.00-1000 cyc)       CB52D01 := 4.00   ?<Enter>
Coupler 1 Close Command (SELogic Equation)
CBCLS1 := NA
?  IN202 <Enter>
Coupler 1 Close Command D/O Delay (0.00-1000 cyc)    CBCLD01 := 5.00   ?<Enter>
Coupler 1 Acc Trip (SELogic Equation)
ACTRP1 := NA
?  87R1 <Enter>
Coupler 1 Acc Trip Pickup Delay (0.00-1000 cyc)      ACTPPU1 := 4.00   ?<Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  87R1 OR 87BTR01 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  87BTR02 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  87BTR03 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
Trip 04 (SELogic Equation)
TR04 := SBFTR04 OR 87BTR04
?  87BTR04 <Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
```

```
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  87BTR05 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?<Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.110 Protection Group Settings for Application 4

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the {RELAY TEST MODE} pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101 through OUT106 = NA. *Figure 1.111* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?  NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?  NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?  NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?  NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?  NA <Enter>

OUT106 := NA
?  > <Enter>

Interface Board #1

OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>
```

```
OUT205 := NA
?   TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.111 Control Output Settings for Application 4

This concludes the settings for Application 4.

Application 5: Double Bus With Bus Coupler

This application describes the busbar arrangement shown in *Figure 1.112*, double bus with tie breaker (buscoupler). The busbar arrangement consists of two busbars (main busbar and transfer busbar), four terminals and a tie breaker. Consider the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection functions selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation and alias name assignment
- ➤ Station layout update
- ➤ Relay setting and configuration

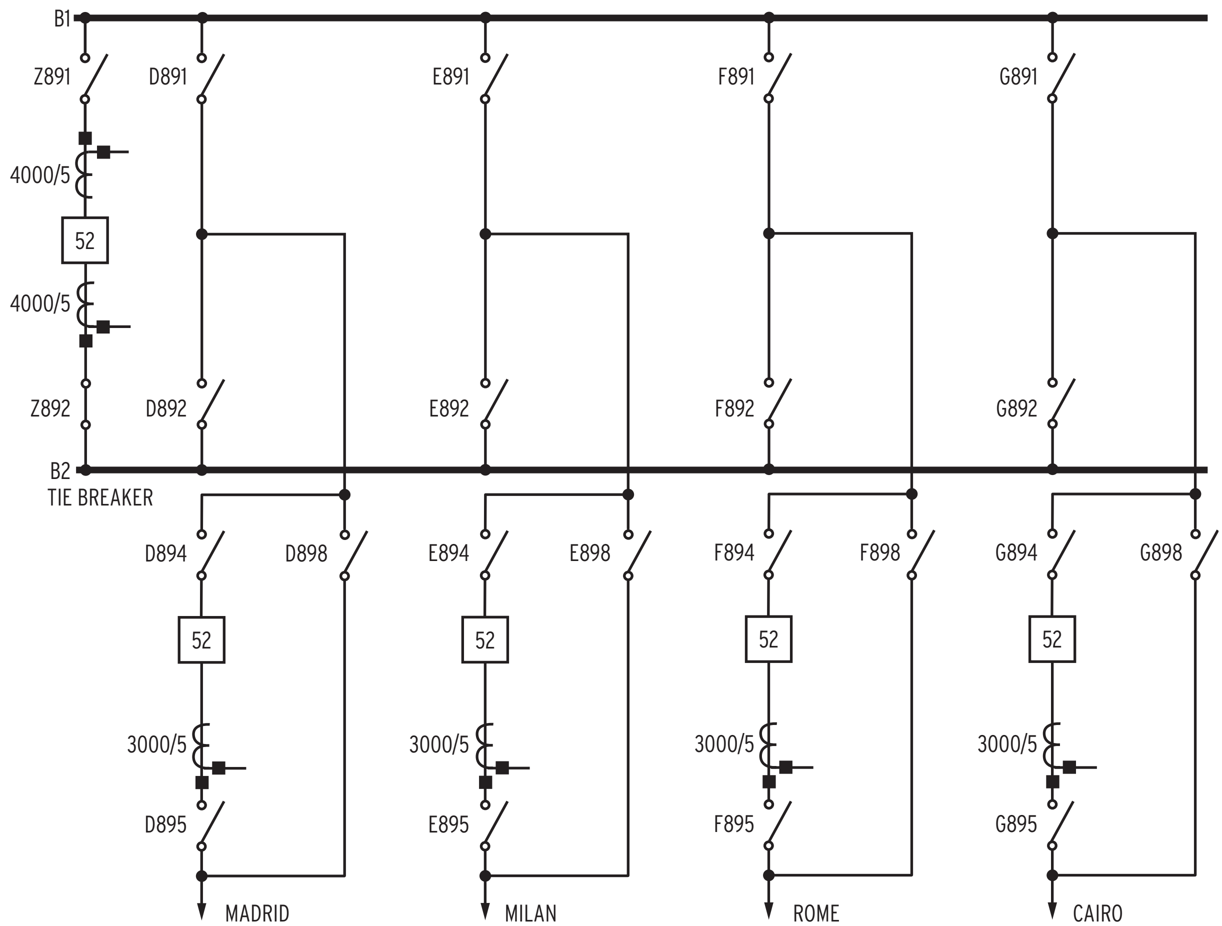


Figure 1.112 Double Bus With Buscoupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (buscoupler) configuration.

- Description:
  - Double bus with tie breaker
- Current Transformers:
  - Inboard
- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Two CTs, configured in overlap
- Future expansion:
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the differential protection.
4. Use the disconnect monitor logic
5. Use external breaker failure protection.
6. Ensure stable differential protection for all operating conditions.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. Requirement 6 of the protection philosophy calls for stable differential protection for all operating conditions. There are two network conditions when the differential protection can become unstable:

- when disconnects *n*891 and *n*892 (*n* = D, E, F,G) of any feeder are closed at the same time
- when the transfer disconnect of any feeder is closed

By declaring the appropriate conditions in the bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable when disconnects *n*891 and *n*892 are closed simultaneously. We use the zone supervision logic to ensure stable differential protection during the time when one of the transfer disconnects is closed.

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 1.65* shows the selection of the standard functions.

Table 1.65 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch.
Circuit breaker status logic	No	Not required.
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available.
Differential protection	Yes	Busbar protection.
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	Use the sensitive differential element as CT open circuit detection.
Zone supervision logic	Yes	Use the zone supervision logic to ensure stable differential protection for all operating conditions.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available so this logic is not required.
Coupler security logic	No	Two CTs in overlap configuration do not require the coupler security logic.
Circuit breaker failure protection	Yes	External breaker failure.
Instantaneous overcurrent protection	No	Not required.
Time-overcurrent protection	No	Not required.
Phase voltage elements	No	Not required.
Zero- or negative-sequence voltage elements	No	Not required.

User-Defined Functions

Identify logic functions we need for the application that is not part of the standard logic in the relay. We comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and 3 voltage channels. For stations with up to 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and up to 54 CTs we install 3 SEL-487B relays. Use *Equation 1.17* to calculate number of current channels at the station, and use *Equation 1.18* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.17**

# of bus-zones required = # of per-phase station bus sections **Equation 1.18**

The number of per-phase CTs at the station is 18 (tie breaker has 6 CT cores), and one SEL-487B suffices. However, the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays. This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires three disconnect monitoring logic and the tie breaker requires two; the number of disconnect logics required is therefore six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.19* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

relay inputs required = 2 • # disconnect monitoring logics **Equation 1.19**

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions, and records the terminals in each bus-zone. The relay then uses this information to only trip the terminals in the bus-zone with the failed breaker, when a circuit breaker fails. Wire an output from each breaker failure relay on each of the terminals to the SEL-487B. *Table 1.66* summarizes the input contact required for this application.

Table 1.66 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 14 = 28
Number of relay inputs required for breaker failure protection	5
Total number of inputs	33

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts for the disconnect auxiliary contact inputs; and five of the six independent input contacts for the breaker failure inputs. From the input contact perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.67* shows the breakdown and the total number of relay output contacts required for tripping.

Table 1.67 Breakdown and Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts; high-speed, high-interrupting output contacts provide for faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts, and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the number of the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and external circuit breaker failure inputs to specific relay input contacts

- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.68* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.68* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.112*.

Table 1.68 CT-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.69*.

Table 1.69 Alias Names for the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input to Logic Allocation

Table 1.66 shows that we require 33 digital inputs. We now assign the 33 digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input Contact to Logic Allocation, Interface Board 1 (200)

Table 1.70 and *Table 1.71* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.70 Disconnect and Circuit Breaker Failure Contact Input Allocation

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN208	MADRID terminal disconnect (ZONE1_A) NO contact
IN209	MADRID terminal disconnect (ZONE1_A) NC contact
IN210	MADRID terminal disconnect (ZONE2_A) NO contact
IN211	MADRID terminal disconnect (ZONE2_A) NC contact
IN212	MADRID terminal disconnect (TRANS _A) NO contact
IN216	MADRID terminal disconnect (TRANS _A) NC contact
IN217	MILAN terminal disconnect (ZONE1_A) NO contact
IN218	MILAN terminal disconnect (ZONE1_A) NC contact
IN219	MILAN terminal disconnect (ZONE2_A) NO contact
IN220	MILAN terminal disconnect (ZONE2_A) NC contact
IN221	MILAN terminal disconnect (TRANS _A) NO contact
IN222	MILAN terminal disconnect (TRANS _A) NC contact

Input Contact to Logic Allocation, Interface Board 2 (300)

Table 1.71 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.71 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 1 of 2)

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact

Table 1.71 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 2 of 2)

Input	Description
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

Referring to *Table 1.65*, the following is a discussion on each selected function.

Disconnect Monitoring Logic

Figure 1.113 shows one of the 48 disconnect monitor logic circuits available in the relay. (See *Dynamic Zone Selection Logic on page R.1.15* for more information on the disconnect auxiliary contact requirements).

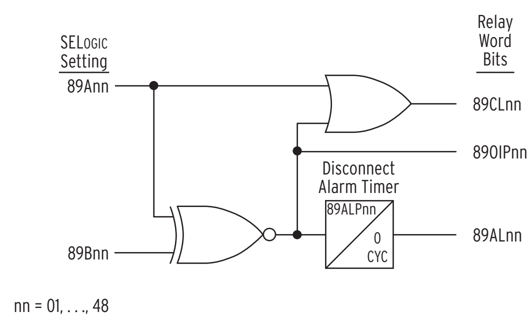


Figure 1.113 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.72 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 1.72 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO
89B02	TIE-BREAKER disconnect (ZONE2_A) NC
89A03	MADRI_A disconnect (ZONE1_A) NO contact
89B03	MADRI_A disconnect (ZONE1_A) NC contact
89A04	MADRI_A disconnect (ZONE2_A) NO contact
89B04	MADRI_A disconnect (ZONE2_A) NC contact
89A05	MADRI_A disconnect (TRANS_A) NO contact
89B05	MADRI_A disconnect (TRANS_A) NC contact
89A06	MILAN_A disconnect (ZONE1_A) NO contact

Table 1.72 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89B06	MILAN _A disconnect (ZONE1_A) NC contact
89A07	MILAN _A disconnect (ZONE2_A) NO contact
89B07	MILAN _A disconnect (ZONE2_A) NC contact
89A08	MILAN _A disconnect (TRANS_A) NO contact
89B08	MILAN _A disconnect (TRANS_A) NC contact
89A09	ROME_A disconnect (ZONE1_A) NO contact
89B09	ROME _A disconnect (ZONE1_A) NC contact
89A10	ROME _A disconnect (ZONE2_A) NO contact
89B10	ROME _A disconnect (ZONE2_A) NC contact
89A11	ROME _A disconnect (TRANS_A) NO contact
89B11	ROME _A disconnect (TRANS_A) NC contact
89A12	CAIRO _A disconnect (ZONE1_A) NO contact
89B12	CAIRO _A disconnect (ZONE1_A) NC contact
89A13	CAIRO _A disconnect (ZONE2_A) NO contact
89B13	CAIRO _A disconnect (ZONE2_A) NC contact
89A14	CAIRO _A disconnect (TRANS_A) NO contact
89B14	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 1.114 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.73* shows the Relay Word bits and description for the zone differential protection outputs.

Table 1.73 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

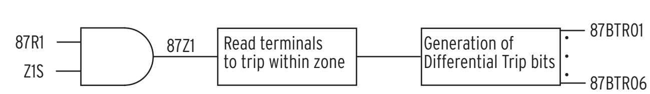


Figure 1.114 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.154* for more information). *Table 1.74* shows the primitive analog channel names, and the differential trip bit names for the differential trip bits.

Table 1.74 Differential Trip Bit Names and Associated Terminal Names

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 1.115 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF06 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR06 are the outputs from the station breaker failure logic. Relay Breaker failure trip bits SBFTR01–SBFTR06 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

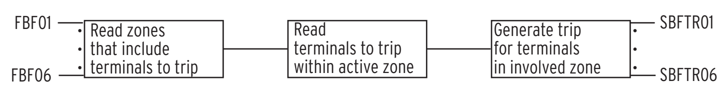


Figure 1.115 Breaker Failure Trip Logic

Table 1.75 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 1.75 Station Breaker Failure Trip Bit Names and Associated Terminal Names

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05
SBFTR06	Associated with Terminal 06

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip six terminals.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 1.116* shows the logic for the external breaker failure function.

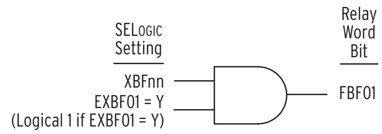


Figure 1.116 Breaker Failure Logic for External Breaker Failure

We assign the relay breaker failure inputs shown in *Table 1.70* to the appropriate XBF*nn* (*nn* = 01 through 06) of the breaker failure protection logic (see *Protection Group Settings on page A.1.162*). *Table 1.76* shows the primitive names and assignments.

Table 1.76 Breaker Failure Logic Output Relay Word Bits

Logic Name	Description
IN201	TIE1_A breaker failure protection asserted
IN201	TIE2_A breaker failure protection asserted
IN202	MADRI_A breaker failure protection asserted
IN203	MILAN_A breaker failure protection asserted
IN301	ROME_A breaker failure protection asserted
IN302	CAIRO_A breaker failure protection asserted

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 1.67 shows the breakdown of the five relay outputs we need for Application 5. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.77* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 1.78* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 1.77 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.78* shows the assignment for the five terminals of the A-phase relay.

Table 1.78 Assignment of the Output Contacts

Output Contact Assignment	Description
OUT201[a]	Tie-Breaker trip logic output
OUT202[a]	MADRID trip logic output
OUT203[a]	MILAN trip logic output
OUT204[a]	ROME trip logic output
OUT205[a]	CAIRO trip logic output

[a] High speed, high interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 1.117*.

1. Write down the bus-zone, terminal and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the terminal digital inputs to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

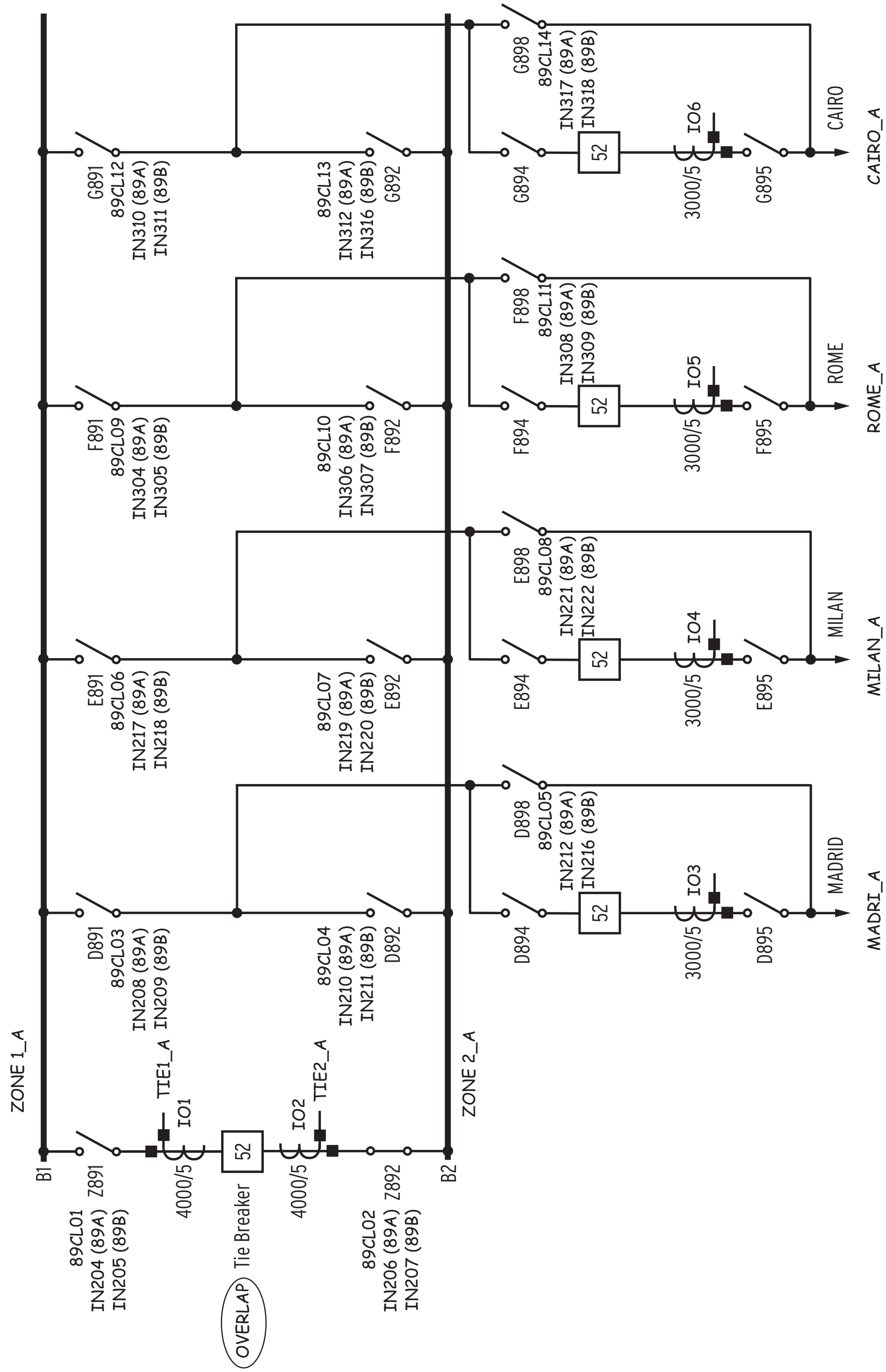


Figure 1.117 Substation Layout With Specific Information

Setting the Relay

The following describes the settings for this application. For this application example, we set the following setting classes:

- ➤ Alias Settings
- ➤ Global Settings
- ➤ Zone Configuration Group Settings
- ➤ Protection Group Settings
- ➤ Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.118*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.118 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.119*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.119 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.120*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TIE1_A <Enter>
20:
?  I02,TIE2_A <Enter>
21:
?  I03,MADRI_A <Enter>
22:
```

```
?   I04,MILAN_A <Enter>
23:
?   I05,ROME_A <Enter>
24:
?   I06,CAIRO_A <Enter>
25:
?   BZ1,ZONE1_A <Enter>
26:
?   BZ2,ZONE2_A <Enter>
27:
?   END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.120 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from protection setting Group 1 to protection setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.121* shows the setting changes we need for our example.

Because we declared the alias names in the previous setting class, use either the alias names or the primitive names when entering settings.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 14 disconnect logics although there are 28 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01 through 48). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 1.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                         NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-48)                      NUMDS   := N      ?14 <Enter>
Nominal System Frequency (50,60 Hz)                 NFREQ   := 60     ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                    EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                     GINPU   := 0.17   ?> <Enter>
Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)               89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)               89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)               89ALP03 := 300    ?<Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)               89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.
N/O Contact Input -DS14 (SELogic Equation)
89A14 := NA
?  IN317 <Enter>
N/C Contact Input -DS14 (SELogic Equation)
89B14 := NA
?  IN318 <Enter>
DS14 Alarm Pickup Delay (0-99999 cyc)               89ALP14 := 300    ? <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.121 Global Settings for Application 5

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the London feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer.
- Transfer busbar: the busbar to which the terminal on transfer is connected.
- Transfer disconnect: the disconnect, when closed, bypasses the circuit breaker (e.g., disconnect G898 on the CAIRO Terminal).

Although the relay is flexible enough to accept settings for the many disconnect combinations, we will configure the relay according to the following operating conditions:

- Only one terminal will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z892 or Z891) and the transfer disconnect (*n*898, *n* = D, E, F and G) of only one of the four feeders can be closed simultaneously.
- Either Busbar B1 or Busbar B2 can be the source busbar.
- When closing the transfer disconnect, the protection of the transfer busbar becomes part of the line protection.
- The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step.

Table 1.79 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Assume that the tie breaker and tie-breaker disconnects are closed. For brevity, we consider only the MADRID and CAIRO Feeders in the following discussion. Consider a case where we put the CAIRO Feeder on transfer, with Busbar B2 selected as the source busbar.

Table 1.79 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Switch Terminals TD, TE, and TF to the source busbar (B2).	Assume that all FDRs are connected to B1. Close the disconnects that connect the terminals to Busbar B2 (D892, E892, F892, and G892), and open the disconnects that connect the terminals to Busbar B1 (D891, E891, and F891). After Step 1, CAIRO is the only feeder connected to Busbar B1, see *Figure 1.122*. Both Bus-zone B2 ($I03 + I01 = I_s - I_s = 0$) and Bus-Zone B1 are balanced ($I02 + I06 = I_s - I_s = 0$).
2	Close the transfer disconnect (G898) of the terminal going on transfer.	This operation forms a parallel path, with current I_S splitting at the G894 and G898 junction; not all current flows through the CAIRO CT. There are still two bus-zones (B1 and B2), but because the current from the CAIRO CT is missing (worst case), Bus-Zone B1 can misoperate. Remove Bus-Zone B1 by removing the CAIRO CT and tie-breaker channel I02 from the differential calculations. (See the ensuing discussion and *Figure 1.123*). The transfer busbar is now part of the line protection.
3	Open the circuit breaker of the terminal going on transfer.	Opening the CAIRO circuit breaker interrupts the current path through the circuit breaker. Tie-breaker channel I01 remains part of the differential calculations to balance the current flow to the CAIRO Feeder.
4	Open the source busbar disconnect (G894) and the line disconnect (G895) to isolate the circuit breaker.	Step 4 is shown here to complete the operating sequence; the operation has no effect on the busbar protection.

Figure 1.122 shows the station after Step 1 in *Table 1.79*. Step 1 is standard operating procedure and requires no special busbar protection settings. With all transfer disconnects open, all the CT secondary currents are available, and both Bus-Zones B1 and B2 are balanced.

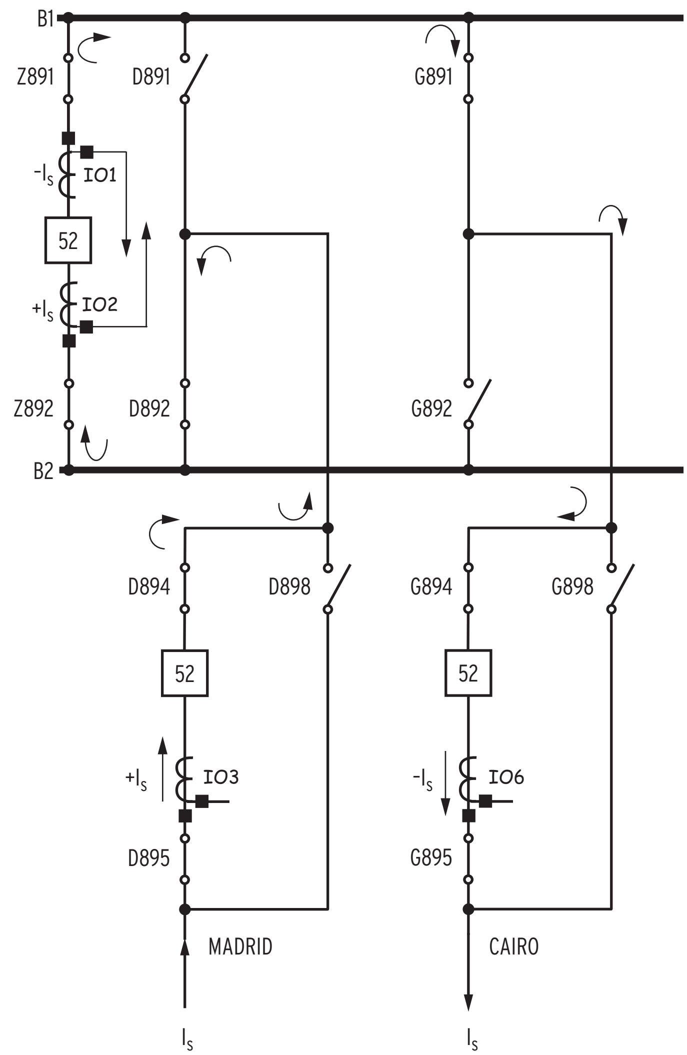


Figure 1.122 Bus-Zone B1 and Bus-Zone B2 Are Balanced When Both Transfer Disconnects Are Open

Figure 1.123 shows the current distribution for the condition when disconnect G891 and disconnect G898 are both closed. Current I_S enters the MADRID terminal, flows through the tie breaker, busbar B1, and up to the junction between disconnect G894 and G898. At this junction, the current splits into i_a and i_b. As a worst-case scenario, assume the entire current, I_S, flows through disconnect G898, with no current flowing through the CAIRO CT. To balance the B1 differential element, we need the sum of the currents in the B1 element to equal zero. Without the CAIRO CT current contribution, the differential element is unbalanced and can result in misoperation. To conclude, the current input from the CAIRO CT is uncertain when disconnect G891 and disconnect G898 are both closed, and disappears when the circuit breaker opens. For these reasons, Bus-Zone B1 cannot form a reliable differential zone when disconnect G898 closes. Differential Element B2 remains stable, and the B2 Busbar protection is secure.

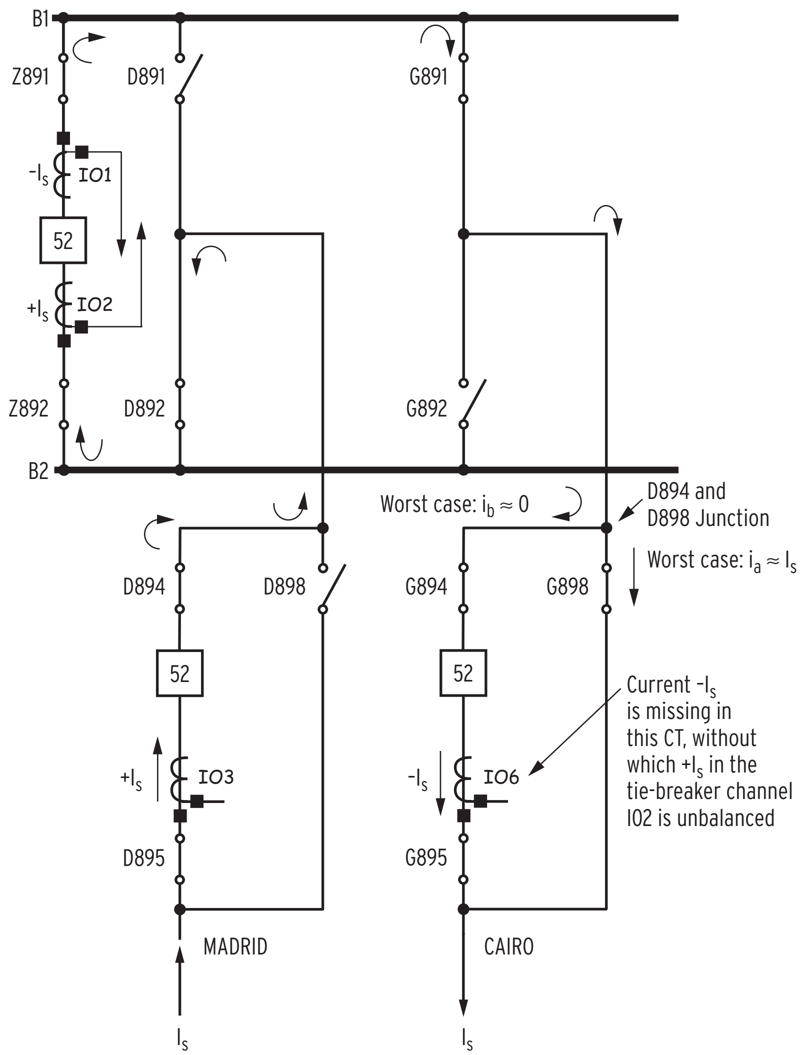


Figure 1.123 Current Distribution During Transfer Procedure Using Inboard CTs

By removing the CAIRO CT as well as the tie-breaker I02 channel from the differential calculations, we effectively remove Differential element B1. We can achieve the same result in two ways:

➤ by using the zone supervision setting (Z*n*S)

➤ entering values for each of the terminal-to-bus-zone settings

This example uses the first option (i.e., the zone supervision setting).

Consider also that by removing Differential Element B1, the transfer busbar is without protection. One solution is to use the tie-breaker I02 CT for the line protection, thereby including the transfer busbar as part of the line. When using the SEL-421 as line protection, program the selection functions in the relay to select current I02 as an alternate current source.

To configure the correct disconnect combinations, use the following conditions:

1. With no feeder on transfer, manipulate the tie-breaker CTs with the bus-zone-to-bus-zone connections.
2. A feeder is on transfer when any *n*898 AND *n*891, or any *n*898 AND *n*892 (*n* = D, E, F and G) disconnects are closed simultaneously.
3. When a feeder is on transfer and B2 is the source busbar, remove I02. B2 is the source busbar when *n*891 AND *n*898 (*n* = D, E, F and G) disconnects are closed.
4. When a feeder is on transfer and B1 is the source busbar, remove I01. B1 is the source busbar when *n*892 AND *n*898 (*n* = D, E, F and G) disconnects are closed.

Z1S:= **NOT ((89CL03 AND 89CL05) OR (89CL06 AND 89CL08) OR (89CL09 AND 89CL11) OR (89CL12 AND 89CL14))**

Z2S:= **NOT ((89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13 AND 89CL14))**

The zone configuration default setting are settings for a specific substation with arbitrarily selected alias names, serving only as an example.

For the ease of setting the zone configuration settings for the new substation, delete the existing zone configuration default settings.

With the zone configuration default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 1.124* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000    ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600     ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600     ?800 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600     ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE1_A, ZONE1_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?  89CL02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,ZONE1_A <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?  89CL01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?  89CL03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?  89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,ZONE1_A,P <Enter>
```

```
MILAN_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
?   89CL06 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
I04BZ2V := NA
?   89CL07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
I05BZ1V := NA
?   89CL09 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
I05BZ2V := NA
?   89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
I06BZ1V := NA
?   89CL12 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
I06BZ2V := NA
?   89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?   ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?   (89CL03 AND 89CL04) OR (89CL06 AND 89CL07) OR (89CL09 AND 89CL10) OR (89CL12\
 AND 89CL13) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?   BZ1BZ2V <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?   TIE1_A,TIE2_A <Enter>
Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?   Y <Enter>
Bus-Zone, Bus-Zone
? <Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?   NOT ((89CL03 AND 89CL05) OR (89CL06 AND 89CL08) OR (89CL09 AND 89CL11) OR (8\
9CL12 AND 89CL14)) <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?   NOT ((89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (8\
9CL13 AND 89CL14)) <Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.124 Zone Configuration Group Settings for Application 5

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available. For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element and the Directional Element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information) to use the sensitive differential element for this requirement. Set TOS := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N because we do not use the Coupler Security Logic, overcurrent elements, terminal out of service, or voltage elements in this application.

Because breaker failure protection measures each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, but six current channels (tie breaker has two CTs). Select six as the number of breaker failure logics for this application.

This application assumes a single breaker failure input from the tie-breaker protection. With a single breaker failure input from the tie-breaker protection, set both tie-breaker breaker failure initiate setting (XBF01 and XBF02) equal to IN201. For tie breakers with two breaker failure relays, allocate an additional relay input for the second breaker failure input, and equate each relay input to an XBF*nn* settings. For example, assume the two breaker failure inputs are assigned to relay input IN201 and relay input IN202. With these input assignments, set XBF01 := IN201 and XBF02 := IN202.

Setting NUMBK equal to five makes five corresponding trip equations (TR01 through TR05) available for setting. There are five trip equations available, but there are six analog channels (I01 though I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 1.74*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Each of the six analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 1.75*) when the breaker failure element asserts. Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

Because the tie breaker has two analog channels, but only one circuit breaker, include both Differential Trip bits (87BTR01 and 87BTR02) as well as both station breaker failure trip bits (SBFTR01 and SBFTR02) in the trip equation of the tie breaker (TR01).

Figure 1.125 shows the protection group settings for this application.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6      ?<Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N      ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Breaker 01 Failure Logic

External Breaker Fail -BK01 (Y,N)                    EXBF01  := N      ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFIDO01 := 1.50   ? <Enter>

Breaker 02 Failure Logic

External Breaker Fail -BK02 (Y,N)                    EXBF02  := N      ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFIDO02 := 1.50   ?<Enter>
.
.
.

External Breaker Fail -BK06 (Y,N)                    EXBF06  := N      ?Y <Enter>
External Brkr Fail Init -BK06 (SELogic Equation)
XBF06 := NA
?  IN302 <Enter>
Brkr Fail Init Dropout Delay -BK06 (0.00-1000 cyc)   BFIDO06 := 1.50   ? <Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR SBFTR02 OR 87BTR02 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>

Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  SBFTR03 OR 87BTR03 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  SBFTR04 OR 87BTR04 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  SBFTR06 OR 87BTR06 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ? <Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
```

```
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.125 Protection Group Settings for Application 5

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts. Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101 through OUT106 = NA.

Figure 1.126 shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?   NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?   NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?   NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?   NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?   TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?   TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?   TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?   TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>

Output
.
.
.
```

```
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.126 Control Output Settings for Application 5

This concludes the settings for Application 5.

Application 6: Double and Transfer Bus With Two Busbars

This describes the busbar arrangement shown in *Figure 1.127*. The busbar arrangement consists of two busbars (main busbar and transfer busbar), four terminals and a tie breaker. Consider the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection functions selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation and alias name assignment
- ➤ Station layout update
- ➤ Relay setting and configuration

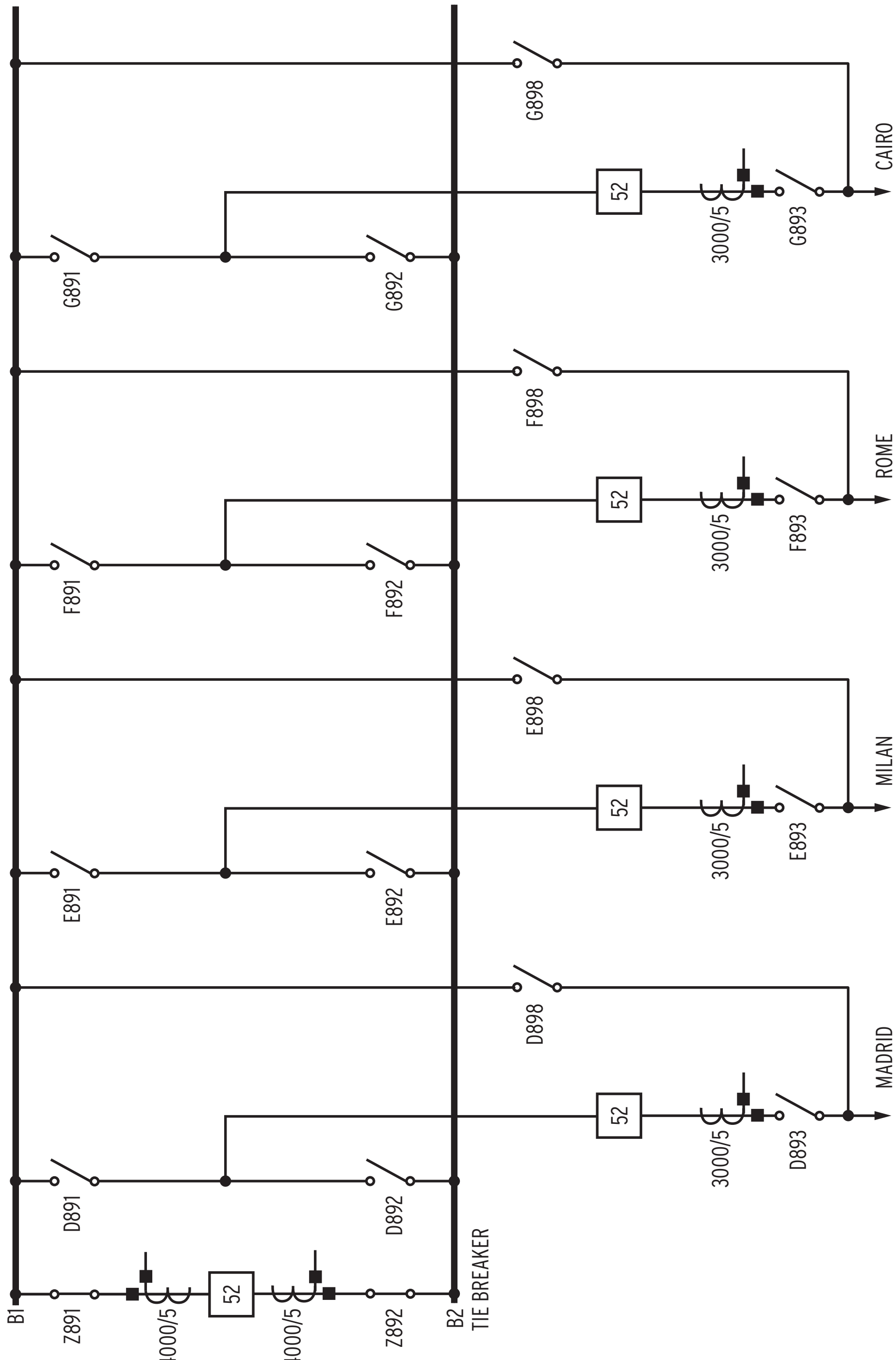


Figure 1.127 Double Bus and Transfer Bus With Buscoupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (buscoupler) configuration.

- Description:
  - Double bus with tie breaker
- Current Transformers:
  - Inboard

- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Two CTs, configured in overlap
- Future expansion:
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open circuit CT.
3. Ensure stable differential protection for all operating conditions.
4. Use the disconnect auxiliary contacts to dynamically configure the station.
5. Use the disconnect monitor logic.
6. Use external breaker failure protection.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. Requirement 3 of the protection philosophy calls for stable differential protection for all operating conditions.

There are two network conditions when the differential protection can become unstable: when disconnects *n*891 and *n*892 (*n* = D, E, F,G) of any feeder are closed at the same time, or when the transfer disconnect of any feeder is closed. By declaring the appropriate conditions in the bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable when disconnects *n*891 and *n*892 are closed simultaneously. We use the zone supervision logic to ensure stable differential protection during the time when one of the transfer disconnects is closed.

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 1.80* shows the selection of the standard functions.

Table 1.80 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the station according to the disconnect positions.

Table 1.80 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Functions	Selection	Comment
Sensitive differential protection	Yes	Use the sensitive differential element as CT open circuit detection.
Zone supervision logic	Yes	Use the zone supervision logic to compensate for the inboard CTs during the bypass period, as well as when a feeder is on transfer.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	No	Not required
Circuit breaker failure protection	Yes	External breaker failure
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need for the application that is not part of the standard logic in the relay. We comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- ➤ the number of relays (single-relay application or three-relay application)
- ➤ the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with up to 18 CTs (per phase), we can install a single SEL-487B. For station with more than 18 and up to 54 CTs we install three SEL-487B relays. Use *Equation 1.20* to calculate number of current channels at the station, and use *Equation 1.21* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs} \quad \textbf{Equation 1.20}$$

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections} \quad \textbf{Equation 1.21}$$

The number of per-phase CTs at the station is 18 (tie breaker has 6 CT cores), and one SEL-487B suffices. However, the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the 4 feeders requires 3 disconnect monitoring logic and the tie breaker requires 2; the number of disconnect logics required is therefore 14. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.22* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics} \quad \textbf{Equation 1.22}$$

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions, and records the terminals in each bus-zone. The relay then uses this information to only trip the terminals in the bus-zone with the failed breaker, when a circuit breaker fails. Wire an output from each breaker failure relay on each of the terminals to the SEL-487B. *Table 1.81* summarizes the input contact required for this application.

Table 1.81 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 14 = 28
Number of relay inputs required for breaker failure protection	5
Total number of inputs	33

The relay main board has seven inputs, which are not enough inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent input contacts. Use the grouped inputs for the disconnect auxiliary contact inputs and the six independent inputs for the breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.82* shows the breakdown and the total number of relay output contacts required for tripping.

Table 1.82 Breakdown and Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts, and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- ➤ the number of SEL-487B relays required for the application
- ➤ the number of input contacts
- ➤ the number of output contacts
- ➤ selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay.

However, we still need to do the following:

- ➤ link specific CT inputs to specific relay analog channels
- ➤ link specific disconnect and circuit breaker inputs to specific relay input contacts
- ➤ link relay element/logic outputs to specific relay output contacts
- ➤ assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- ➤ Relay Word bit
- ➤ Analog quantity
- ➤ Terminal name
- ➤ Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.83* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.83* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.127*.

Table 1.83 CT-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.84*.

Table 1.84 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input-to-Logic Allocation

Table 1.81 shows that we require 33 digital inputs. We now assign the digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input Contact-to-Logic Allocation, Interface Board 1 (200)

Table 1.85 and *Table 1.86* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.85 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 1 of 2)

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE2_A) NC contact

Table 1.85 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 2 of 2)

Input	Description
IN206	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN208	MADRID terminal disconnect (ZONE1_A) NO contact
IN209	MADRID terminal disconnect (ZONE1_A) NC contact
IN210	MADRID terminal disconnect (ZONE2_A) NO contact
IN211	MADRID terminal disconnect (ZONE2_A) NC contact
IN212	MADRID terminal disconnect (TRANS _A) NO contact
IN216	MADRID terminal disconnect (TRANS _A) NC contact
IN217	MILAN terminal disconnect (ZONE1_A) NO contact
IN218	MILAN terminal disconnect (ZONE1_A) NC contact
IN219	MILAN terminal disconnect (ZONE2_A) NO contact
IN220	MILAN terminal disconnect (ZONE2_A) NC contact
IN221	MILAN terminal disconnect (TRANS _A) NO contact
IN222	MILAN terminal disconnect (TRANS _A) NC contact

Input Contact to Logic allocation, Interface Board 2 (300)

Table 1.86 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.86 Disconnect and Circuit Breaker Failure Contact Input Allocations

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

Referring to *Table 1.80*, the following is a discussion on each selected function.

Disconnect Monitoring Logic

Figure 1.128 shows one of the 48 disconnect monitor logic circuits available in the relay. (See *Figure 1.20*).

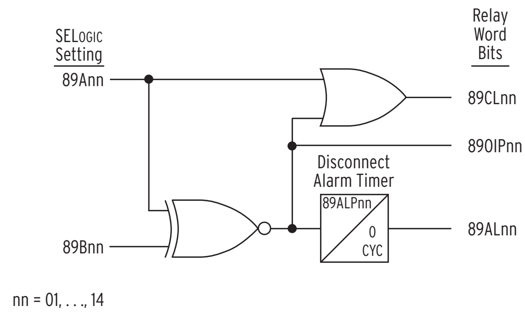


Figure 1.128 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.87 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 1.87 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Disconnect Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO contact
89B02	TIE-BREAKER disconnect (ZONE2_A) NC contact
89A03	MADRI_A disconnect (ZONE1_A) NO contact
89B03	MADRI_A disconnect (ZONE1_A) NC contact
89A04	MADRI_A disconnect (ZONE2_A) NO contact
89B04	MADRI_A disconnect (ZONE2_A) NC contact
89A05	MADRI_A disconnect (TRANS_A) NO contact
89B05	MADRI_A disconnect (TRANS_A) NC contact
89A06	MILAN_A disconnect (ZONE1_A) NO contact
89B06	MILAN _A disconnect (ZONE1_A) NC contact
89A07	MILAN _A disconnect (ZONE2_A) NO contact
89B07	MILAN _A disconnect (ZONE2_A) NC contact
89A08	MILAN _A disconnect (TRANS_A) NO contact
89B08	MILAN _A disconnect (TRANS_A) NC contact
89A09	ROME_A disconnect (ZONE1_A) NO contact
89B09	ROME _A disconnect (ZONE1_A) NC contact
89A10	ROME _A disconnect (ZONE2_A) NO contact
89B10	ROME _A disconnect (ZONE2_A) NC contact
89A11	ROME _A disconnect (TRANS_A) NO contact

Table 1.87 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Disconnect Input	Description
89B11	ROME _A disconnect (TRANS_A) NC contact
89A12	CAIRO _A disconnect (ZONE1_A) NO contact
89B12	CAIRO _A disconnect (ZONE1_A) NC contact
89A13	CAIRO _A disconnect (ZONE2_A) NO contact
89B13	CAIRO _A disconnect (ZONE2_A) NC contact
89A14	CAIRO _A disconnect (TRANS_A) NO contact
89B14	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 1.129 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.88* shows the Relay Word bits and description for the zone differential protection outputs.

Table 1.88 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

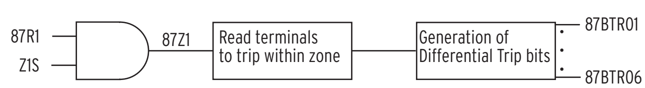


Figure 1.129 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.179* for more information). *Table 1.89* shows the primitive analog channel names, and the differential trip bit names for the differential trip bits.

Table 1.89 Differential Trip Bit Names and the Associated Terminals (Sheet 1 of 2)

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03

Table 1.89 Differential Trip Bit Names and the Associated Terminals (Sheet 2 of 2)

Differential Trip Bit	Description
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 1.130 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF06 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR06 are the outputs from the station breaker failure logic. Relay Breaker failure trip bits SBFTR01–SBFTR06 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

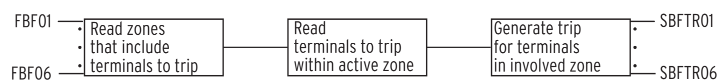


Figure 1.130 Breaker Failure Trip Logic

Table 1.90 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 1.90 Station Breaker Failure Trip Relay Word Bit Names and Associated Terminals

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05
SBFTR06	Associated with Terminal 06

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip six terminals.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 1.131* shows the logic for the external breaker failure function.

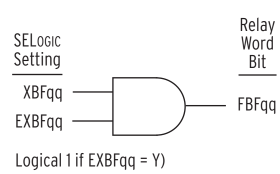


Figure 1.131 Breaker Failure Logic for External Breaker Failure

Table 1.85 and *Table 1.86* show the appropriate XBFqq (qq = 1–6) and relay input assignment (see *Protection Group Settings on page A.1.186*).

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 1.82 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.91* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 1.92* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 1.91 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.92* shows the assignment for the five terminals of the A-phase relay.

Table 1.92 Assignment of the Output Contacts

Output Contact Assignment	Description
OUT201[a]	TIE-BREAKER trip logic output
OUT202[a]	MADRID trip logic output
OUT203[a]	MILAN trip logic output
OUT204[a]	ROME trip logic output
OUT205[a]	CAIRO trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 1.132*.

1. Write down the bus-zone, terminal and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

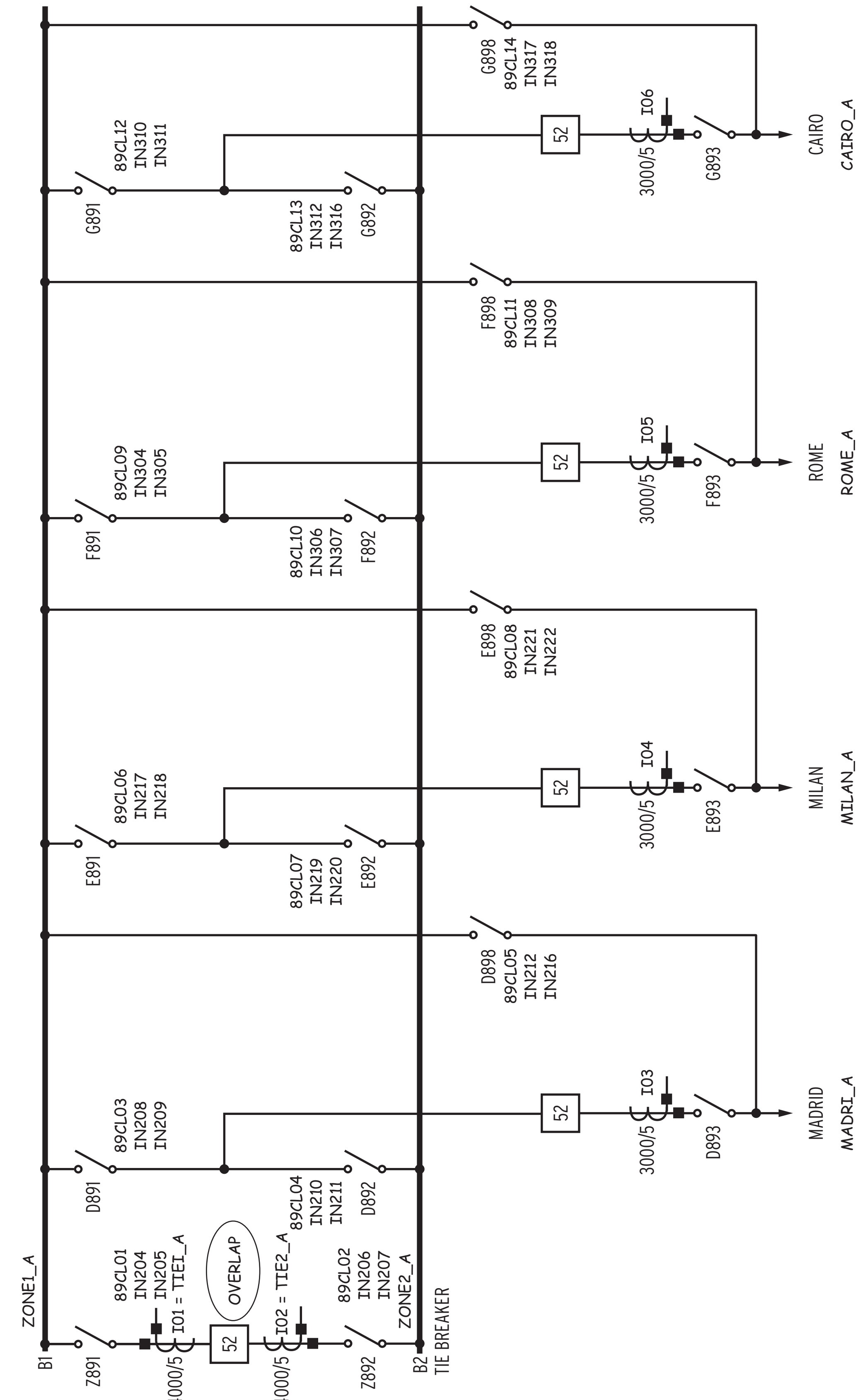


Figure 1.132 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following setting classes:

- ➤ Alias Settings
- ➤ Global Settings
- ➤ Zone Configuration Group Settings
- ➤ Protection Group Settings
- ➤ Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.133*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.133 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.134*.

```
1: I01,"FDR_1"
? DELETE 43 <Enter>
```

Figure 1.134 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.135*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TIE1_A <Enter>
20:
?  I02,TIE2_A <Enter>
21:
?  I03,MADRI_A <Enter>
22:
```

```
?   IO4,MILAN_A <Enter>
23:
?   IO5,ROME_A <Enter>
24:
?   IO6,CAIRO_A <Enter>
25:
?   BZ1,ZONE1_A <Enter>
26:
?   BZ2,ZONE2_A <Enter>
27:
?   END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.135 Analog Quantities and Relay Word Bit Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.136* shows the setting changes we need for our example. Because we declared the alias names in the previous setting class, use either the alias names or the primitive names when entering settings.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 14 disconnect logics although there are 28 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01 through 14). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 1.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                      NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-48)                   NUMDS   := N      ?14 <Enter>
Nominal System Frequency (50,60 Hz)              NFREQ   := 60     ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                 EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                  GINPU   := 0.17   ?> <Enter>
Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?   > <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?   > <Enter>
```

```
Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)            89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)            89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)            89ALP03 := 300    ?<Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)            89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.
N/O Contact Input -DS14 (SELogic Equation)
89A14 := NA
?  IN317 <Enter>
N/C Contact Input -DS14 (SELogic Equation)
89B14 := NA
?  IN318 <Enter>
DS14 Alarm Pickup Delay (0-99999 cyc)            89ALP14 := 300    ?<Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.136 Global Settings for Application 6

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfiguring the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information). In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration, and assign the input currents from the CTs to the appropriate differential elements. For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the Milan feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer.
- Transfer busbar: the busbar to which the terminal on transfer is connected (B1).
- Transfer disconnect: the disconnect, when closed, bypasses the circuit breaker (e.g., Disconnect G898 on the Cairo Terminal).

Although the relay is flexible enough to accept settings for the many disconnect combinations, we will configure the relay according to the following operating conditions:

- Only one terminal will be on transfer at any given time, i.e., the transfer Disconnect (*n*898, *n* = D, E, F and G) of only one of the four feeders can be closed at a time.
- Only Busbar B2 can be the source busbar.
- The transfer busbar (B1) becomes part of the line protection when a terminal is on transfer.
- The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step.

Table 1.93 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Assume that Disconnects Z891 and Z892 and the tie-breaker circuit breaker are closed. For brevity, we consider only the MADRID and CAIRO terminals in the following discussion. Consider the case where we put Terminal CAIRO on transfer.

Table 1.93 Fixed Operating Sequence to Put a Terminal on Transfer

Step Number	Description	Comment
1	Switch terminals TD, TE, and TF to the source busbar (B2).	Close all disconnects that connect the terminals to busbar B2 (D892, E892, F892, and G892), and open all disconnects that connect the terminals to busbar B1 (D891, E891, F891, and G891). No current flows through the tie breaker, see *Figure 1.137*. Bus-Zone B1 does not operate because no current flows through the tie breaker. Bus-Zone B2 is balanced because I03 + I06 = 0.
2	Close the transfer Disconnect (G898) of the terminal going on transfer.	This operation forms a parallel path, with ($i_a + i_b - i_a - i_b$) current I_s splitting into i_a and i_b at the D892 and Busbar B2 junction, as shown in *Figure 1.138*. To overcome this problem, remove tie-breaker Channel I02 from the B1 differential calculations when G898 closes. (See the ensuing discussion and *Figure 1.138*).

Table 1.93 Fixed Operating Sequence to Put a Terminal on Transfer

Step Number	Description	Comment
3	Open the circuit breaker of the terminal going on transfer.	Opening the CAIRO circuit breaker interrupts the current path through the circuit breaker. Tie-breaker Channel I01 remains part of the B2 differential calculations to balance the current flow to the CAIRO Terminal.
4	Open the source busbar Disconnect (G892) and the line Disconnect (G893) to isolate the circuit breaker.	Step 4 is shown here to complete the operating sequence; the operation has no effect on the busbar protection.

Figure 1.137 shows the station after Step 1 in *Table 1.93*. Step 1 is standard operating procedure and requires no special busbar protection settings. Because tie-breaker Disconnect Z891 is still closed, both bus-zones B1 and B2 are active. Bus-Zone B1 has only one CT (tie-breaker Channel I02) in place, but because no current flows through the tie breaker, the relay does not operate. Having both zones active provides the benefit of detecting faults on B1 during these operating conditions.

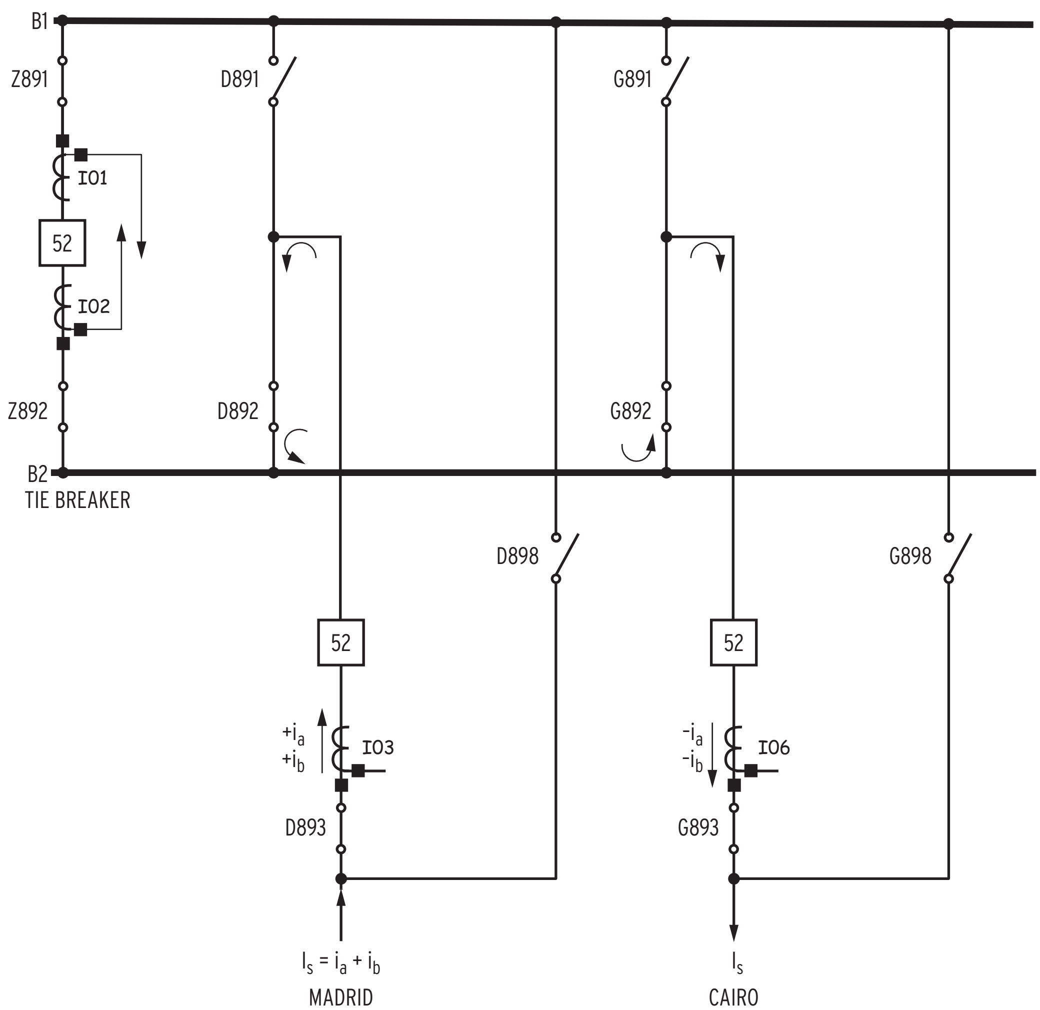


Figure 1.137 Bus-Zones B1 and B2 Are Balanced When All Transfer Disconnects Are Open

Closing Disconnect G898 in Step 2 of *Table 1.93* forms a parallel path. Current I_s enters at the MADRID terminal and splits into i_a and i_b at the D892 and Busbar B2 junction. This current distribution unbalances B1 because current $-i_a$ is missing in the CAIRO CT. The two differential elements calculate the differential currents as follows:

Element for Busbar B1:

$$\begin{aligned} I_{diff} &= (I02) + 0 \text{ (no other CT in place)} \\ &= i_a + 0 \\ &= i_a \text{ (element is unbalanced)} \end{aligned} \quad \textbf{Equation 1.23}$$

Element for Busbar B2:

$$\begin{aligned} I_{diff} &= (I01) + (I03) + (I06) \\ &= (i_a + i_b) - i_a - i_b \\ &= 0 \text{ (element is balanced)} \end{aligned} \quad \textbf{Equation 1.24}$$

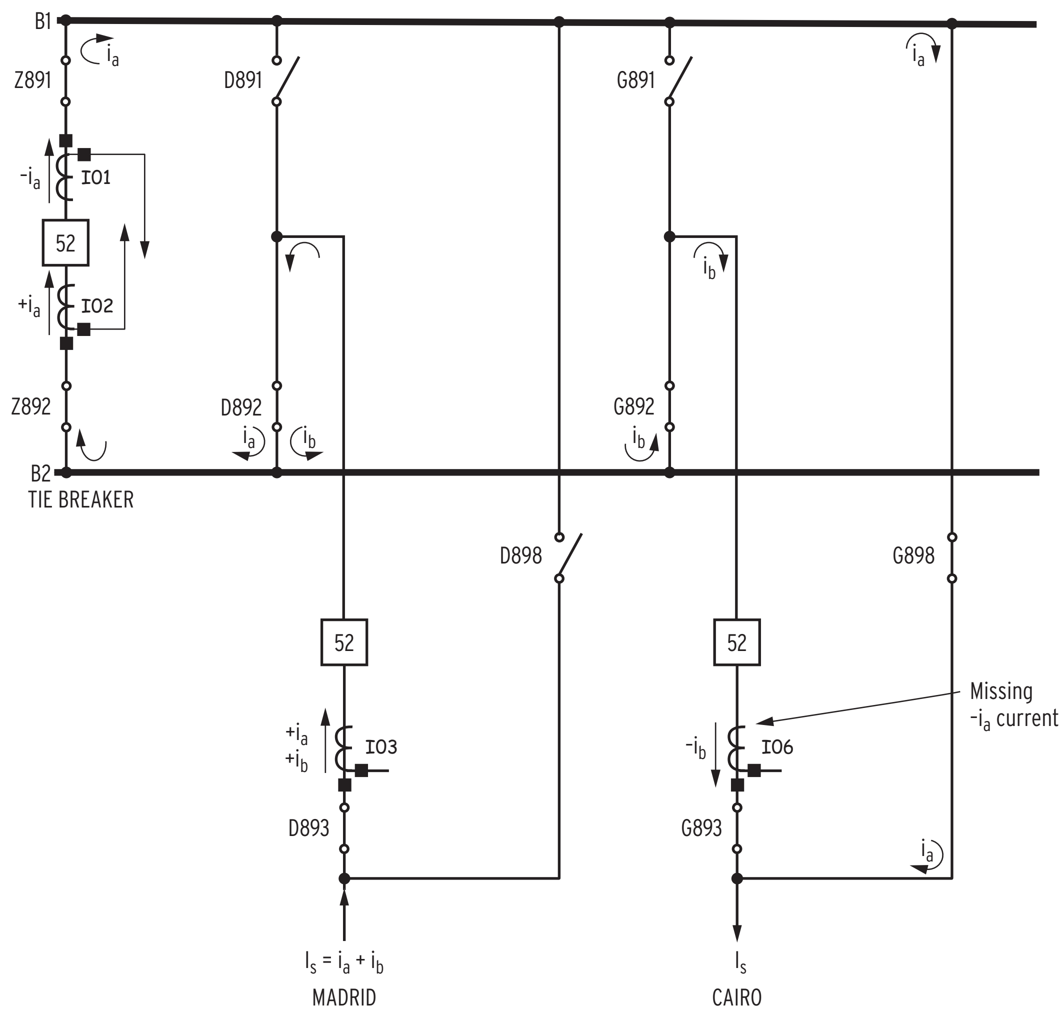


Figure 1.138 Current Distribution During Transfer Procedure Using Inboard CTs

In Step 3 of *Table 1.93*, we open the CAIRO circuit breaker, and the parallel path no longer exists. Current i_b disappears, and I_s flows as shown in *Figure 1.139*. The differential element for Busbar B2 is stable (I01 + I03 = 0), but the differential element for Busbar B1 is unbalanced. To conclude, the differential element for Busbar B1 is unbalanced during the transition period (when a parallel path exists) as well as when the terminal is on transfer.

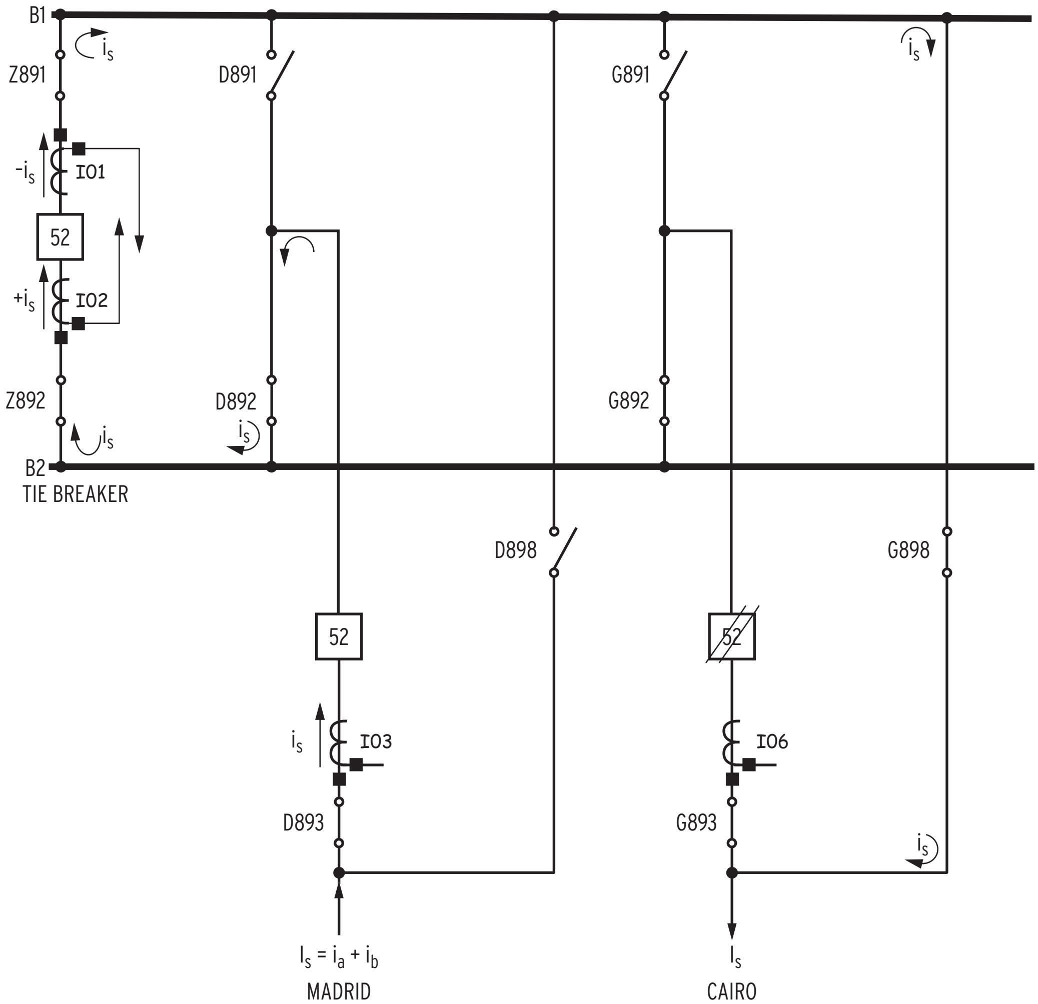


Figure 1.139 Current Distribution After Opening the Circuit Breaker of the Terminal Going on Transfer

Because Disconnect G898 bypasses the CAIRO CT, we cannot provide differential protection for Busbar B1. Because we cannot provide differential protection for Busbar B1, we need to remove the existing differential B1 element to prevent misoperation. We remove differential B1 element by using a zone supervision setting (Z*n*S).

In this application, the tie-breaker current assignment to the differential elements depends on the position of only one of the tie-breaker disconnects: current channel I01 is assigned to B2 when Z892 is closed. Likewise, current channel I02 is assigned to B1 when Z891 is closed. The assignment of the feeder currents to the differential elements depends solely on the corresponding B1 and B2 disconnect positions (*n*891 and *n*892).

Consider also that by removing Differential Element B1, the transfer busbar is without protection. One solution is to use the tie-breaker I02 CT for the line protection, thereby including the transfer busbar as part of the line. When using the SEL-421 as line protection, program the selection functions in the relay to select current I02 as an alternate current source.

To configure the correct disconnect combinations, use the following conditions:

- ➤ With no terminal on transfer, manipulate the tie-breaker CTs with the bus-zone-to-bus-zone connections.
- ➤ A terminal is on transfer when any *n*898 (*n* = D, E, F and G) disconnect is closed.
- ➤ When a terminal is on transfer, disable the differential element for Busbar B1.

Set the Zone Supervision setting for Busbar B1 as follows: Z1S:= NOT (89CL05 OR 89CL08 OR 89CL11 OR 89CL14). *Figure 1.140* shows the Zone Configuration settings for this application.

The zone configuration default setting are settings for a specific substation with arbitrarily selected alias names, serving only as an example. For the ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 1.140* shows the Zone Configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?800 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE1_A, ZONE1_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?  89CL02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,ZONE1_A,P <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?  89CL01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?  89CL03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?  89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
?  89CL06 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
I04BZ2V := NA
?  89CL07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,ZONE1_A, <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
I05BZ1V := NA
?  89CL09 <Enter>
```

```
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
I05BZ2V := NA
?   89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
I06BZ1V := NA
?   89CL12 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
I06BZ2V := NA
?   89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?   ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?   (89CL03 AND 89CL04) OR (89CL06 AND 89CL07) OR (89CL09 AND 89CL10) OR (89CL12\
 AND 89CL13) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?   BZ1BZ2V <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?   TIE1_A,TIE2_A <Enter>
Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?   Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?   NOT(89CL05 OR 89CL08 OR 89CL11 OR 89CL14) <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?<Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.140 Zone Configuration Group Settings for Application 6

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element and the Directional Element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information) to use the sensitive differential element for this requirement. Set TOS := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N because we do not use the Coupler Security Logic, overcurrent elements, terminal out of service, or voltage elements in this application.

Because breaker failure protection measures each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, but six current channels (tie breaker has two CTs). Therefore, select six as the number of breaker failure logics for this application.

This application assumes a single breaker failure input from the tie-breaker protection. With a single breaker failure input from the tie-breaker protection, set both tie-breaker breaker failure initiate setting (XBF01 and XBF02) equal to IN201. For tie breakers with two breaker failure relays, allocate an additional relay input for the second breaker failure input, and equate each relay input to an XBF*nn* settings. For example, assume the two breaker failure inputs are assigned to relay input IN201 and relay input IN202. With these input assignments, set XBF01 := IN201 and XBF02 := IN202.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01 through 52A05), and five corresponding trip equations (TR01 through TR05) available for setting. There are five trip equations available, but there are six analog channels (I01 though I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 1.89*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Each of the six analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 1.90*) when the breaker failure element asserts. Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

Because the tie breaker has two analog channels, but only one circuit breaker, include both differential trip bits (87BTR01 and 87BTR02) as well as both station breaker failure trip bits (SBFTR01 and SBFTR02) in the trip equation of the tie breaker (TR01). *Figure 1.41* shows the protection group settings for this application.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6      ?<Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N      ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
```

```
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Breaker 01 Failure Logic

External Breaker Fail -BK01 (Y,N)                    EXBF01  := N      ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFIDO01 := 1.50   ? <Enter>

Breaker 02 Failure Logic

External Breaker Fail -BK02 (Y,N)                    EXBF02  := N      ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFIDO02 := 1.50   ?<Enter>
.
.
.

External Breaker Fail -BK06 (Y,N)                    EXBF06  := N      ?Y <Enter>
External Brkr Fail Init -BK06 (SELogic Equation)
XBF05 := NA
?  IN302<Enter>
Brkr Fail Init Dropout Delay -BK05 (0.00-1000 cyc)   BFIDO05 := 1.50   ?<Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR SBFTR02 OR 87BTR02 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  SBFTR03 OR 87BTR03 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  SBFTR04 OR 87BTR04 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?4 <Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  SBFTR06 OR 87BTR06 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?4 <Enter>
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.141 Protection Group Settings for Application 6

This concludes the protection group settings. The next settings class is control output settings.

Control Output Settings

In this setting class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relay in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101 through OUT106 = NA. *Figure 1.142* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?   NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?   NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?   NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?   NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?   TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?   TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?   TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?   TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>

Output
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.142 Control Output Settings for Application 6

Application 7: Double and Transfer Bus (Outboard CTs)

This application describes the busbar arrangement shown in *Figure 1.143*. The busbar arrangement consists of three busbars, four terminals, and a tie breaker. Use the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection function selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation
- ➤ Station layout update
- ➤ Relay setting and configuration

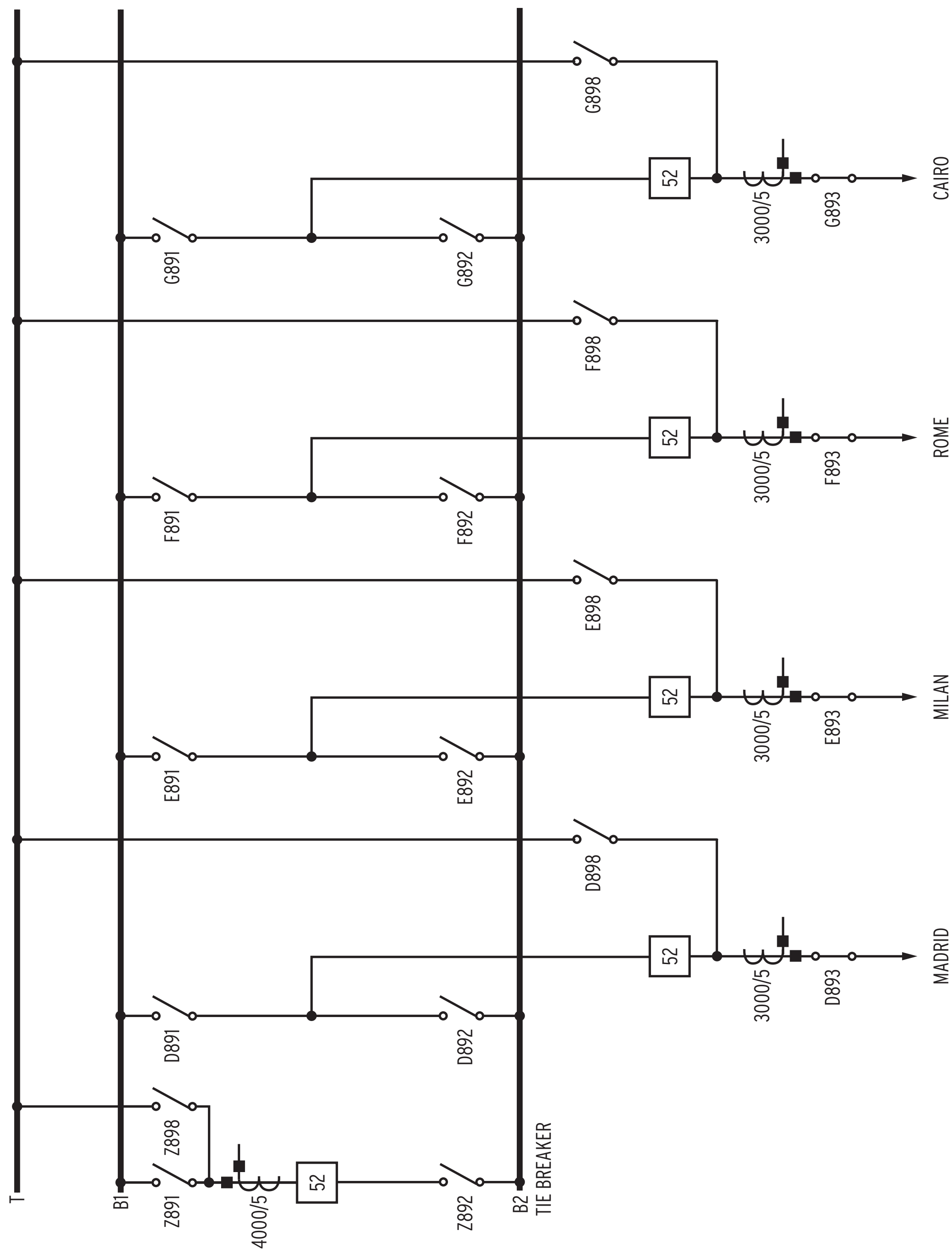


Figure 1.143 Double Bus and Transfer Bus With Buscoupler (Tie Breaker) and Outboard CTs

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and it declares the tie-breaker (buscoupler) configuration.

- Description:
  - Double bus with transfer busbar
- Current transformers:
  - Outboard (free standing)

- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Single CT with one core used for busbar protection
- Future expansion:
  - Five feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every application uses all these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the station.
4. Use the disconnect monitor logic.
5. Use external breaker failure protection.
6. Prevent the loss of Busbar B2 for a fault between the tie breaker and tie-breaker CT.

Protection Functions Selection

We select protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for the use of breaker failure protection but not for overcurrent protection. The SEL-487B offers a number of protection functions as standard features, but it also offers the capability through SELOGIC control equations for you to create user-configurable functions.

To prevent tripping of Busbar B2 when there is a fault between the tie breaker and tie-breaker CT, we can delay tripping of Busbar B2 and trip the tie breaker first (see *Protection Group Settings on page A.1.209*). We then remove the tie-breaker currents from the differential calculations of both zones to trip Busbar B1 and not Busbar B2.

To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created with SELOGIC control equations).

Standard Functions

Refer to *Protection Philosophy* and select the standard functions necessary for the application. *Table 1.94* shows the selection of standard functions.

Table 1.94 Selection of the Standard Protection Functions

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Use the zone supervision logic as part of preventing the loss of Busbar B2 for a fault between the tie breaker and the tie-breaker CT.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	Yes	Use the coupler security logic in a single CT application for enhanced protection for faults between the tie-breaker CT and the circuit breaker.
Circuit breaker failure protection	Yes	External breaker failure
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need that is not part of the standard relay logic in the relay. In this application, we comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay).

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with up to 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.25* to calculate the number of current channels at the station, and use *Equation 1.26* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.25**

# of bus-zones required = # of per-phase station CTs **Equation 1.26**

The number of per-phase CTs at the station is 15 (tie breaker has three CT cores), so one SEL-487B suffices. However, the requirement for 5 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, the tie breaker and each of the 4 feeders require 3 disconnect monitoring logics; the number of disconnect logics required therefore is 15. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.27* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

relay inputs required = 2 • # disconnect monitoring logics **Equation 1.27**

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions, and records the terminals in each bus-zone. When a circuit breaker fails, the relay uses this information to only trip the terminals in the bus-zone with the failed circuit breaker. Wire a breaker failure output contact from each breaker failure relay on each of the terminals to the SEL-487B.

We will use the coupler security logic to prevent tripping of Busbar B2 when there is a fault between the tie breaker and the tie-breaker CT. The coupler security logic requires three inputs: a close signal, a circuit breaker 52A auxiliary contact, and an input for the accelerated tripping function (see *Figure 1.108* for more information). We need one input for the circuit breaker 52A auxiliary contact and one input for the closing signal. For the accelerated tripping input (ACTRP1), we use the output from the B2 differential element (87R2). *Table 1.95* summarizes the input contact necessary for this application.

Table 1.95 Relay Input Contacts Requirement

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 15 = 30
Number of relay inputs required for breaker failure protection	5
Number of relay inputs required for the coupler security logic on the tie breaker	2 (one closing signal and one circuit breaker auxiliary 52A contact)
Total number of inputs	37

The relay main board has seven input contacts, an insufficient number of inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs, and use the six independent inputs for the breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.96* shows the breakdown and the number of relay output contacts necessary for tripping.

Table 1.96 Breakdown and Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B relays required for the application
- the number of inputs
- the number of output contacts
- the selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay inputs
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog Quantity
- Terminal Name
- Bus-Zone Name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.97* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.97* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.143*.

Table 1.97 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT, A-phase	I01	TIE_A
MADRID terminal, A-phase	I02	MADRI_A
MILAN terminal, A-phase	I03	MILAN_A
ROME terminal, A-phase	I04	ROME_A
CAIRO terminal, A-phase	I05	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use three bus-zone alias names, as shown in *Table 1.98*.

Table 1.98 Alias Names for the Three Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A
BZ3	Transfer busbar	TRANS_A

Input-to-Logic Allocation

Table 1.95 shows that we require 37 digital inputs. We now assign the digital inputs to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input-to-Logic Allocation, Interface Board 1 (200)

Table 1.99 and *Table 1.100* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure (only one breaker failure initiate input for the tie breaker) initiate input signals, tie-breaker 52A auxiliary contact, and the tie-breaker closing signal to these relay inputs.

Table 1.99 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 1 of 2)

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN208	TIE-BREAKER disconnect (TRANS _A) NO contact
IN209	TIE-BREAKER disconnect (TRANS _A) NC contact
IN210	MADRID terminal disconnect (ZONE1_A) NO contact
IN211	MADRID terminal disconnect (ZONE1_A) NC contact
IN212	MADRID terminal disconnect (ZONE2_A) NO contact
IN213	TIE-BREAKER circuit breaker 52A auxiliary contact
IN214	TIE-BREAKER circuit breaker closing signal
IN216	MADRID terminal disconnect (ZONE2_A) NC contact
IN217	MADRID terminal disconnect (TRANS _A) NO contact
IN218	MADRID terminal disconnect (TRANS _A) NC contact
IN219	MILAN terminal disconnect (ZONE1_A) NO contact
IN220	MILAN terminal disconnect (ZONE1_A) NC contact

Table 1.99 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 2 of 2)

Input	Description
IN221	MILAN terminal disconnect (ZONE2_A) NO contact
IN222	MILAN terminal disconnect (ZONE2_A) NC contact
IN223	MILAN terminal disconnect (TRANS _A) NO contact
IN224	MILAN terminal disconnect (TRANS _A) NC contact

Input-to-Logic Allocation, Interface Board 2 (300)

Table 1.100 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.100 Disconnect and Circuit Breaker Failure Contact Input Allocations

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

The following discussion references *Table 1.94* in explaining each selected function.

Disconnect Monitoring Logic

Figure 1.144 shows one of the 48 disconnect monitor logic circuits available in the relay.

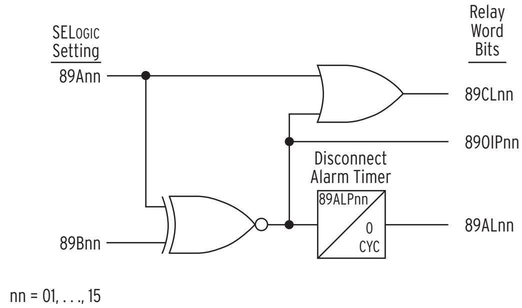


Figure 1.144 Disconnect Monitoring Logic Circuit for Terminal 01

Table 1.101 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 1.101 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO contact
89B02	TIE-BREAKER disconnect (ZONE2_A) NC contact
89A03	TIE-BREAKER disconnect (TRANS_A) NO contact
89B03	TIE-BREAKER disconnect (TRANS_A) NC contact
89A04	MADRI_A disconnect (ZONE1_A) NO contact
89B04	MADRI_A disconnect (ZONE1_A) NC contact
89A05	MADRI_A disconnect (ZONE2_A) NO contact
89B05	MADRI_A disconnect (ZONE2_A) NC contact
89A06	MADRI_A disconnect (TRANS_A) NO contact
89B06	MADRI_A disconnect (TRANS_A) NC contact
89A07	MILAN_A disconnect (ZONE1_A) NO contact
89B07	MILAN_A disconnect (ZONE1_A) NC contact
89A08	MILAN_A disconnect (ZONE2_A) NO contact
89B08	MILAN_A disconnect (ZONE2_A) NC contact
89A09	MILAN_A disconnect (TRANS_A) NO contact
89B09	MILAN_A disconnect (TRANS_A) NC contact
89A10	ROME_A disconnect (ZONE1_A) NO contact
89B10	ROME_A disconnect (ZONE1_A) NC contact
89A11	ROME_A disconnect (ZONE2_A) NO contact
89B11	ROME_A disconnect (ZONE2_A) NC contact
89A12	ROME_A disconnect (TRANS_A) NO contact
89B12	ROME_A disconnect (TRANS_A) NC contact
89A13	CAIRO_A disconnect (ZONE1_A) NO contact
89B13	CAIRO_A disconnect (ZONE1_A) NC contact
89A14	CAIRO_A disconnect (ZONE2_A) NO contact
89B14	CAIRO_A disconnect (ZONE2_A) NC contact

Table 1.101 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89A15	CAIRO_A disconnect (TRANS_A) NO contact
89B15	CAIRO_A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect inputs to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 1.145 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.102* shows Relay Word bits and description for the differential protection outputs.

Table 1.102 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip
87Z3	Transfer zone differential element trip

Differential trip bits 87BTR01–87BTR05 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

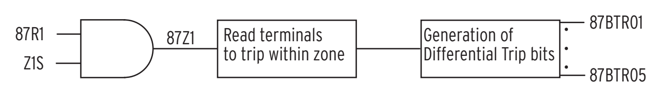


Figure 1.145 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.205*). *Table 1.103* shows the differential trip bit names and the associated terminal current channels.

Table 1.103 Differential Trip Bit and Associated Terminals

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 1.146 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF05 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR05 are the outputs from the station breaker failure logic. Breaker failure trip bits SBFTR01–SBFTR05 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

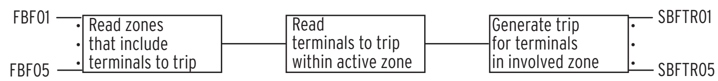


Figure 1.146 Breaker Failure Trip Logic

Table 1.104 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 1.104 Station Breaker Failure Trip Bits and Associated Terminals

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip five circuit breakers.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 1.147* shows the logic for the external breaker failure function.

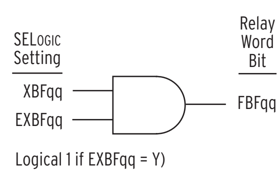


Figure 1.147 Breaker Failure Logic for External Breaker Failure

We assign the relay breaker failure inputs shown in *Table 1.99* and *Table 1.100* to the appropriate XBF*qq* (*qq* = 01 through 05) of the breaker failure protection logic (see *Protection Group Settings on page A.1.209*). *Table 1.105* shows the relay input and terminal assignments.

Table 1.105 Breaker Failure Logic Input Relay Word Bits

Logic Name	Description
IN201	TIE_A breaker failure protection asserted
IN202	MADRI_A breaker failure protection asserted
IN203	MILAN_A breaker failure protection asserted
IN301	ROME_A breaker failure protection asserted
IN302	CAIRO_A breaker failure protection asserted

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 1.96 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.106* shows TEST and ALARM protection logic output assignment to the main board output contacts. *Table 1.107* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 1.106 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.107* shows the assignments for the five terminals of the A-phase relay.

Table 1.107 Assignment of the Output Terminals

Output Contact Assignment	Description
OUT201[a]	TIE-BREAKER trip output
OUT202[a]	MADRID trip output
OUT203[a]	MILAN trip output
OUT204[a]	ROME trip output
OUT205[a]	CAIRO trip output

[a] High speed, high interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 1.148*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Allocate the terminal CTs to the relay input current channels.
3. Allocate the terminal auxiliary contacts to the relay digital inputs.
4. Allocate the digital outputs from the relay to the terminals.

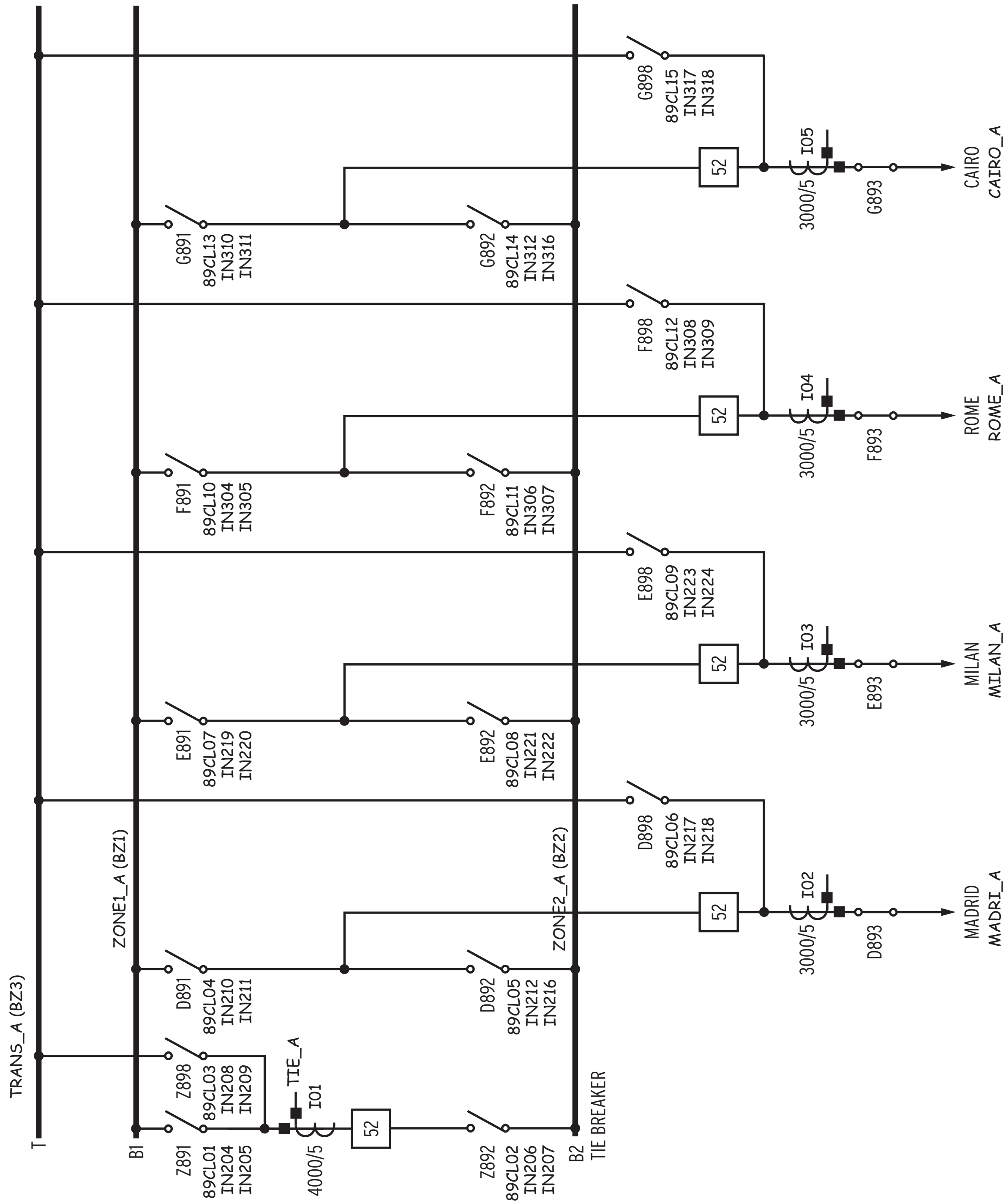


Figure 1.148 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. We set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings

➤ Protection Group Settings

➤ Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias settings class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.149*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.149 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.150*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.150 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the settings list.

Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.151*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TIE_A <Enter>
20:
?  I02,MADRI_A <Enter>
21:
?  I03, MILAN_A <Enter>
22:
?  I04, ROME_A <Enter>
23:
?  I05, CAIRO_A <Enter>
24:
?  BZ1,ZONE1_A <Enter>
25:
?  BZ2,ZONE2_A <Enter>
26:
?  BZ3,TRANS_A <Enter>
```

```
27:
?  END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.151 Analog Quantities and Relay Word Bit Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.152* shows the settings changes we need for our example. Because we declared the alias names in the previous settings class, use either the alias names or the primitive names when entering settings.

Set NUMBK to 5 because there are five circuit breakers at the station. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting.

Declare here the input for the breaker status logic (52A01) for current channel I01 (52A01:= IN213). Set the remaining four circuit breaker auxiliary input equations (52A02–52A05) to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 15 disconnect logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–15). Travel time is the period during which both disconnect auxiliary contacts are in the open position. Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                        NUMBK   := 5     ?<Enter>
Number of Disconnects (N,1-48)                     NUMDS   := N     ?15 <Enter>
Nominal System Frequency (50,60 Hz)                NFREQ   := 60    ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                   EDCMON  := N     ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                    GINPU   := 0.17  ?> <Enter>

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
```

```
Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  IN213 <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
? <Enter>
N/O Contact Input -BK03 (SELogic Equation)
52A03 := NA
?  > <Enter>

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)            89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)            89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)            89ALP03 := 300    ?400 <Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)            89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.152 Global Settings

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism for automatically reconfiguring the zone of protection, without any wiring changes (see *Dynamic Zone Selection Logic on page R.1.15* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements.

For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay. Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the Milan feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- Transfer busbar: the busbar to which the terminal on transfer is connected
- Transfer disconnect: the disconnect that connects the feeder to the transfer busbar (Disconnect G898 on the CAIRO Feeder)

Although the relay is flexible enough to accept settings for many possible disconnect combinations, we will configure the relay according to the following operating conditions:

1. Only one terminal will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z898) and the transfer disconnect (*n*898, *n* = D, E, F, G) of only one of the four terminals can be closed simultaneously.
2. Only Busbar B2 can be the source busbar.
3. The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step. *Table 1.108* shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Refer to *Figure 1.155* and consider a case in which we put the CAIRO Feeder on transfer. Assume that the tie breaker is closed and that tie-breaker disconnect Z891 and disconnect Z892 are closed.

Table 1.108 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Switch all terminals to the source busbar (B2).	Close all the disconnects that connect the terminals to ZONE2_A (D892, E892, etc.)
2	Open the tie-breaker circuit breaker. Open Disconnect Z891, and close Disconnect Z898.	Closing Disconnects Z891 and Z898 forms the path from source busbar to transfer busbar (Busbar B2 to Busbar T).
3	Close the tie-breaker circuit breaker.	Busbar B2 and Busbar T are at the same potential.
4	Close the transfer disconnect of the terminal going on transfer (G898).	The relay now forms a differential zone for the transfer busbar.
5	Open the circuit breaker of the terminal going on transfer (Cairo circuit breaker).	Terminal G is now on transfer. Operation of disconnect G893 does not affect the busbar protection, and is not mentioned.

The zone configuration default settings are settings for a specific substation with arbitrarily selected alias names serving only as an example.

We use a combination of the zone supervision and coupler security logic to prevent tripping Busbar 2 for a fault between the tie-breaker circuit breaker and CT. For the zone supervision setting, we supervise the BZ2 differential element output by the negated coupler security output (ZS2 := NOT CSL1) see the *Protection Group Settings on page A.1.209* for more information.

For ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 1.153* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000    ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600     ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600     ? <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600     ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE_A, ZONE1_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,ZONE2_A,P <Enter>
TIE_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?  (89CL01 OR 89CL03) AND 89CL02 AND (CB52A1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,ZONE1_A,N <Enter>
TIE_A to ZONE1_A Connection (SELogic Equation)
I01BZ1V := NA
?  89CL01 AND 89CL02 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,TRANS_A,N <Enter>
TIE_A to TRANS_A Connection (SELogic Equation)
I01BZ3V := NA
?  89CL03 AND 89CL02 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?  89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I02BZ2V := NA
?  89CL05 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,TRANS_A,P <Enter>
MADRI_A to TRANS_A Connection (SELogic Equation)
I02BZ3V := NA
?  89CL06 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?  89CL07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?  89CL08 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,TRANS_A,P <Enter>
MILAN_A to TRANS_A Connection (SELogic Equation)
I03BZ3V := NA
?  89CL09 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
```

```
?  89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
I04BZ2V := NA
?  89CL11 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,TRANS_A,P <Enter>
ROME_A to TRANS_A Connection (SELogic Equation)
I04BZ3V := NA
?  89CL12 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
I05BZ1V := NA
?  89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
I05BZ2V := NA
?  89CL14 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,TRANS_A,P <Enter>
CAIRO_A to TRANS_A Connection (SELogic Equation)
I05BZ3V := NA
?  89CL15 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?  ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?  (89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?  BZ1BZ2V <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?  I01 <Enter>
Trip Terminals TIE_A (Y,N)
BZ1BZ2T := N
?  Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>
Zone Supervision
Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?<Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  NOT CSL1 <Enter>
Zone 3 Supervision (SELogic Equation)
Z3S := 1
?  <Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.153 Zone Configuration Group Settings

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the sensitive differential element, the restrained differential element and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13*). Because we do not use the terminal out of service, overcurrent elements, or voltage elements in this application, set ETOS := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N.

Because the relay associates breaker failure protection with each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, and also five current channels (tie breaker has one CT channel). Therefore, select 5 as the number of breaker failure logics for this application. Setting NUMBK equal to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. Be sure to include the Differential Trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the {TARGET RESET} pushbutton on the front panel. An alternative way is to enter specific reset conditions at the ULTR*kk* settings.

Each of the five analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 1.105*) when the breaker failure element asserts.

Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

We use a combination of the zone supervision and coupler security logics to prevent tripping Busbar 2 for faults between the tie-breaker circuit breaker and the CT.

Figure 1.154 shows the combination of the coupler security logic and the zone supervision, with the input settings applied. Notice that Gate 1 and Gate 2 represent the tie-breaker terminal-to-bus-zone connection settings; they are not part of the logic.

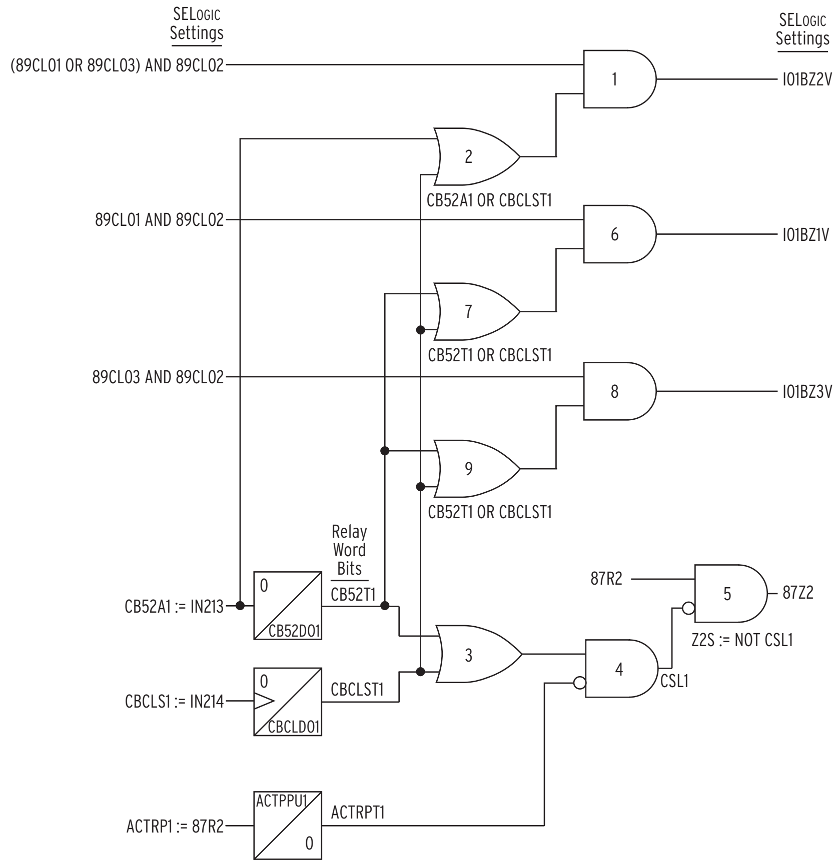


Figure 1.154 Combination of the Coupler Security Logic and the Zone Supervision to Prevent the Loss of Two Zones

Assume for this application that the maximum circuit breaker tripping time is 2 cycles and that the maximum closing time is 3 cycles. Refer to *Figure 1.154*, and notice that Inputs CB52A1 and CBCLS1 provide the circuit breaker status and the closing signal information to the relay. These two inputs are in parallel, complementing each other to provide accurate circuit breaker status during open-to-close and close-to-open circuit breaker operations.

When the operator issues a closing signal to the circuit breaker, Input CBCLS1 asserts, asserting Relay Word bit CBCLST1. We used CBCLST1 in the I01BZ1V, I01BZ2V, and I01BZ3V terminal-to-bus-zone settings. When Relay Word bits I01BZ1V, I01BZ2V, and I01BZ3V assert, the relay considers the CT in the differential calculations.

Set the timer dropout time (CBCLDO1) to a value longer than the maximum breaker closing time. In this example, allow a short safety margin and set CBCLDO1 to 5 cycles (default value).

Inserting the CTs in the differential equations before primary current flows emulates the early make, late break timing requirement for the disconnect auxiliary contacts. A setting of 5 cycles allows the circuit breaker ample time to change state, during which time the CB52A1 Relay Word bit asserts.

When opening the circuit breaker, the inverse applies. For a close-to-open circuit breaker operation, we must guard against prematurely removing the CTs from the differential equations due to circuit breaker auxiliary contact misalignment. We use CB52T1 in the tie-breaker terminal-to-bus-zone connection settings to accomplish this for Zone 1 and Zone 3. However, because we supervise all Zone 2 faults, premature removal of the CTs does not adversely affect Zone 2 differential elements.

Two tie-breaker operating conditions are possible: when the tie breaker connects between Busbar B1 and Busbar B2 (Disconnect Z891 and Disconnect Z892 are closed) or when the tie breaker connects between Busbar B2 and the Transfer busbar (Disconnect Z892 and Disconnect Z898 are closed).

The following discussion describes the prevention of the loss of Busbar 2 when the tie breaker connects between Busbar B1 and Busbar B2, but the same argument applies when a feeder is on transfer.

Figure 1.155 shows Busbar B1, Busbar B2, the tie breaker, and two of the four terminals at the station. The challenge to the coupler security logic is to trip Busbar B1 and not Busbar B2 for Fault F1. This requirement contradicts the existing configuration, for it calls for the coupler security logic to prevent the differential element of Busbar B2 from operating for an in-zone fault (fault on Busbar 2), and for the differential element of Busbar B1 to operate for an out-of-zone fault (fault on Busbar 2).

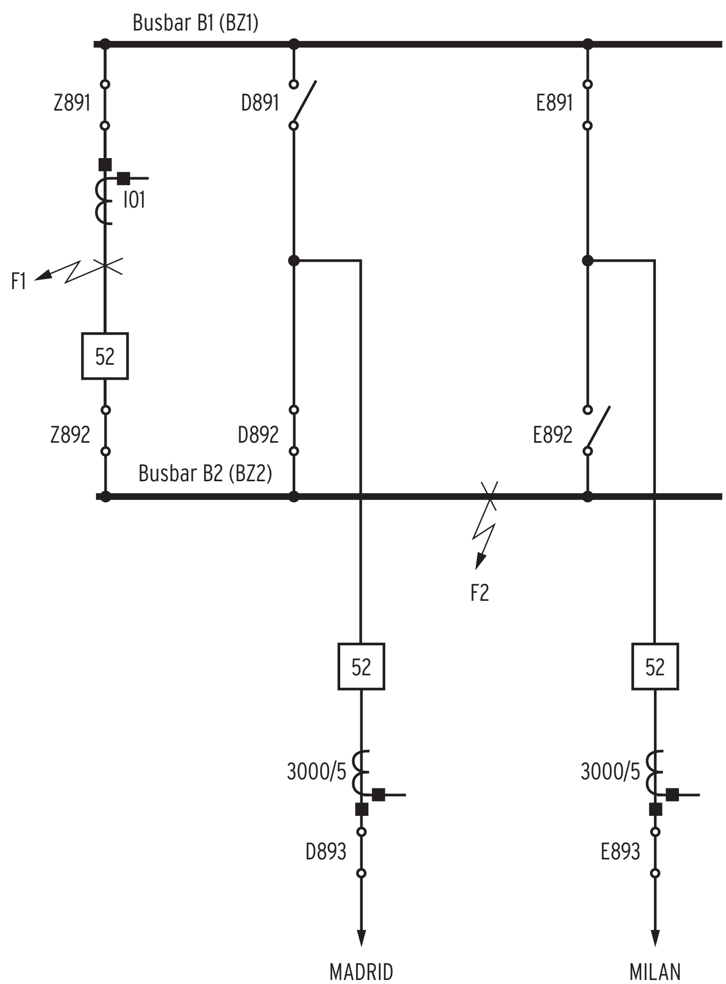


Figure 1.155 Single CT Application With Faults Between the Circuit Breaker and Tie-Breaker CT

Consider the operation when Fault F1 occurs without the coupler security logic. Differential protection B1 is stable, and differential protection B2 immediately trips the MADRID circuit breaker and the tie-breaker circuit breaker. However, tripping the MADRID circuit breaker and the tie-breaker circuit breaker does not clear Fault F1. Fault current still flows from the MILAN Feeder through Busbar B1 and into the fault. Although breaker failure protection will operate to trip the MILAN circuit breaker, this operation takes place after the breaker failure time delay. After the tie-breaker breaker failure timer times out, all circuit breakers in B1 trip, resulting in both B1 and B2 tripping to clear Fault F1.

If a delay in bus-zone protection operation is in order, implement the coupler security logic in a way that trips bus-zone B2 only when the tie-breaker circuit breaker is open. To prevent tripping of bus-zone B2, configure the relay to achieve the following:

1. Check if the tie breaker is closed. If the tie breaker is closed, trip only the tie breaker to interrupt the fault current from B2; trip no other circuit breakers. If the tie breaker is open, allow normal busbar protection tripping.
2. When the tie breaker is open, remove the tie-breaker CT from the differential calculations of B2 and eventually B1.

To check the tie-breaker status and remove the CT from the supervised zone when the tie breaker is open, use the tie-breaker auxiliary contact in the tie-breaker terminal-to-bus-zone connection settings. To remove the CT from the unsupervised zone, use the coupler status timed-out bit (CB52T1) in the tie-breaker terminal-to-bus-zone connection settings. To trip only the tie breaker for a fault on Busbar 2 requires the following two settings:

➤ Supervising the BZ2 differential element
➤ Issuing a trip signal to the tie breaker first

Supervise the BZ2 differential element output with the negated output from the coupler security logic (Z2S := NOT CSL1). We assign 87R2, the unsupervised output from the BZ2 differential element, to ACTRP1, the accelerated trip input of the coupler security logic. When accelerated trip timer output (ACTRPT1) asserts, Gate 4 in *Figure 1.154* turns off and Relay Word bit CSL1 deasserts. When Relay Word bit CSL1 deasserts, Relay Word bit Z2S asserts, removing the supervision from the BZ2 differential element.

Supervising the BZ2 differential element in this way prevents the tripping of all terminals in BZ2, including the tie breaker. To still trip the tie breaker, include 87R2, the unsupervised output from Differential Element 2, in the trip equation of the tie breaker.

After the tie breaker opens, we remove the tie-breaker CT from the differential calculations of BZ2 but not the BZ2 supervision. Maintain the BZ2 supervision for at least another 1.25 cycles (add a safety margin of 0.75 cycle) to allow the differential element to reset. Achieve this delay by setting ACTPPU1 to at least 4 cycles.

For Fault F1, BZ2 operates, asserting Relay Word bit 87R2. When Relay Word bit 87R2 asserts, the accelerated trip timer starts timing. Because of the BZ2 zone supervision (NOT CSL1), 87Z2 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie breaker trips, interrupting the fault current contribution from BZ2. Assume the circuit breaker auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ2V and eventually I01BZ1V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. For Fault F1, the bus coupler circuit breaker is open, but fault current still flows through the CT. BZ2 is stable when the relay removes the CTs because the bus coupler circuit breaker is open, and terminals from BZ2 no longer contribute to the fault. However, removing the CTs causes BZ1 to operate because the BZ1 balancing current from the bus coupler CT disappeared. Removing the bus sectionalizer CTs also deasserts Relay Word bit 87R2, causing the accelerated trip timer to stop timing. Fault F1 is now cleared, by tripping the correct busbar, although after a time delay.

For Fault F2, the initial tripping is the same as for Fault F1: BZ2 operates, asserting Relay Word bit 87R2. When Relay Word bit 87R2 asserts, the accelerated trip timer starts timing. Because of the BZ2 zone supervision (NOT CSL1), 87Z2 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie breaker trips, and the auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ2V and eventually I01BZ1V to also deassert. When Relay Word bits I01BZ2V and I01BZ1V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. Because the bus coupler circuit breaker is open, terminals from BZ1 no longer contribute to the fault and BZ1 is stable. However, the BZ2 zone supervision (NOT CSL1) still supervises the BZ2 trip output for another two cycles. Two cycles later, Accelerate Trip Timer ACTRP1 times out, causing CSL1 to deassert. When Relay Word bit CSL1 deasserts, Relay Word bit Z2S asserts, removing the zone supervision from BZ2 and issuing a trip signal to all circuit breakers on Busbar 2.

Although each SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 1.156* shows the Group 1 settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y       ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N       ?1 <Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5       ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6       ?5 <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N       ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N       ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y       ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N       ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>

Coupler 1 Security Logic

Coupler 1 Status (SELogic Equation)
CB52A1 := NA
?  IN213 <Enter>
Coupler 1 Status Dropout Delay (0.00-1000 cyc)       CB52DO1 := 4.00    ?<Enter>
Coupler 1 Close Command (SELogic Equation)
CBCLS1 := NA
?  IN214 <Enter>

Coupler 1 Close Command D/O Delay (0.00-1000 cyc)    CBCLDO1 := 5.00    ?<Enter>
```

```
Coupler 1 Acc Trip (SELogic Equation)
ACTRP1 := NA
?  87R2 <Enter>
Coupler 1 Acc Trip Pickup Delay (0.00-1000 cyc)      ACTPPU1 := 4.00   ?<Enter>

Breaker 01 Failure Logic

External Breaker Fail -BK01 (Y,N)                    EXBF01  := N      ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>

Breaker 02 Failure Logic

External Breaker Fail -BK02 (Y,N)                    EXBF02  := N      ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN202 <Enter>

Breaker 03 Failure Logic

External Breaker Fail -BK03 (Y,N)                    EXBF03  := N      ?Y <Enter>
External Brkr Fail Init -BK03 (SELogic Equation)
XBF03 := NA
?  IN203 <Enter>

Breaker 04 Failure Logic

External Breaker Fail -BK04 (Y,N)                    EXBF04  := N      ?Y <Enter>
External Brkr Fail Init -BK04 (SELogic Equation)
XBF04 := NA
?  IN301<Enter>

External Breaker Fail -BK05 (Y,N)                    EXBF05  := N      ?Y <Enter>
External Brkr Fail Init -BK05 (SELogic Equation)
XBF05 := NA
?  IN302 <Enter>
Brkr Fail Init Dropout Delay -BK05 (0.00-1000 cyc)   BFIDO05 := 1.50   ?<Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR 87R2 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.

Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?<Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.156 Protection Group Settings for Application 7

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101 through OUT106 = NA. *Figure 1.157* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?  NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?  NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?  NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?  NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?  NA <Enter>

OUT106 := NA
?  > <Enter>
Interface Board #1

OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?  TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?  END <Enter>
Output
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.157 Control Output Settings for Application 7

This concludes the settings for Application 7.

Application 8: Double and Transfer Bus (Inboard CTs)

This application describes the busbar arrangement shown in *Figure 1.158*. The busbar arrangement consists of three busbars, four terminals, and a tie breaker. Use the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection function selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation
- ➤ Station layout update
- ➤ Relay setting and configuration

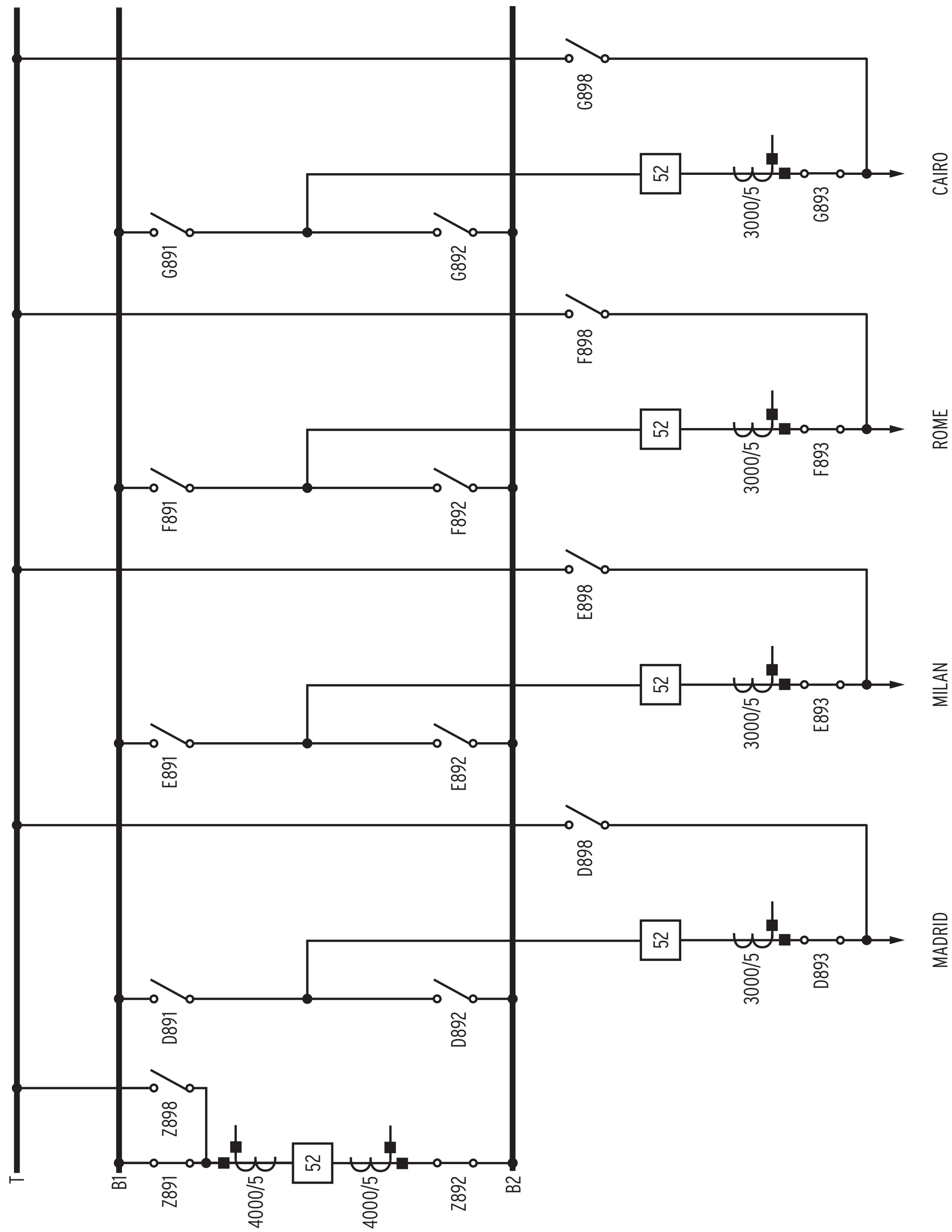


Figure 1.158 Double Bus and Transfer Bus With Buscoupler (Tie Breaker) and Inboard CTs

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and it declares the tie-breaker (buscoupler) configuration.

- Description:
  - Double bus with transfer busbar
- Current transformers:
  - Bushing (inboard)

- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Two CTs, configured in overlap
- Future expansion:
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every application uses all these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the station.
4. Use the disconnect monitor logic.
5. Ensure stable differential protection for all operating conditions.

Protection Functions Selection

We select protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. The SEL-487B offers a number of protection functions as standard features, but it also offers the capability through SELOGIC control equations for you to create user-configurable functions. Requirement 5 of the protection philosophy calls for stable differential protection for all operating conditions. There are two network conditions when the differential protection can become unstable:

- when disconnects *n*891 and *n*892 (*n* = D, E, F, G) of any feeder are closed at the same time
- when the transfer disconnect of any feeder is closed

By following the correct operating sequence, and by declaring the appropriate conditions in the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable for all operating conditions.

Standard Functions

Refer to the *Protection Philosophy* and select the standard functions necessary for the application. *Table 1.109* shows the selection of standard functions.

Table 1.109 Selection of the Standard Protection Functions

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	Use the sensitive differential element as CT open-circuit detection.
Zone supervision logic	No	Not required. We achieve relay stability with terminal-to-bus-zone and bus-zone-to-bus-zone connection settings.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	No	Two CTs configured in overlap do not require the coupler security logic.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need that is not part of the standard relay logic in the relay. In this application, we comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- ➤ the number of relays (single-relay application or three-relay application)
- ➤ the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with up to 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.28* to calculate the number of current channels at the station, and use *Equation 1.29* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.28**

# of bus-zones required = # of per-phase station bus sections **Equation 1.29**

The number of per-phase CTs at the station is 18 (tie breaker has six CT cores), so one SEL-487B suffices. However, the requirement for four future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need three relays. This is known as a three-relay application. In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, all the B-phase CTs to Relay 2, and all the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, the tie breaker and each of the 4 feeders require 3 disconnect monitoring logics; the number of disconnect logics required is therefore 15. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.30* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

relay inputs required = 2 • # disconnect monitoring logics **Equation 1.30**

Table 1.110 summarizes the input contact required for this application.

Table 1.110 Relay Input Contacts Requirement

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 15 = 30
Total number of inputs	30

The relay main board has seven inputs, an insufficient number of inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs, and use the six independent inputs for future breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.111* shows the breakdown and the number of relay output contacts necessary for tripping.

Table 1.111 Breakdown and Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board output contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- the selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- assign each CT input to a specific relay analog channel
- assign each disconnect input to specific relay inputs
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog Quantity
- Terminal Name
- Bus-Zone Name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.112* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.112* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.158*.

Table 1.112 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. Although there are three busbars at the station, we only provide differential protection for Busbar B1 and Busbar B2. Because the feeders have bushing CTs, the transfer busbar never forms part of the busbar protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.113*.

Table 1.113 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input-to-Logic Allocation

Table 1.110 shows that we require 30 digital inputs. We now assign the digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input-to-Logic Allocation, Interface Board 1 (200)

Table 1.114 and *Table 1.115* show the disconnect auxiliary contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we preserve these for future circuit breaker failure inputs.

Table 1.114 Disconnect Contact Input Allocations

Input	Description
IN204	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN208	TIE-BREAKER disconnect (TRANS_A) NO contact
IN209	TIE-BREAKER disconnect (TRANS_A) NC contact
IN210	MADRID terminal disconnect (ZONE1_A) NO contact
IN211	MADRID terminal disconnect (ZONE1_A) NC contact
IN212	MADRID terminal disconnect (ZONE2_A) NO contact
IN216	MADRID terminal disconnect (ZONE2_A) NC contact
IN217	MADRID terminal disconnect (TRANS_A) NO contact
IN218	MADRID terminal disconnect (TRANS_A) NC contact
IN219	MILAN terminal disconnect (ZONE1_A) NO contact
IN220	MILAN terminal disconnect (ZONE1_A) NC contact
IN221	MILAN terminal disconnect (ZONE2_A) NO contact
IN222	MILAN terminal disconnect (ZONE2_A) NC contact
IN223	MILAN terminal disconnect (TRANS_A) NO contact
IN224	MILAN terminal disconnect (TRANS_A) NC contact

Input-to-Logic Allocation, Interface Board 2 (300)

Table 1.115 shows the disconnect and auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we preserve these inputs for future circuit breaker failure inputs.

Table 1.115 Disconnect Contact Input Allocations

Input	Description
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

The following discussion references *Table 1.109* in explaining each selected function.

Disconnect Monitoring Logic

Figure 1.159 shows the disconnect monitor logic circuit available in the relay. See *Figure 1.20* for more information.

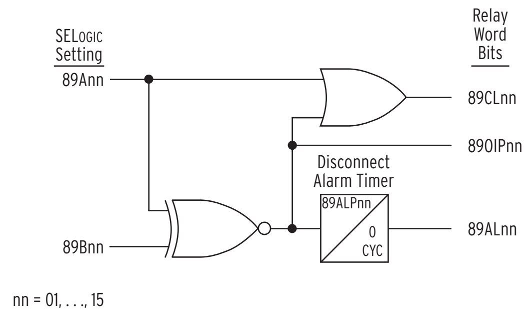


Figure 1.159 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.116 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 1.116 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO
89B02	TIE-BREAKER disconnect (ZONE2_A) NC
89A03	TIE-BREAKER disconnect (TRANS_A) NO
89B03	TIE-BREAKER disconnect (TRANS _A) NC
89A04	MADRI_A disconnect (ZONE1_A) NO contact
89B04	MADRI_A disconnect (ZONE1_A) NC contact
89A05	MADRI_A disconnect (ZONE2_A) NO contact
89B05	MADRI_A disconnect (ZONE2_A) NC contact
89A06	MADRI_A disconnect (TRANS_A) NO contact
89B06	MADRI_A disconnect (TRANS_A) NC contact
89A07	MILAN_A disconnect (ZONE1_A) NO contact
89B07	MILAN _A disconnect (ZONE1_A) NC contact
89A08	MILAN _A disconnect (ZONE2_A) NO contact
89B08	MILAN _A disconnect (ZONE2_A) NC contact
89A09	MILAN _A disconnect (TRANS_A) NO contact
89B09	MILAN _A disconnect (TRANS_A) NC contact
89A10	ROME_A disconnect (ZONE1_A) NO contact
89B10	ROME _A disconnect (ZONE1_A) NC contact
89A11	ROME _A disconnect (ZONE2_A) NO contact
89B11	ROME _A disconnect (ZONE2_A) NC contact

Table 1.116 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89A12	ROME _A disconnect (TRANS_A) NO contact
89B12	ROME _A disconnect (TRANS_A) NC contact
89A13	CAIRO _A disconnect (ZONE1_A) NO contact
89B13	CAIRO _A disconnect (ZONE1_A) NC contact
89A14	CAIRO _A disconnect (ZONE2_A) NO contact
89B14	CAIRO _A disconnect (ZONE2_A) NC contact
89A15	CAIRO _A disconnect (TRANS_A) NO contact
89B15	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 1.160 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.117* shows Relay Word bits and description for the zone differential protection outputs. Because of the bushing (inboard) CTs, we cannot provide differential protection for the transfer busbar.

Table 1.117 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

Figure 1.160 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see Global settings for more information). *Table 1.118* shows the differential trip bit names and the associated terminal current channels.

Table 1.118 Differential Trip Bit Names and Associated Terminal Names

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 1.111 shows the relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.119* shows TEST and ALARM protection logic output assignment to the main board output contacts. *Table 1.120* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 1.119 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.120* shows the assignment of the A-phase relay output terminals.

Table 1.120 Assignment of the Output Terminals

Output Contact Assignment	Description
OUT201[a]	TIE-BREAKER trip logic output
OUT202[a]	MADRID trip logic output
OUT203[a]	MILAN trip logic output
OUT204[a]	ROME trip logic output
OUT205[a]	CAIRO trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 1.161*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.

4. Allocate the terminal auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

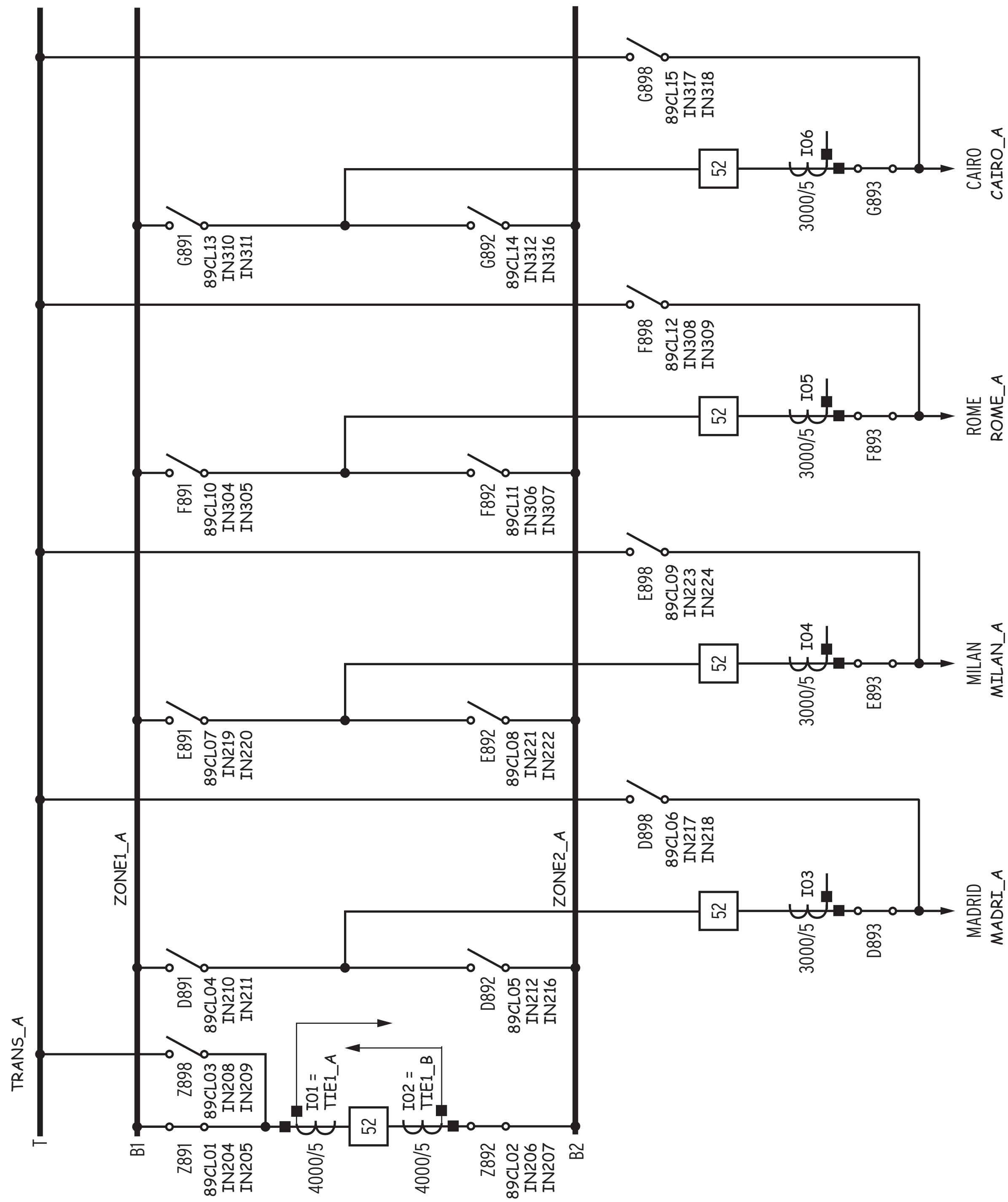


Figure 1.161 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following setting classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.162*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.162 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.163*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.163 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list.

Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.164*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TIE1_A <Enter>
20:
?  I02,TIE2_A <Enter>
21:
?  I03,MADRI_A <Enter>
22:
?  I04,MILAN_A <Enter>
23:
?  I05,ROME_A <Enter>
24:
?  I06,CAIRO_A <Enter>
25:
?  BZ1,ZONE1_A <Enter>
26:
?  BZ2,ZONE2_A <Enter>
27:
?  END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.164 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.165* shows the setting changes we need for our example. Because we declared the alias names in the alias setting class, use either the alias names or the primitive names when entering settings.

The NUMBK setting declares the number of circuit breakers at the station. In our example, there are five circuit breakers at the station, and we set NUMBK to 5. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting.

In this application, we do no require circuit breaker auxiliary contacts, therefore set all circuit breaker auxiliary input equations to NA.

The NUMDS setting declares the number of disconnect monitor logics we need, not the number of disconnect inputs. In our example, we need 15 disconnect monitor logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–15). Travel time is the period during which both disconnect auxiliary contacts are in the open position. Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                          NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-48)                       NUMDS   := N      ?15 <Enter>
Nominal System Frequency (50,60 Hz)                  NFREQ   := 60     ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                     EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                      GINPU   := 0.17   ?> <Enter>

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)                89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)                89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)                89ALP03 := 300    ?<Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)                89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.165 Global Settings for Application 8

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism for automatically reconfiguring the zone of protection, without any wiring changes. In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements.

For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay. Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays.

Because we wire a disconnect auxiliary contact to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the MILAN feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- ➤ Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- ➤ Transfer busbar: the busbar to which the terminal on transfer is connected
- ➤ Transfer disconnect: the disconnect, when closed, bypasses the feeder circuit breaker (e.g., Disconnect G898 on the CAIRO Feeder)

Although the relay is flexible enough to accept settings for many disconnect combinations, we will configure the relay according to a fixed operating sequence. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone settings for each step. The following defines the operating sequence for this application; many other operating sequences are possible and in use:

1. Only one feeder will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z898) and the transfer disconnect (*n*898, *n* = D, E, F and G) of only one of the four terminals can be closed simultaneously.
2. Only Busbar B2 can be the source busbar.
3. No busbar protection exists for the transfer busbar. The transfer busbar is always part of the line protection. This is the key statement from the setting viewpoint. By declaring appropriate terminal-to-bus-zone connection conditions, we can prevent relay misoperation when putting a feeder on transfer. In particular, we do not assign a differential element for the transfer busbar. Remove channel I02 from Busbar B1 differential calculations when any transfer disconnect closes.

The zone configuration default setting are settings for a specific substation with arbitrarily selected alias names, serving only as an example.

For ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone settings. *Figure 1.166* shows the Zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?800 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE1_A, ZONE1_A, P
?   DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I01,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?   89CL02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I02,ZONE1_A,P <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?   89CL02 AND 89CL01 AND NOT(89CL03 OR 89CL06 OR 89CL09 OR 89CL12 OR 89CL15) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?   89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?   89CL05 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
?   89CL07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
I04BZ2V := NA
?   89CL08 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
I05BZ1V := NA
?   89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
I05BZ2V := NA
?   89CL11 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
I06BZ1V := NA
?   89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
I06BZ2V := NA
?   89CL14 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>
Zone Configuration: Bus-Zone to Bus-Zone Connections
```

```
Bus-Zone, Bus-Zone
?  ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?  (89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?  (89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?  TIE1_A,TIE2_A <Enter>
Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?  Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?<Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.166 Zone Configuration Group Settings for Application 8

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the sensitive differential element, the restrained differential element, and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information).

Because we do not use the coupler security logic, overcurrent elements, terminal out of service, breaker failure protection, or voltage elements in this application, set ESCL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N.

Setting NUMBK equal to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. There are five trip equations available, but there are six analog channels (I01–I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 1.118*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Although each SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 1.167* shows the Group 1 settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6      ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N      ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  87BTR01 OR 87BTR02 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  87BTR03 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  87BTR04 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
Trip 04 (SELogic Equation)
TR04 := SBFTR04 OR 87BTR04
?  87BTR05 <Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  87BTR06 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?<Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.167 Protection Group Settings for Application 8

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relay in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 1.168* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?   NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?   NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?   NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?   NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?   TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?   TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?   TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?   TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.168 Control Output Settings for Application 8

This concludes the settings for Application 8.

Section 2
Monitoring and Metering

Overview

The SEL-487B Relay provides extensive capabilities for monitoring substation components and metering important power system parameters. The relay provides the following useful features:

- Station dc battery system monitor
- Metering
  - Instantaneous primary and secondary current metering
  - Instantaneous primary and secondary voltage metering
  - Differential currents
  - Protection math variables
  - Automation math variables
  - Analog values used with MIRRORED BITS® communications
  - Station battery values

This section explains each of these features and gives practical examples for applying the dc battery monitor and using the **METER** command.

Station DC Battery System Monitor

The SEL-487B automatically monitors station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. Each relay provides one dc monitor channel, Vdc1. With the four voltage thresholds, you can create five sensing zones (low failure, low warning, normal, high warning, and high failure) for the dc voltage.

The ac ripple quantity indicates battery charger health. When configuring the ac ripple setting, DC1RP, you can define the ripple content of a dc supply as the peak-to-peak ac component of the output supply waveform.

The relay also provides measurements between the battery terminal voltages and station ground to detect positive and negative dc ground faults. *Figure 2.1* shows a typical dual-battery dc system.

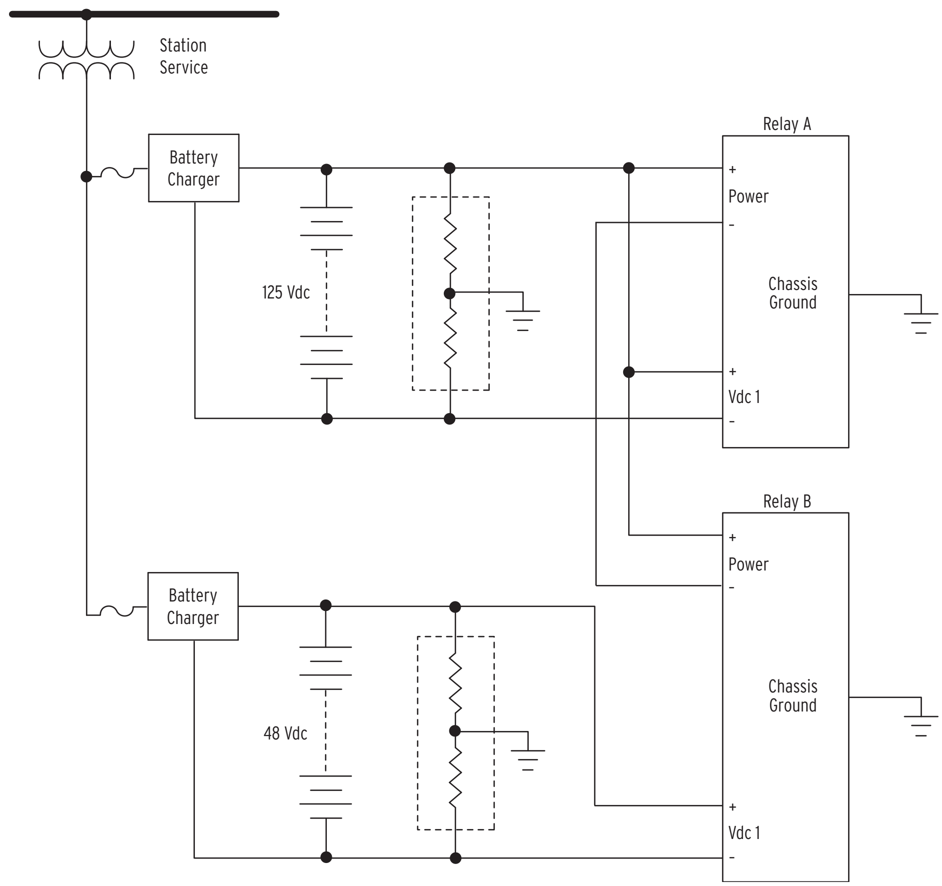


Figure 2.1 Typical Station DC Battery System

The dc battery monitor measures the station battery voltage applied at the rear-panel terminals labeled **Vdc1** (**+** and **–**). In a three-relay application, connect the 125 Vdc supply to the monitoring connections of the first relay, and the 48 Vdc supply to the monitoring connections of the second relay. See *Section 1: Protection Applications Examples in the Application Handbook* for more information about single- and three-relay applications.

NOTE: First enable Station DC Monitoring (with the Global setting EDCMON) to access station dc battery monitor settings.

Table 2.1 lists the station dc battery monitor settings and the corresponding Relay Word bits that assert when battery quantities exceed these settings thresholds. Use the **SET G** ASCII command from a terminal or use the ACSELERATOR QuickSet® SEL-5030 software **Global > Station DC Monitoring** branch of the Settings tree view to access the DC Monitor settings.

Table 2.1 DC Monitor Settings[a] and Relay Word Bit Alarms

Setting	Definition	Relay Word Bit
DC1LFP	Low-Level Fail Pickup (OFF, 15–300 Vdc)	DC1F
DC1LWP	Low-Level Warn Pickup (OFF, 15–300 Vdc)	DC1W
DC1HWP	High-Level Warn Pickup (OFF, 15–300 Vdc)	DC1W
DC1HFP	High-Level Fail Pickup (OFF, 15–300 Vdc)	DC1F
DC1RP	Peak-to-Peak AC Ripple Pickup (1–300 Vac)	DC1R
DC1GF	Ground Detection Factor (1.00–2.00) (advanced setting)	DC1G

[a] Minimum setting step size is 1 V for voltage settings.

Station DC Battery System Monitor Application

The dc monitor alarms for undervoltage or overvoltage dc battery conditions in five sensing regions. The following describes how to apply the dc battery monitor to a typical 125 Vdc protection battery system connected to one SEL-487B (Relay A in *Figure 2.1*) and a 48 Vdc communication equipment battery system connected to another SEL-487B (Relay B in *Figure 2.1*) in a three-relay application. Adjust the values used here to meet the specifications of your company.

Battery Voltage

When setting the station dc battery monitor, determine the minimum and maximum dc levels in the battery system. In addition, establish the threshold levels for different battery system states or conditions. The following voltage levels describe these battery system conditions:

- ➤ Trip/Close—the lowest dc voltage point that circuit breaker trip and close operations occur
- ➤ Open-circuit—the dc battery voltage when all cells are fully charged and disconnected from the battery charger or load
- ➤ Float low—the lowest charging voltage supplied by the battery charger
- ➤ Float high—the highest charging voltage supplied by the battery charger
- ➤ Equalize mode—a procedure where the batteries are overcharged intentionally for a preselected time in order to bring all cells to a uniform output

Set the low end of the allowable dc battery system voltage according to the recommendations of C37.90-1989 (R1994) IEEE® Standard for Relays and Relay Systems Associated with Electric Power. Section 6.4 in this standard is titled “Allowable Variation from Rated Voltage for Voltage Operated Auxiliary Relays.” This section calls for an 80 percent low-end voltage and 28, 56, 140, or 280 Vdc high-end voltages for the popular nominal station battery voltages. *Table 2.2* lists expected battery voltages under various conditions using commonly accepted per-cell voltages.

Table 2.2 Example DC Battery Voltage Conditions (Sheet 1 of 2)

Condition	Calculation	Battery Voltage (Vdc)
Trip/Close	80% • 125 Vdc	100.0
Open-Circuit	60 (cells) • 2.06 (volts/cell)	123.6
Float Low	60 (cells) • 2.15 (volts/cell)	129.0
Float High	60 (cells) • 2.23 (volts/cell)	133.8
Equalize Mode	60 (cells) • 2.33 (volts/cell)	139.8
Trip/Close	80% • 48 Vdc	38.4
Open Circuit	24 (cells) • 2.06 (volts/cell)	49.4
Float Low	24 (cells) • 2.15 (volts/cell)	51.6
Float High	24 (cells) • 2.23 (volts/cell)	53.5
Equalize Mode	24 (cells) • 2.33 (volts/cell)	55.9

Table 2.2 Example DC Battery Voltage Conditions (Sheet 2 of 2)

Condition	Calculation	Battery Voltage (Vdc)
Trip/Close	80% • 24 Vdc	19.2
Open Circuit	12 (cells) • 2.06 (volts/cell)	24.7
Float Low	12 (cells) • 2.15 (volts/cell)	25.8
Float High	12 (cells) • 2.23 (volts/cell)	26.8
Equalize Mode	12 (cells) • 2.33 (volts/cell)	28.0

Use the expected battery voltages in *Table 2.2* to determine the SEL-487B station dc battery monitor threshold settings. *Table 2.3* shows these threshold settings in Relay A for a nominal 125 Vdc battery system, and *Table 2.4* shows the settings in Relay B for a nominal 48 Vdc battery system.

Table 2.3 Example DC Battery Monitor Settings—125 Vdc for Relay A

Setting	Description	Indication	Value (Vdc)
DC1LFP	Low-fail threshold	Poor battery performance	100
DC1LWP	Low-warning threshold	Charger malfunction	127
DC1HWP	High-warning threshold	Equalization	137
DC1HFP	High-fail threshold	Charger malfunction	142

Table 2.4 Example DC Battery Monitor Settings—48 Vdc for Relay B

Setting	Description	Indication	Value (Vdc)
DC1LFP	Low-fail threshold	Poor battery performance	38
DC1LWP	Low-warning threshold	Charger malfunction	50
DC1HWP	High-warning threshold	Equalization	55
DC1HFP	High-fail threshold	Charger malfunction	57

AC Ripple

Another method for determining whether the substation battery charger has failed is to monitor the amount of ac ripple on the station dc battery system. The IEEE C37.90-1989 standard also identifies an "Allowable AC Component in DC Control Voltage Supply" (Section 6.5) as an alternating component (ripple) of 5 percent peak or less. (This definition is valid if the minimum instantaneous battery voltage is not less than 80 percent of the rated voltage.) The SEL-487B measures ac ripple as a peak-to-peak waveform, consequently, DC1RP (Relay A) and DC1RP (Relay B) should be set at or greater than 10 percent (2 • 5% peak) of the equalizing voltage. *Table 2.5* shows the ac ripple threshold settings for this example.

Table 2.5 Example DC Battery Monitor Settings—AC Ripple Voltages

Setting	Description	Indication	Value (Vac)
DC1RP	AC ripple threshold, Relay A	Charger malfunction	14
DC1RP	AC ripple threshold, Relay B	Charger malfunction	6

DC Ground

If a battery system is centered around chassis ground, the magnitude of the voltage measured from the positive terminal to ground and from the negative terminal of the battery to ground should be approximately half of the nominal battery system voltage. The ideal ratio of the positive-to-ground battery voltage to the negative-to-ground battery voltage is 1 to 1, or 1.00. *Equation 2.1* is the balanced ratio for a 125 Vdc battery system.

$$k = \frac{Vdc1_{pos}}{Vdc1_{neg}} = \frac{62.50\ V}{62.50\ V} = 1.00$$

Equation 2.1

If either terminal is partially or completely shorted to chassis ground, the terminal voltage will be less than the nominal terminal-to-ground voltage. This causes the ratio of positive voltage to negative voltage to differ from 1.00. *Equation 2.2* is an example of the unbalanced (grounding) ratio for a partial short circuit to ground on the negative side of a 125 Vdc battery system.

$$k = \frac{Vdc1_{pos}}{Vdc1_{neg}} = \frac{64.30\ V}{60.70\ V} = 1.06$$

Equation 2.2

The SEL-487B uses this voltage ratio to calculate a ground detection factor. *Figure 2.2* shows a graphical representation of the ground detection factor setting and battery system performance.

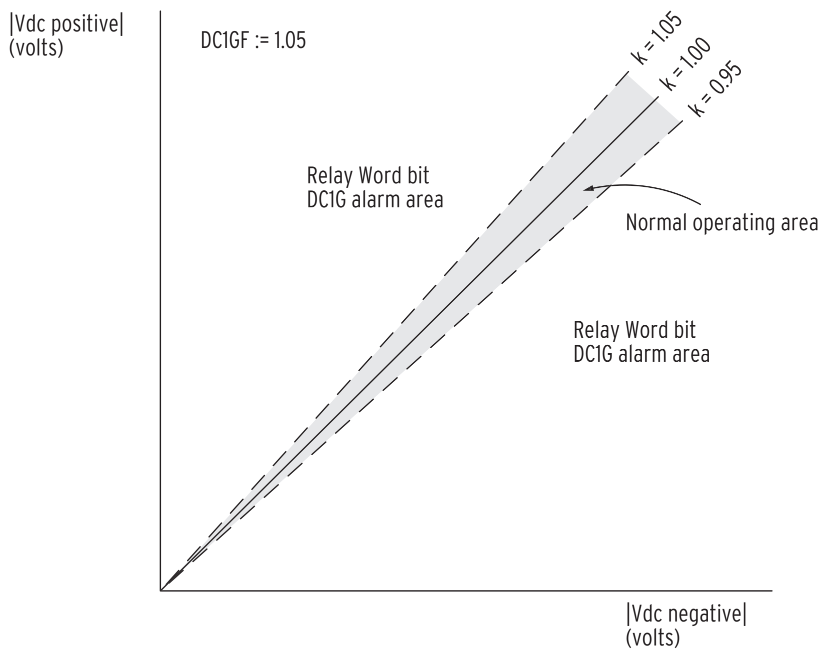


Figure 2.2 Ground Detection Factor Areas

If the ground detection factor ratio exceeds a setting threshold, the relay asserts the DC1G Relay Word bit. To set the ground detection factor threshold, enable the advanced Global settings (EGADVS := Y), and set the DC1GF threshold at a value close to 1.05 (the factory default setting) to allow for some slight battery system unbalance of around 5 percent. *Table 2.6* lists the ground detection factor threshold settings for this example.

Table 2.6 Example DC Battery Monitor Settings-Ground Detection Factor (EGADVS := Y)

Setting	Description	Indication	Value
DC1GF	Ground detection factor	Battery wiring ground(s)	1.05

DC Battery Monitor Alarm

You can use the battery monitor Relay Word bits to alert operators for out-of-tolerance conditions in the battery systems. Add the appropriate Relay Word bit to the SELOGIC® control equation that drives the relay control output you have selected for alarms. For example, use the b contact of control output OUT108. Set the SELOGIC control equation to include the battery monitor thresholds:

OUT108 := **NOT (HALARM OR SALARM OR DC1F OR DC1W OR DC1R OR DC1G)**
Output SELOGIC control equation

This example shows one setting possibility. You can implement many other methods as well. See *Alarm Output on page U.2.33* for more information.

DC Battery Monitor Metering

The SEL-487B monitors battery system voltages and records time stamps for voltage excursions. In addition, the relay records maximum and minimum battery voltages. *Figure 2.3* shows a sample dc battery monitor meter report. Use the **MET BAT** command from a communications terminal to obtain this report. For more information on the **MET** commands, see *METER on page R.7.22*.

```
=>MET BAT <Enter>

Relay 1                                       Date: 03/22/2001  Time: 09:37:10.035
Station A                                     Serial Number: 2001001234

Station Battery        VDC      VDCPO     VDCNE      VAC
   VDC1 (V)            24.17     11.98    -12.19      0.01

             VDC1(V)    Date       Time
Minimum        20.12 03/15/2001  14:28:59.172
Enter L-Zone         03/15/2001  14:28:51.490
Exit L-Zone          03/15/2001  14:29:05.035

Maximum        27.19 03/19/2001  08:34:49.761
Enter H-Zone         03/19/2001  08:34:27.172
Exit H-Zone          03/19/2001  08:37:01.041

LAST DC RESET:  03/15/2001  12:30:30.492

=>
```

Figure 2.3 Battery Metering: Terminal

Any battery voltage between setting DC1LWP and the dc battery monitor low limit of 15 Vdc is in the L-Zone. Any battery voltage between setting DC1HWP and the dc battery monitor high limit of 300 Vdc is in the H-Zone.

Reset DC Battery Monitor Metering

Use the **MET RBM** command from a communications terminal to reset the dc battery monitor. You can program a SELOGIC control equation RST_BAT (in Global settings) to control dc battery monitor reset. Enable data reset control with global setting EDRSTC := Y.

Metering

The SEL-487B provides one-cycle average metering for measuring power system conditions and differential protection values. Each SEL-487B processes 18 currents, 3 voltages, and 1 battery monitor.

Use the **MET** command to access the metering functions. Issuing the **MET** command with no options returns the fundamental frequency primary measurement quantities listed in *Table 2.7*.

Table 2.7 Instantaneous Metering Quantities—Voltages and Currents

Metered Quantity	Symbol	Units
Phase voltage magnitude	V01–V03	kV
Phase voltage angle	∠V01, –∠V03	degrees
Phase current magnitude	I01–I18	A
Phase current angle	∠I01, –∠I18	degrees

The **MET** command followed by a number, **MET *k***, specifies the number of times the command will repeat (*k* can range from 1 to 32767). This is useful for troubleshooting or investigating uncharacteristic power system conditions. With other command options, you can view currents from the terminals.

Table 2.8 shows the **MET** command options, followed by a short description of each option.

Table 2.8 MET Command—Metering Only

Name[a]	Description
MET *k*	Displays fundamental primary phase information *k* times for all terminals
MET *k* **CZ1**	Displays fundamental primary phase information *k* times for all terminals in Check Zone 1
MET *k* **Z***n*	Displays fundamental primary phase information *k* times for all terminals in Zone *n*
MET SEC *k*	Displays fundamental secondary phase information *k* times for all terminals
MET SEC *k* **CZ1**	Displays fundamental secondary phase information *k* times for all terminals in Check Zone 1
MET SEC *k* **Z***n*	Displays fundamental secondary phase information *k* times for all terminals in Zone *n*
MET DIF	Displays per unit operating and restraint currents for all active zones
MET BAT	Displays station battery measurements
MET RBM	Reset station battery max/min measurements
MET ANA	Displays the analog values used with MIRRORED BITS communications
MET PMV	Displays the last 16 Protection Math Variables
MET PMV A	Displays all the Protection Math Variables
MET AMV	Displays the last 16 Automation Math Variables
MET AMV A	Displays all the Automation Math Variables

[a] k = 1–32767; n = 1–6.

Use the **MET** command to obtain the current and voltage quantities in primary values, as shown in *Table 2.9*.

Table 2.9 Information Available With the MET Command

Command	Information
MET	Primary current magnitudes and angles from all 18 terminals in Amps. Primary voltage magnitudes and angles from the 3 voltage inputs in kV.

Figure 2.4 shows the relay response to the **MET** command of one phase in a three-relay application.

```
=>>MET <Enter>

Relay 1                                     Date: 05/14/2003  Time: 14:55:16.098
Station A                                   Serial Number: 2003000403

       Primary Currents
Terminal    MAG(A)   ANG(DEG)           Terminal    MAG(A)   ANG(DEG)
 FDR_1     2397.801     0.00             I10          0.000   -82.49
 FDR_2     2998.418     0.00             I11          0.000   -82.49
 FDR_3     1797.579   180.00             I12          0.000   -82.49
 TRFR_1    3597.560   180.00             I13          0.000   -82.49
 TB_1      5398.476   180.00             I14          0.000   -82.49
 TB_2      5398.476     0.00             I15          0.000   -82.49
 I07          0.000   -82.49             I16          0.000   -82.49
 I08          0.000   -82.49             I17          0.000   -82.49
 I09          0.000   -82.49             I18          0.000   -82.49

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01         66.996     0.00
 V02        133.991  -120.00
 V03        133.991   120.00

=>>
```

Figure 2.4 Relay Response to the MET Command of One Phase of a Three-Relay Application

All angles are referenced to the voltage connected to Voltage Terminal V01. If voltage at Terminal V01 is not available, the relay selects V02 and then V03 as reference. In the absence of voltage inputs, the relay references the current input of I01, provided the current is above $0.05 \bullet I_{NOM}$. If I01 is not above this current level, the relay references the current from I02, if available. If I02 is not available, the relay continues to I03, I04, and so on until it finds a current input above $0.05 \bullet I_{NOM}$.

For check-zone-specific primary values information, use the **MET CZ1** command. *Table 2.10* shows the information, including the CT polarity, included in Check Zone 1.

Table 2.10 Information Available With the MET CZ1 Command

Command	Information
MET CZ1	Primary current magnitudes, angles, and CT polarities from the active terminals in Amps. Primary voltage magnitudes and angles from the three voltage inputs in kV.

For the relay to display any measured values, at least one Terminal-to-Check-Zone equation must be a logical 1 (i.e., at least one terminal must be connected to the Check Zone). *Figure 2.5* shows the relay response to the **MET CZ1** command if no such connection exists.

```
=>>MET CZ1 <Enter>
Specified zone is inactive
```

Figure 2.5 Response to MET CZ1 Command When All Terminals Are Inactive

Figure 2.6 shows the relay response of one phase in a three-relay application when Terminals I01 and I02 are connected to Check Zone 1.

```
=>>MET CZ1 <Enter>

Relay 1                                    Date: 02/06/2008  Time: 23:51:51.027
Station A                                  Serial Number: 0000000001

Current Terminals in Check Zone 1

       Primary Currents
Terminal    MAG(A)   ANG(DEG)  POL
 FDR_1       98.131     0.00    P
 FDR_2       98.677   180.00    P

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        133.990     0.00
 V02        133.990  -119.99
 V03        133.990   120.00

=>>
```

Figure 2.6 Response to the MET CZ1 Command of One Phase in a Three-Relay Application

For zone-specific primary values information, use the **MET Z*n*** (*n* = 1–6) command. *Table 2.11* shows the information, including the CT polarity and Bus-Zones, included in Protection Zone *n*, if two Bus-Zones are combined.

Table 2.11 Information Available With the MET Zn Command

Command	Information
MET Z*n*	Primary current magnitudes, angles, and CT polarities from the active terminals in Amps. Primary voltage magnitudes and angles from the three voltage inputs in kV. Bus-Zones in Protection Zone *n*.

For the relay to display any measured values, at least one Terminal-to-Bus-Zone equation must be a logical 1 (i.e., at least one terminal must be connected to the specified Bus-Zone). *Figure 2.7* shows the relay response to the **MET Z*n*** command if no such connection exists.

```
=>>MET Z1 <Enter>
All terminals in the specified zone are inactive
```

Figure 2.7 Response to MET Z1 Command When All Terminals Are Inactive

Figure 2.8 shows the relay response of one phase in a three-relay application when Terminals I01 and I02 are connected to Bus-Zone 1.

```
=>>MET Z1 <Enter>

Relay 1                                     Date: 02/27/2003  Time: 13:56:37.718
Station A                                   Serial Number: 0000000001

Current Terminals in Protection Zone 1

       Primary Currents
Terminal    MAG(A)   ANG(DEG)  POL
 FDR_1       98.131     0.00    P
 FDR_2       98.677   180.00    P

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        133.990     0.00
 V02        133.990  -119.99
 V03        133.990   120.00

Bus-Zones in Protection Zone 1
BUS_1


=>>
```

Figure 2.8 Response to the MET Z1 Command of One Phase in a Three-Relay Application

MET SEC provides secondary information similar to the **MET** command, but includes the CT and PT ratios, as shown in *Table 2.12*.

Table 2.12 Information Available With the MET SEC Command

Command	Information
MET SEC	Secondary current magnitudes, angles, and CT ratios from all 18 terminals in Amps. Secondary voltage magnitudes and angles from the three voltage inputs in Volts, and each PT ratio.

Figure 2.9 shows the relay response to the **MET SEC** command of one phase in a three-relay application.

```
=>>MET SEC <Enter>

Relay 1                                     Date: 05/14/2003  Time: 14:59:04.360
Station A                                   Serial Number: 2003000403

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR        Terminal   MAG(A)  ANG(DEG)  CTR
 FDR_1      3.996     0.00   600         I10        0.000   -82.49    600
 FDR_2      4.997     0.00   600         I11        0.000   -82.49    600
 FDR_3      2.996   180.00   600         I12        0.000   -82.49    600
 TRFR_1     5.996   180.00   600         I13        0.000   -82.49    600
 TB_1       8.997   180.00   600         I14        0.000   -82.49    600
 TB_2       8.997     0.00   600         I15        0.000   -82.49    600
 I07        0.000   -82.49   600         I16        0.000   -82.49    600
 I08        0.000   -82.49   600         I17        0.000   -82.49    600
 I09        0.000   -82.49   600         I18        0.000   -82.49    600

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       66.996     0.00   1000
 V02       66.996  -120.00   2000
 V03       66.996   120.00   2000

=>>
```

Figure 2.9 Relay Response to the MET SEC Command of One Phase of a Three-Relay Application

For check-zone-specific secondary information, use the **MET SEC CZ1** command. The information includes the CT polarity, as shown in *Table 2.13*.

Table 2.13 Information Available With the MET SEC CZ1 Command

Command	Information
MET SEC CZ1	Secondary current magnitudes, angles, CT ratios, and polarities from the active terminals in the check zone in Amps. Secondary voltage magnitudes and angles from the three voltage inputs in Volts, and each PT ratio.

Figure 2.10 shows the relay response to the **MET SEC CZ1** command of one phase in a three-relay application with these terminals connected to Check Zone 1.

```
=>>MET SEC CZ1 <Enter>

Relay 1                                      Date: 02/06/2008  Time: 23:51:51.027
Station A                                    Serial Number: 0000000001

Current Terminals in Check Zone 1

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR  POL
 FDR_1      3.996    0.00     600  P
 FDR_2      4.997    0.00     600  P

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       66.996     0.00   1000
 V02       66.996  -120.00   2000

=>>
```

Figure 2.10 Response to the MET SEC CZ1 Command of One Phase in a Three-Relay Application

For zone-specific secondary information, use the **MET SEC Z*n*** (*n* = 1–6) command. The information includes the CT polarity, as shown in *Table 2.14*.

Table 2.14 Information Available With the MET SEC Zn Command

Command	Information
MET SEC Z*n*	Secondary current magnitudes, angles, CT ratios, and polarities from the active terminals in the specific zone in Amps. Secondary voltage magnitudes and angles from the three voltage inputs in Volts, and each PT ratio. Bus-Zones in Protection Zone *n*.

Figure 2.11 shows the relay response to the **MET SEC Z*n*** command of one phase in a three-relay application with these terminals connected to Bus-Zone 1.

```
=>>MET SEC Z1 <Enter>

Relay 1                                     Date: 05/14/2003  Time: 15:00:43.237
Station A                                   Serial Number: 2003000403

Current Terminals in Protection Zone 1

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR  POL
 FDR_1      3.996     0.00    600  P
 FDR_2      4.997     0.00    600  P
 TB_1       8.997   180.00    600  P

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       66.996     0.00   1000
 V02       66.996  -120.00   2000
 V03       66.996   120.00   2000

Bus-Zones in Protection Zone 1
BUS_1
=>>
```

Figure 2.11 Relay Response to the MET SEC Z1 Command of One Phase in a Three-Relay Application

NOTE: A zone is active when any IqqBZpV (qq = 01–18, p = 1–6) Relay Word bit asserts. For example, Zone 1 becomes active when Relay Word bit I01BZ1V asserts. The check zone is active when any IqqCZ1V (qq = 01–18) Relay Word bit asserts and ECHKZN := Y.

View the differential currents of all active zones with the **MET DIF** command. The information includes per unit operating and restraint currents from each active zone, as well as the reference current, as shown in *Table 2.15*. The reference current is the product of the SEL-487B nominal current and the maximum CT ratio in an active zone as defined in the zone configuration settings.

Table 2.15 Information Available With the MET DIF Command

Command	Information
MET DIF	Operate current of all active zones in per unit. Restraint current of all active zones in per unit. Product of relay nominal current and highest CT ratio of the connected CTs, used as reference current.

Figure 2.12 shows the relay response to the **MET DIF** command of one phase in a three-relay application when Bus-Zones 1 and 2 are active.

```
=>>MET DIF <Enter>

Relay 1                                     Date: 02/27/2003  Time: 14:28:06.955
Station A                                   Serial Number: 0000000001

       Operate Currents     Restraint Currents
           (Per Unit)            (Per Unit)
ZONE          IOP                   IRT
  1           0.00                  0.25
  2           0.01                  0.44

Current Reference (A)
IREF
800

=>>
```

Figure 2.12 Relay Response to the MET DIF Command of One Phase in a Three-Relay Application

The relay includes 64 protection math variables and 256 automation math variables. Use the **MET PMV** and **MET AMV** commands to see the last 16 of each, as shown in *Table 2.16*.

Table 2.16 Information Available With the MET PMV and MET AMV Commands

Command	Information
MET PMV	PMV49–PMV64
MET AMV	AMV241–AMV256

To see all of the variables, use the **MET PMV A** and **MET AMV A** commands, as shown in *Table 2.17*.

Table 2.17 Information Available With the MET PMV A and MET AMV A Commands

Command	Information
MET PMV A	PMV01–PMV64
MET AMV A	AMV001–AMV256

Use the **MET ANA** command to display the analog values used with MIRRORED BITS communications, as shown in *Table 2.18*.

Table 2.18 Information Available With the MET ANA Command

Command	Information
MET ANA	Analog value in channel A Analog value in channel B

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Section 3
Analyzing Data

Overview

The SEL-487B Relay features comprehensive power system data analysis capabilities. The relay provides these useful analysis tools:

- Event reporting
- Event reports
- Event summaries
- Event histories
- Combined event report
- SER (Sequential Events Recorder)

An event shows selected data of the power system at a specific time. Events include instances such as a relay trip, an abnormal situation in the power system that triggers a relay element, or an event capture command.

Information from relay event reports and SER data is very valuable if you are responsible for outage analysis, outage management, or relay settings coordination.

Data Processing

The SEL-487B is a microprocessor-based relay that samples power system conditions via CT and PT inputs. The relay converts these analog inputs to digital information for processing to determine relaying quantities for protection and automation. *Figure 3.1* shows a general overview of the input processing diagram for the SEL-487B. A CT or PT analog input begins at hardware acquisition and sampling, continues through software filtering, and progresses to protection, automation processing, and event storage.

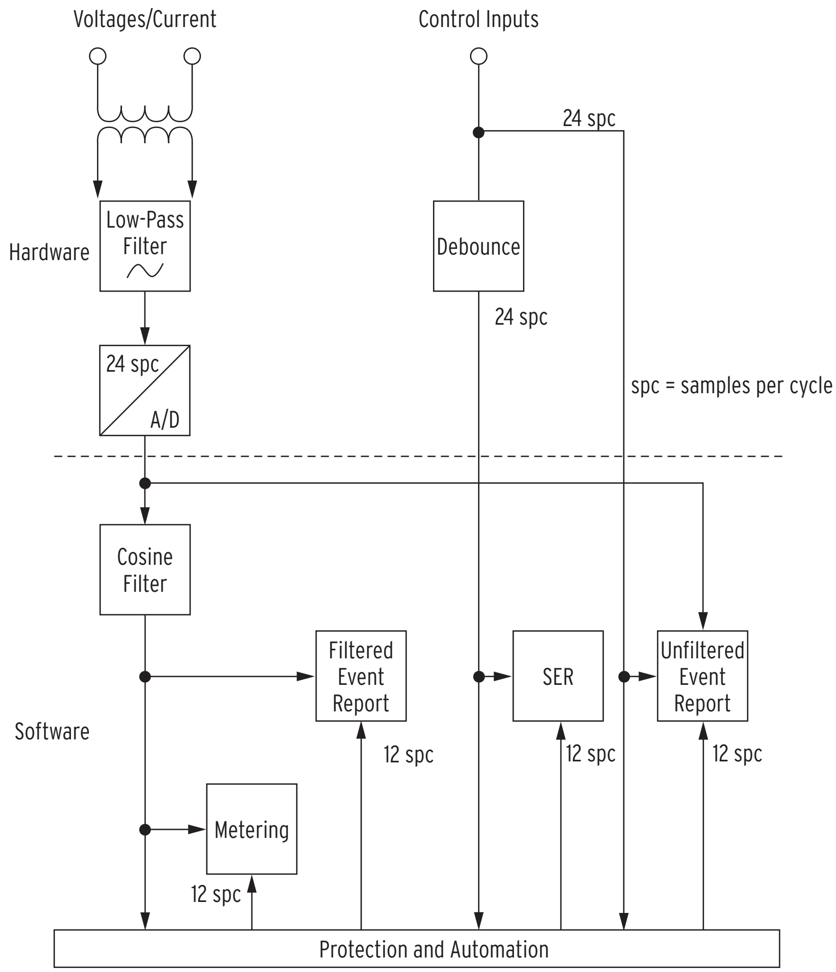

Figure 3.1 SEL-487B Input Processing

Raw and Filtered Data

The SEL-487B provides two types of data: unfiltered (raw) data and filtered data, available in ASCII or Compressed ASCII format. *Table 3.1* shows the various types of events reports and the contents of each.

Table 3.1 Event Report Types Available in the SEL-487B

Event File Types	Samples/Cycle	Type	Format
E4_10000.TXT	4	Filtered	ASCII
E1210000.TXT	12	Filtered	ASCII
E2410000.TXT	24	Raw	ASCII
D1210000.TXT	12	Filtered (differential)	ASCII
C1210000.TXT	12	Filtered	Compressed ASCII
C2410000.TXT	24	Raw	Compressed ASCII
Z2410000.TXT[a]	24/12	Raw and filtered (differential)	Compressed ASCII

[a] Combination of C2410000.TXT and D1210000.TXT.

Event File Types

When starting at the number 10000, the SEL-487B assigns a unique number to each event.

Triggering Data Captures and Event Reports

The SEL-487B displays power system data from event reports, event summaries, event histories, and SER data. For information on the SER, see *SER (Sequential Events Recorder) on page A.3.31*. Events can be triggered from both internal to the relay or external to the relay, depending on the event trigger conditions that you program in the relay.

Use an event trigger to initiate capturing an event report. Both raw data and filtered event reports use the same triggering methods. Any one of the five possible sources shown in *Table 3.2* can provide the trigger for a data capture.

Table 3.2 Five Sources That Can Initiate a Data Capture in the Relay

Event	Description
87BTR	Rising edge of Relay Word bit 87BTR on or after trigger
SBFTR	Rising edge of Relay Word bit SBFTR on or after trigger
TRIP	Rising edge of Relay Word bit TRIP on or after trigger
ER	Rising edge of ER, the event report trigger
TRI	Execution of the ASCII **TRIGGER** command

In previous SEL relays, the **PUL** command initiated event recording. If you want the **PUL** command to initiate data capture, add the Relay Word bit TESTPUL to the SELOGIC® control equation ER (See *SELOGIC Control Equation ER* and *Example 3.2*. For more information on the **PUL** command, see *PULSE on page R.7.29* and *Operating the Relay Inputs and Outputs on page U.4.40*.

Relay Word Bits 87BTR, SBFTR and TRIP

Relay Word bit 87BTR asserts when any one of the Relay Word bits 87BTR01–87BTR18 asserts, Relay Word bit SBFTR asserts when any one of Relay Word bits SBFTR01–SBFTR18 asserts, and Relay Word bit TRIP asserts when any one of Relay Word bits TRIP01–TRIP18 asserts. When any of the Relay Word bits 87BTR, SBFTR, or TRIP asserts, the relay automatically initiates event recording on the rising edge of the particular Relay Word bit state change. Therefore, enter only conditions for which these Relay Word bits do not already assert in the ER SELOGIC control equation. For information on Relay Word bits 87BTR, SBFTR, and TRIP see *Differential Trip Logic on page R.1.53*, *Circuit Breaker Failure Trip Logic on page R.1.41*, and *Breaker Trip Logic on page R.1.55*.

SELOGIC Control Equation ER

Program the SELOGIC control equation ER to trigger event reports for conditions other than 87BTR, SBFTR, or TRIP conditions. When ER asserts, the SEL-487B begins recording data if the relay is not already capturing data initiated by another trigger.

EXAMPLE 3.1 Triggering Event Report/Data Capture Using the ER SELOGIC Control Equation

This example shows how the elements in the ER SELOGIC control equation initiate relay data capture. See Section 2: SELOGIC Control Equation Programming in the Reference Manual for more information on rising-edge operators and SELOGIC control equations.

The factory default setting for the six Group settings SELOGIC control equations ER is:

ER := **R_TRIG 87ST** Event Report Trigger Equation (SELOGIC Equation)

Relay Word Bit 87ST is the OR combination of the six sensitive differential elements time-delayed outputs.

Use 87ST instead of the elaborate equation of 87ST1 OR 87ST2 OR 87ST3 OR 87ST4 OR 87ST5 OR 87ST6 to trigger an event when any time-delayed sensitive differential element operates.

The rising-edge operator, R_TRIG, occurs in front of element 87ST in the factory-default ER equation. Rising-edge operators are especially useful for generating an event report at fault inception. The relay processes the assertion elements with the R_TRIG operator for only one processing interval at the beginning of element assertion, clearing the way for other elements to also assert ER. Thus, the starting element in a continuously occurring fault does not mask other possible element triggers, provided that subsequent triggers are later than the time window as specified by the LER setting (**SET R)**. This allows another rising-edge sensitive element to generate another event report should an element stays asserted for the same continuous fault (such as an overcurrent situation with the R_TRIG 51P01 element).

Other elements in the ER SELOGIC control equation (for example, 51P01 if it was entered) can trigger event reports while the 87ST element remains asserted throughout the fault duration.

You can also use the falling-edge operator, F_TRIG, to initiate data captures. See *Section 2: SELOGIC Control Equation Programming in the Reference Manual* for more information on falling-edge operators.

EXAMPLE 3.2 Including PUL Command Triggering in the ER SELOGIC Control Equation

This example shows you how to add the effect of the **PUL** command to emulate previous SEL relays. The relay asserts Relay Word bit, TESTPUL, when any output pulses via the **PUL** command. For more information on the **PUL** command, see PULSE on page R.7.29.

Program the Group settings SELOGIC control equation ER as follows:

ER := **R_TRIG 87ST OR TESTPUL** Event Report Trigger Equation (SELOGIC Equation)

TRI (Trigger Event Report) Command

Use the **TRI** command from any communications port to trigger the SEL-487B to begin the recording of an event report. When testing with the **TRI** command, the relay records power system operating conditions that occur immediately after you issue the **TRI** command. See *TRIGGER on page R.7.49* and *Triggering an Event on page U.4.35* for more information on the **TRI** command.

Duration of Data Captures and Event Reports

The SEL-487B stores unfiltered raw data and filtered data. The number of stored unfiltered raw data captures and event reports is a function of the amount of data contained in each capture. You can configure the relay to record data captures at either 15, 30, 60, or 120 cycles, as shown in *Table 3.3*.

Table 3.3 LER and PRE Report Settings

Label	Description	Range	Default
LER	Length of event report	15, 30, 60, or 120 cycles	15 cycles
PRE	Length of prefault	1 – (LER – 2) cycles	5 cycles

The length of the data capture/event report (setting LER) and the pretrigger or prefault time (setting PRE) are related as shown in *Figure 3.2*. Setting LER is the overall length of the event report data capture; and setting PRE determines the time reserved in the LER period when the relay records pretrigger (prefault) data.

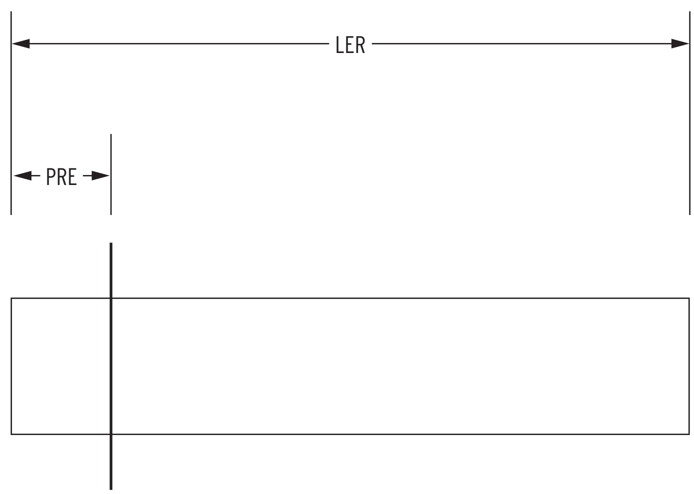

Figure 3.2 Data Capture/Event Report Times

The relay stores all data captures to volatile RAM and then moves these data to nonvolatile memory storage. There is enough volatile RAM to store one maximum length capture (maximum LER time). No data captures can be triggered while the volatile RAM is full; the relay must move at least one data capture to nonvolatile storage to reenable data capture triggering. Thus, to record different events sequentially, you must set LER to half or less than half of the maximum LER setting. The relay stores more sequential data captures as you set LER smaller.

The relay automatically overwrites the oldest events with the newest events when the nonvolatile storage capacity is exceeded.

Table 3.4 shows the number of events the relay stores in nonvolatile memory for different LER settings.

Table 3.4 Event Report Nonvolatile Storage Capability

Event Report Length (LER)	Number of Events Stored
15 cycles	24
30 cycles	15
60 cycles	8
120 cycles	4

Event Report Oscillography

Use a terminal or SEL-supplied PC software to retrieve event report files stored in the relay and transfer these files to your computer. Both the ACSELERATOR QuickSet® SEL-5030 Software Program and the SEL-5601 Analytic Assistant read the event files that the relay generates for an event. See *Section 3: PC Software in the User's Guide* for instructions on viewing event report oscillography with the ACSELERATOR software.

Event Reports, Summaries, and Histories

Event reports simplify post-fault analysis and help you improve your understanding of protection scheme operations. Event reports also aid in testing and troubleshooting relay settings and protection schemes because these reports contain detailed data on voltage, current, and relay element status. For further analysis assistance, the relay appends the active relay settings to each event report. The relay stores event reports in nonvolatile memory, and you can clear the event report memory on a port-by-port basis (see the **EVE** command in *EVENT on page R.7.14*).

Alias Names

NOTE: If alias names were changed after an event was recorded, the relay uses the present alias names in subsequent event reports.

To customize your event report, rename any Relay Word bit, analog quantity, or default terminal name with more meaningful names to improve the readability of fault analysis and customized programming. See *Section 1: System Configuration Guideline and Application Examples* for more information. After renaming the primitive quantities, the alias names rather than the primitive names appear in the event reports and SER. The primitive names of the analog channels still appear in the event reports.

You decide the amount of information and length in an event report. See *Duration of Data Captures and Event Reports on page A.3.5*. You can view the information in one or more of the following forms:

- Event report
- Event summary
- Event history

Event Report

The relay generates event reports to display analog data, digital data (control inputs, control outputs, and the state of Relay Word bits), and relay settings. Each event report includes these components:

- Report header
- Analog section
  - Currents, voltages, and battery voltage

- Digital section
  - User-defined Relay Word bit elements, control outputs, control inputs
- Event summary
- Settings
  - Group settings
  - Zone configuration group settings
  - Global settings
  - Output settings
  - SELOGIC control equations protection logic
  - Alias settings

Viewing the Event Report

Step 1. Access event reports from the communications ports and communications cards at Access Level 1 and higher.

You cannot view event reports at the front panel, although you can view event summary information at the front-panel display; see *EVENT on page R.7.14*.

Step 2. You can independently acknowledge the oldest event report at each communications port (**EVE ACK** command) so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete sets of event reports.

a. To acknowledge the oldest event report, you must first view that event report at a particular port by using the **EVE N(EXT**) command (see *EVENT*).

Step 3. You can use the **EVE** command at a terminal to retrieve event reports by event order or by event serial number.

The relay labels each new event with a unique serial number as reported in the **HIS** command history report; see *Event History on page A.3.27*.

Event Numbering

Event reports are numbered with an event identifier starting at the number 10000 and ending at the number 42767. The event identifier is called the Event Number in the event reports and is a unique number generated sequentially as the events are recorded. Event numbers remain associated with a particular event, even when new events are recorded.

However, when using the **EVE**, **CEV**, **CSU**, or **SUM** commands, the relay displays the most recent event. For example, if three events were recorded, the event numbers are 10001, 10002, and 10003.

1. After the **EVE <Enter>** command is entered, the relay displays the newest event, which is 10003.

   a. To distinguish between the two sequences, include an argument *n* with the **EVE**, **CEV**, **CSU**, or **SUM** commands.

   When parameter *n* is 1 through 100, *n* indicates the order of the event report, the most recent event report is 1, the next most recent report is 2, and so on.

When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

2. You can retrieve analog or digital information separately, and you can exclude the summary or settings portions of the report. The default **EVE** command event report data resolution is 4 samples/cycle with the factory default setting for LER = 15 cycles.

Table 3.5 lists a summary of **EVE** commands. See *EVENT* for complete information on the **EVE** command. *Table 3.6* shows a few examples of command options that you can use with the **EVE** command. The **EVE L** and **EVE C** commands provide compatibility with older command sets.

Table 3.5 EVE Command

Command	Description
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.
EVE ACK	Acknowledge the oldest unacknowledged event at the present communications port.
EVE *n*	Return a particular *n* event report (including settings and summary) at full length with 4-samples/cycle data.
EVE A	Return only the analog information for the most recent event report with 4-samples/cycle data.
EVE C	Return the most recent report at full length with 12-samples/cycle data.
EVE D	Return only the digital information for the most recent event report with 4-samples/cycle data.
EVE DIF	Return the differential information of the most recent report with 4-samples/cycle data.
EVE L	Return the most recent event report at full length with 12-samples/cycle sampling.
EVE L*y*	Return *y* cycles of the most recent event report with 4-samples/cycle data.
EVE NEXT	Return the oldest unacknowledged event report with 4-samples/cycle data.
EVE NSET	Return the most recent event report without settings at full length with 4-samples/cycle data.
EVE NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data.
EVE S*x*[a]	Return the most recent event report at full length with *x*-samples/cycle data.

[a] Where x = 4 or 12.

Table 3.6 shows examples of the **EVE** command.

Table 3.6 EVE Command Examples

Example	Description
EVE L10 S12	Return 10 cycles of a 12-samples/cycle event report for the most recent event.
EVE L10 A	Return 10 cycles of the analog portion only of the most recent event report at 4-samples/cycle resolution.
EVE 2 NSET	For the second most recent event, return the event report with no settings at 4-samples/cycle data.

You can retrieve event reports with the ACSELERATOR software. See *Section 3: PC Software in the User's Guide* for more information on viewing event reports with the ACSELERATOR software.

You can also download event files from the relay.

Step 1. Use a terminal emulation program with file transfer capability.

Step 2. At the Access Level 1 prompt or higher, type **FILE DIR EVENTS <Enter>** to view the available events. *Figure 3.3* shows an example of the relay response to the **FILE DIR EVENTS** command.

```
=>>FILE DIR EVENTS <Enter>
C1210000.TXT                R   03/01/2003 14:23:19
C1210001.TXT                R   03/01/2003 14:48:21
C1210002.TXT                R   03/01/2003 14:48:24
C2410000.TXT                R   03/01/2003 14:23:19
C2410001.TXT                R   03/01/2003 14:48:21
C2410002.TXT                R   03/01/2003 14:48:24
CHISTORY.TXT                R
D1210000.TXT                R   03/01/2003 14:23:19
D1210001.TXT                R   03/01/2003 14:48:21
D1210002.TXT                R   03/01/2003 14:48:24
E1210000.TXT                R   03/01/2003 14:23:19
E1210001.TXT                R   03/01/2003 14:48:21
E1210002.TXT                R   03/01/2003 14:48:24
E2410000.TXT                R   03/01/2003 14:23:19
E2410001.TXT                R   03/01/2003 14:48:21
E2410002.TXT                R   03/01/2003 14:48:24
E4_10000.TXT                R   03/01/2003 14:23:19
E4_10001.TXT                R   03/01/2003 14:48:21
E4_10002.TXT                R   03/01/2003 14:48:24
HISTORY.TXT                 R
Z2410000.TXT                R   03/01/2003 14:23:19
Z2410001.TXT                R   03/01/2003 14:48:21
Z2410002.TXT                R   03/01/2003 14:48:24

=>>
```

Figure 3.3 Example of the Relay Response to the FILE DIR EVENTS Command

Step 3. Type **FILE READ EVENTS E4_*nnnnn*.TXT <Enter>** to retrieve a 4-sample event report (*nnnnn* is the event serial number).

Step 4. Start the terminal download routine to store the file on your computer.

The following discussion shows sample portions of an event report that you download from the relay using a terminal emulation program and the **EVE** command.

Report Header and Analog Section of the Event Report

Figure 3.4 shows a substation with two busbars (WEST and EAST), a tie breaker, and three terminals (LONDON, NEW YORK, and CANBERRA). In this example, the event report shows the individual phases of the power system. The EAST busbar comprises three phases with alias names EAST_A, EAST_B, and EAST_C. *Figure 3.4* shows only the A-phase alias names (EAST_A, for example), but the event report includes all three phases. Therefore, the LONDON terminal has three phases labeled LOND_A (A-phase), LOND_B (B-phase), and LOND_C (C-phase).

Assume that Fault F1, a three-phase fault, occurs on the EAST busbar. Because Fault F1 is a three-phase fault, all three of the phase elements assert. For example, differential elements for phases EAST_A, EAST_B, and EAST_C assert for Fault F1.

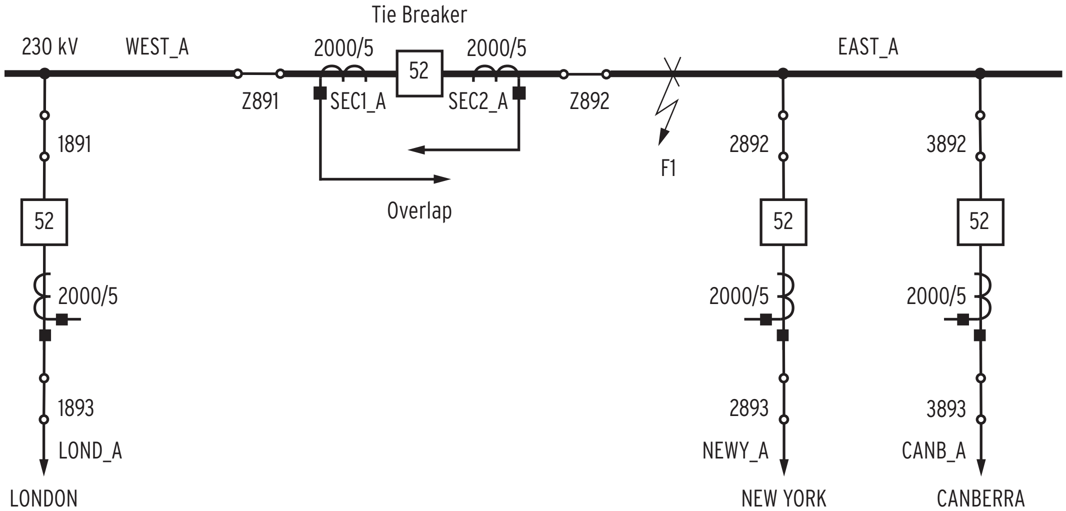

Figure 3.4 Substation With Two Busbars, a Tie Breaker, and Three Feeders

The first portion of an event report is the report header and the analog section. See *Figure 3.5* for the location of items included in a sample analog section of an event report. If you want to view only the analog portion of an event report, use the **EVE A** command.

The report header is the standard SEL-487B header listing the relay identifiers, date, and time. Report headers help you organize report data. Each event report begins with information about the relay and the event. The report header lists the:

- RID setting (Relay ID)
- SID setting (Station ID)

The FID string identifies the:

- Relay model
- Firmware version
- Date code of the firmware

See *Appendix A: Firmware and Manual Versions in the User's Guide* for a description of the FID string. The relay reports a date and time stamp to indicate the internal clock time when the relay triggered the event. The relay reports the firmware checksum as CID.

The event report column labels follow the header. The data underneath the analog column labels contain samples of the following:

- First nine currents channels in primary amps
- Three voltage channels in primary kilovolts
- Second group of nine current channels in primary amps
- Battery channel voltage in volts

These quantities are in instantaneous rms values and are described in *Table 3.7*. To obtain phasors, use the methods illustrated in *Obtaining RMS Phasors From 4-Samples/Cycle Event Reports on page A.3.12*, *Figure 3.6*, and *Figure 3.7*.

```
=>>EVE A <Enter>

Relay 1                                      Date: 07/24/2003  Time: 18:02:37.099
Station A                                    Serial Number: 2003004005
FID=SEL-487B-R102-V0-Z001001-D20030724 Event Number = 10057     CID=0xBF4D

                   Currents (Pri. Amps)                    Voltages (Pri. kV)
   I01   I02   I03   I04   I05   I06   I07   I08   I09      V01    V02    V03

[1]
   861 -1146   277   872 -1142   266   439  -568   124     99.4 -126.8   26.2
   829   339 -1162   820   352 -1159   401   185  -580     89.3   42.2 -131.0
  -862  1147  -276  -873  1142  -265  -438   568  -125    -99.4  126.8  -26.2
  -831  -342  1164  -818  -352  1161  -401  -185   582    -89.3  -42.2  131.0
.
.
.
[6]
  -637  2301 -1650  -668  2327 -1656  2562 -5257  2687     93.0 -112.3   18.1>
 -3399   301  3096 -3381   252  3142  5933   478 -6428     72.3   41.1 -112.9
  6481-10043  3496  6572-10045  3431-10565 15503 -4900    -68.5   81.0  -11.7
  8983  2019-10965  8901  2120-11025-13155 -3801 16970    -50.3  -30.7   80.7
[7]
-10822 14336 -3423-10940 14297 -3287 16439-21057  4554     50.5  -64.3   13.1
-10335 -4297 14572-10217 -4394 14600 14840  6832-21661     45.2   21.5  -66.5*
 10824-14331  3424 10940-14295  3285-16437 21055 -4552    -50.5   64.3  -13.1
 10329  4301-14568 10212  4397-14598-14832 -6836 21657    -45.2  -21.6   66.5
.
.
.

                   Currents (Pri. Amps)                   Battery (V)
   I10   I11   I12   I13   I14   I15   I16   I17   I18      VDC1

[1]
   901 -1127   216   907 -1122   206   455  -558    94      28.33
   789   393 -1174   775   411 -1174   380   211  -584      28.33
  -902  1127  -216  -910  1122  -206  -459   558   -95      28.32
  -786  -394  1175  -771  -410  1177  -378  -211   584      28.33
.
.
.
[6]
  -757  2479 -1711  -793  2526 -1725  2792 -5466  2663      28.32>
 -3304   -47  3354 -3282  -131  3424  5721  1056 -6813      28.32
  6862-10098  3164  6956-10115  3078-11115 15543 -4341      28.32
  8601  2731-11307  8511  2906-11390-12565 -4856 17455      28.32
[7]
-11304 14107 -2692-11417 14053 -2510 17099-20708  3453      28.33
 -9800 -4977 14729 -9677 -5140 14756 14065  7815-21866      28.33*
 11304-14104  2690 11413-14050  2510-17097 20705 -3451      28.33
  9795  4981-14725  9672  5143-14756-14059 -7820 21863      28.33
.
.
.
[15]
     1    -2    -1    -1     3     0     1    -1     5      28.32
     2     1     2    -2     1     3    -1     2     3      28.32
     0     1     2     5    -1    -3     0    -1    -2      28.32
     1    -2    -1     2    -1    -2     0    -2    -3      28.33

=>>
```

Header

Firmware ID

One Cycle of Data

See Figure 3.6 and Figure 3.7 to calculate phasors for this data

Trigger

1.25 Cycles After Event Trigger Current (to Event Summary)

Figure 3.5 Analog Section of the Event Report

Table 3.7 Event Report Metered Analog Quantities (Sheet 1 of 2)

Quantity	Description
I01	Channel 01 phase filtered instantaneous current
I02	Channel 02 phase filtered instantaneous current
I03	Channel 03 phase filtered instantaneous current
I04	Channel 04 phase filtered instantaneous current
I05	Channel 05 phase filtered instantaneous current
I06	Channel 06 phase filtered instantaneous current
I07	Channel 07 phase filtered instantaneous current

Table 3.7 Event Report Metered Analog Quantities (Sheet 2 of 2)

Quantity	Description
I08	Channel 08 phase filtered instantaneous current
I09	Channel 09 phase filtered instantaneous current
V01	Channel 01 phase filtered instantaneous voltage
V02	Channel 02 phase filtered instantaneous voltage
V03	Channel 03 phase filtered instantaneous voltage
I10	Channel 10 phase filtered instantaneous current
I11	Channel 11 phase filtered instantaneous current
I12	Channel 12 phase filtered instantaneous current
I13	Channel 13 phase filtered instantaneous current
I14	Channel 14 phase filtered instantaneous current
I15	Channel 15 phase filtered instantaneous current
I16	Channel 16 phase filtered instantaneous current
I17	Channel 17 phase filtered instantaneous current
I18	Channel 18 phase filtered instantaneous current
VDC1	Filtered dc monitor voltage

Figure 3.5 contains selected data from the analog section of a 4-samples/cycle event report initiated using the **TRIGGER** command. The bracketed numbers at the left of the report (for example, [6]) indicate the cycle number; *Figure 3.5* shows three cycles of 4-samples/cycle data.

The trigger row includes a > character following immediately after the V03 column to indicate the trigger point. This is the dividing point between the prefault or PRE time and the fault or remainder of the data capture.

The row that the relay uses for the currents in the event summary is the row with the largest current magnitudes; the relay marks this row on the event report with an asterisk * character immediately after the V03 column. The * takes precedence over the > if both occur on the same row in the analog section of the event report.

Obtaining RMS Phasors From 4-Samples/Cycle Event Reports

Use the column data in an event report to calculate rms values. You can use a calculator to convert rectangular data to phasor data, or use hand calculations to separately determine the magnitude and angle of the rms phasor.

Hand Calculation Method. The procedure in the following steps explains a method for obtaining a current phasor from the I01 channel data in the event report of *Figure 3.5*. You can process voltage data columns similarly. *Figure 3.6* and *Figure 3.7* show one cycle of I01 current in detail. *Figure 3.6* shows how to relate the event report ac current column data to the sampled waveform and rms values. *Figure 3.7* shows how to find the phasor angle. If you use the larger 12-samples/cycle event report, take every third sample and apply those values in this procedure.

This example demonstrates using a terminal emulation program. A more convenient method is to use the ACSELERATOR software or the SEL-5601 Analytic Assistant. These programs automate the analysis process presented in this example and provide you with voltage and current phasors as software outputs.

This example assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for step-by-step instructions. In addition, you must understand relay access levels and passwords. See *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

Step 2. Identify an event.

a. Type **HIS <Enter>**.

The **HIS** command gives a quick, one-row listing of relay-stored events. See *Event History on page A.3.27* for more information. This example uses the latest captured event.

b. If no events are available, use the **TRI** command to generate an event (see *Triggering Data Captures and Event Reports on page A.3.3*).

Step 3. Gather data from the event report.

a. Enable terminal data capture (usually a **Transfer > Capture Text** menu) in your terminal emulation program.

b. Type **EVE A <Enter>** at the => prompt to obtain the analog part of an event report similar to *Figure 3.5*. (See *Table 3.5* for a summary of **EVENT** commands.)

The relay responds with the analog portion of the event report.

Step 4. Calculate the phasor magnitude.

a. Select a cycle of data from the I01 column of the event report in *Figure 3.5*. Cycle [1] data for this example are shown in *Figure 3.6*.

b. Compute phasor magnitude using *Equation 3.1*:

$$\sqrt{X^2 + Y^2} = |\text{Phasor}| \qquad \textbf{Equation 3.1}$$

In *Equation 3.1*, Y is the first row of the I01 column current of a data pair. The next row is X, the present value of the pair. For this example, the computation shown in *Figure 3.6*. yields 1195 A.

c. Compute phasor magnitudes from the remaining data pairs for Cycle [1].

d. Confirm that all values are similar.

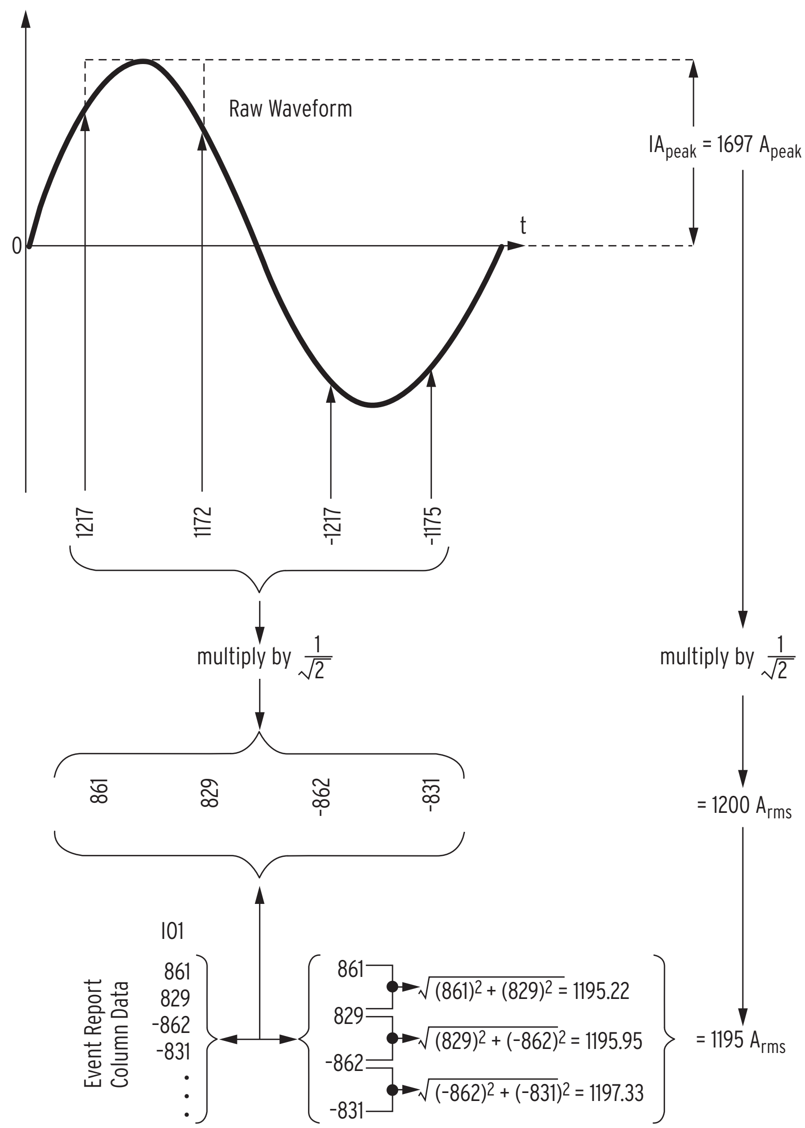

Figure 3.6 Event Report Current Column Data and RMS Current Magnitude

NOTE: The arctan function of many calculators and computing programs does not return the correct angle for the second and third quadrants (when X is negative). When in doubt, graph the X and Y quantities to confirm that the angle that your calculator reports is correct.

Step 5. Calculate the immediate phase angle.

a. Select the same cycle of data from the I01 column of the event report as you did when finding the magnitude (Cycle [1] data for this example).

b. Compute phasor angle using *Equation 3.2*:

$$\theta = \arctan\left(\frac{Y}{X}\right) = \angle \text{Phasor}$$

Equation 3.2

In *Equation 3.2*, Y is the first (or previous value) I01 column current of a data pair, and X is the present value of the pair. For this example, the computation shown in *Figure 3.7* yields 46.1 degrees.

c. Compute phasor angles from the remaining data pairs for Cycle [1].

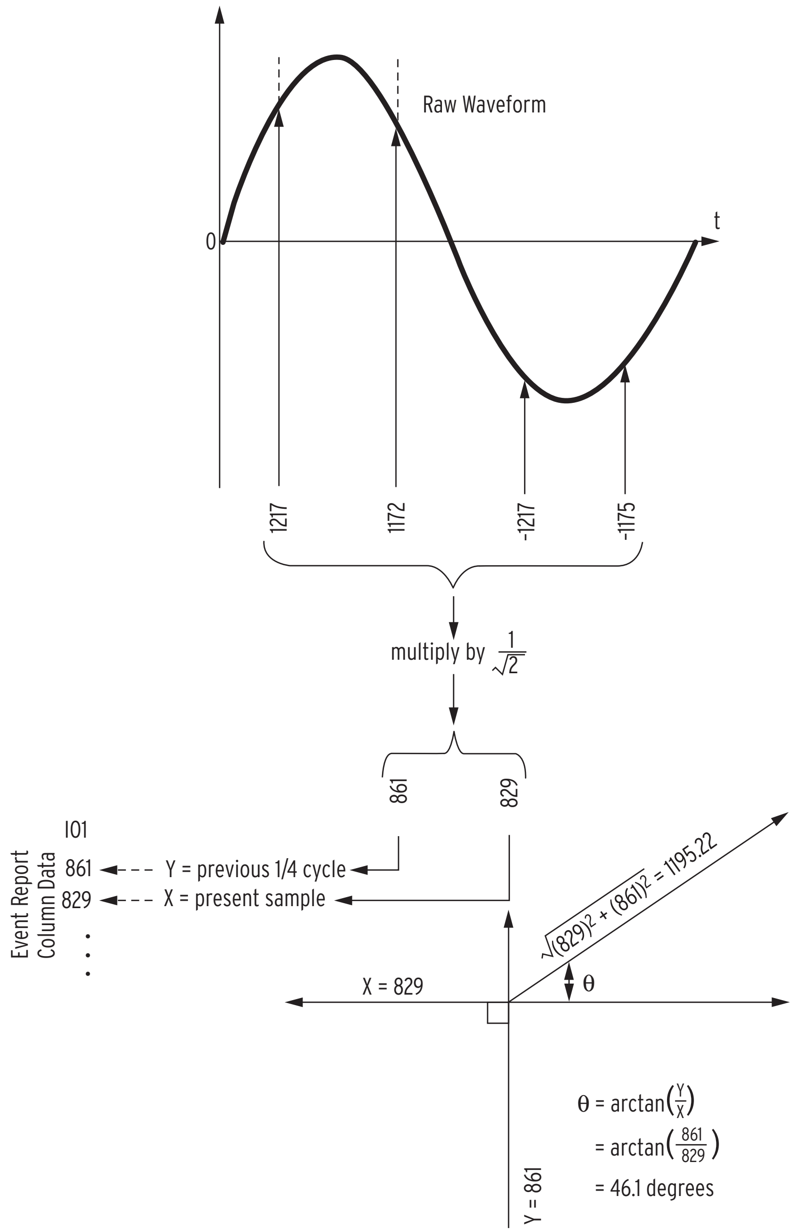

Figure 3.7 Event Report Current Column Data and RMS Current Angle

Step 6. Calculate the reference phase angle.

a. Usually, you compare power system angles to a reference phasor (A-phase voltage, for example).

b. Repeat *Step 5 on page A.3.14* for the row data in the V01 column that correspond to the I01 column data values you used in *Step 5*. Use *Equation 3.3* to calculate the angle for the V01 data:

$$\begin{aligned}\theta &= \arctan\frac{Y}{X} = \angle\text{Phasor}\\ &= \arctan\left(\frac{99.4}{89.3}\right)\\ &= 48.1^\circ\end{aligned}$$

Equation 3.3

Step 7. Calculate the absolute phase angle.

a. Subtract the I01 angle from the V01 angle to obtain the A-phase-referenced phasor angle for I01.

$$\angle V01 - \angle I01 = 48.1 - 46.1 = 2.0° \quad \textbf{Equation 3.4}$$

Therefore, the rms phasor for current I01 at the present sample is 1195.22 A ∠46.1°, lagging reference voltage V01 by 2.0 degrees.

In the procedure above, you use two rows of current data from the event report to calculate an rms phasor current. At the first sample pair of Cycle [1], the rms phasor is I01 = 1195.22 A ∠46.1°. The present sample of the sample pair (X = 829) is a scaled instantaneous current value (not an rms quantity) that relates to the rms phasor current value by the expression

$$X = 829 = 1195.22 \bullet \cos(46.1°) \quad \textbf{Equation 3.5}$$

Polar Calculator Method. A method for finding the phasor magnitude and angle from event report quarter-cycle data pairs is to use a polar-capable calculator or computer program. Many calculators and computer programs convert Cartesian (X and Y) coordinate data to polar data.

Step 1. Key or enter the X value (present value or lower value of a column pair) and the Y value (later value or upper value in a column pair) as Cartesian (rectangular) coordinates.

Step 2. Perform the keystrokes necessary for your calculator or computing program to convert to polar coordinates. This is the phasor value for the data pair.

Digital Section of the Event Report

The second portion of an event report is the digital section.

Step 1. Inspect the digital data to evaluate relay element response during an event.

a. See *Figure 3.8* for the locations of items in a sample event report digital section.

Step 2. If you want to view only the digital portion of an event report, use the **EVE D** command.

See *Table 3.5* or *Section 7: ASCII Command Reference in the Reference Manual* for details.

In the digital portion of the event report, the relay indicates deasserted elements with a period (.) and asserted elements with an asterisk (*) character.

The element and digital information labels are single-character columns. Read these columns from top to bottom. The trigger row includes a > character following immediately after the last digital element column to indicate the trigger point. The relay marks the row used to report the maximum fault current with an asterisk * character at the right of the last digital element column. Event reports that are 4-samples/cycle reports show the OR combination of digital elements in the 12-samples/cycle rows to make the quarter-cycle entry.

The digital report arranges the event report digital settings into 79 column pages. For every 79 columns, the relay generates a new report that follows the previous report.

The report displays the digital label header for each column in a vertical fashion, aligned on the last character. If the Relay Word bits included in the header were assigned aliases, the alias names appear in the report. For example, the first six Relay Word bits in the event report are 87Z1, 87Z2, 87Z3, 87Z4, 87Z5, and 87Z6. Each Relay Word bit has an alias name as shown in *Table 3.8*.

Table 3.8 Primitive and Alias Names of the First Four Digital Label Headers in the Default Event Report

Primitive Name	Alias Name
87Z1	WEST_A
87Z2	WEST_B
87Z3	WEST_C
87Z4	EAST_A
87Z5	EAST_B
87Z6	EAST_C

Figure 3.8 shows the digital section of the event report for fault F1.

```
=>>EVE D <Enter>

Relay 1                                      Date: 07/24/2003  Time: 18:02:37.099
Station A                                    Serial Number: 2003004005
FID=SEL-487B-R102-V0-Z001001-D20030724 Event Number = 10057     CID=0xBF4D

              D
WWWEEE LNCS I   LLLSSSNNNSSSCCC
EEEAAA OEAE FB  OOOEEEEEEEEEAAA
SSSSSS NWNC FF  NNNCCCWWWCCCNNN
TTTTTT ____ __T DDD222YYY111BBB
______ BBBB EEN _______________
ABCABC FFFF NNS ABCABCABCABCABC

[1]
...... .... **. ...............
...... .... **. ...............
...... .... **. ...............
...... .... **. ...............
.
.
.

[5]
...... .... **. ...............
...... .... **. ...............
...... .... **. ...............
...... .... **. ...............
[6]
...*** .... **. ......*********>
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
[7]
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
[8]
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
[9]
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
[10]
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
[11]
...*** .... **. ......*********
...... .... **. ......*********
...... .... **. ......*********
...... .... **. ......*********
.
.
.

[15]
...... .... **. ......*********
...... .... **. ......*********
...... .... **. ......*********
...... .... **. ......*********

=>>
```

Digital Column Labels

One Cycle of Data

Trigger

Trip outputs assert for the tie breaker and FDR_1

Differential element resets

Figure 3.8 Digital Section of the Event Report

Figure 3.9 shows the first six digital label headers in the default event report and the same information in a horizontal format.

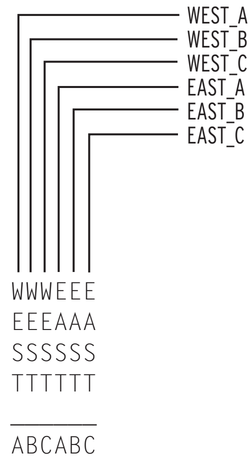

Figure 3.9 Sample Digital Portion of the Event Report

EXAMPLE 3.3 Reading the Digital Portion of the Event Report

This example shows how to read the digital event report shown in Figure 3.9. The sample digital event report shows nine cycles of 4-samples/cycle data for a three-phase fault.

Relay Word bit DIFF_EN in the 13th column from the left is picked up, enabling the differential elements. In this particular report, the three differential elements, EAST_A, EAST_B, and EAST_C, pick up in the first sample of Cycle [6]. The relay asserts the tripping Relay Word bits when the differential elements operate.

Selecting Event Digital Elements

Specify the digital elements in the digital section of the event report by using the Event Reporting Digital Elements settings found in the Report settings (the **SET R** command from a terminal or the Report branch of the Settings tree view of the ACSELERATOR software). You can enter at least 647 Relay Word bits from at least 73 Relay Word bit rows in the event report. The **#** symbol places a blank column in the digital report. Use the **#** symbol to organize the digital section of the event report. See *Report Settings on page R.8.29* for a list of the default programmed digital elements.

Event Summary Section of the Event Report

The third portion of an event report is the summary section. See *Figure 3.10* for the location of items included in a sample summary section of an event report. If you want to exclude the summary portion from an event report, use the **EVE NSUM** command. See *EVENT on page R.7.14* for details.

The information in the summary portion of the event report is the same information in the event summary, except that the report header does not appear immediately before the event information when you view a summary in the event report. See *Event Summary on page A.3.24* for a description of the items in the summary portion of the event report.

```
=>>SUM <Enter>

Relay 1                                      Date: 03/02/2003  Time: 12:33:51.078
                                             Serial Number: 2003030400
Event: 87BTR                                                   Time Source: OTHER
Event Number: 10057                                                       Group: 1
Targets: TLED_1 TLED_6 TLED_7 TLED_8

Fault:       I01   I02   I03   I04   I05   I06   I07   I08   I09   I10   I11
MAG(A)     14964 14966 14968 14969 14957 14966 22146 22138 22135 14960 14959
ANG(DEG)     178    59   -61   179    59   -61     0  -120   120  -179    61
             I12   I13   I14   I15   I16   I17   I18   V01   V02   V03
MAG(A/kV)  14973 14967 14964 14968 22140 22134 22136  67.8  67.8  67.8
ANG(DEG)     -59  -178    62   -58     2  -117   123     0  -120   121

Tripped Terminals
    I07         I08         I09         I10         I11         I12
    I16         I17         I18

Bus-Zones in Protection Zone 4
    BZ4

Bus-Zones in Protection Zone 5
    BZ5

Bus-Zones in Protection Zone 6
    BZ6

=>>
```

Figure 3.10 Summary Section of the Event Report

Settings Section of the Event Report

The final portion of an event report is the settings section. See *Figure 3.11* for the locations of items included in a sample settings section of an event report. If you want to exclude the settings portion from an event report, use the **EVE NSET** command. See *EVENT on page R.7.14* for details.

The settings portion of the event report lists important relay settings at the time the relay event triggered. The event report shows group, zone configuration settings, global, output, protection SELOGIC control equation settings, and alias settings. For the group settings, zone configuration, and protection SELOGIC control equation settings, the relay reports only the active group. The settings order in the event report is the same order as when you issue a **SHOW** command from a terminal. See *SHOW on page R.7.37* for information on the **SHOW** command, and *Making Simple Settings Changes on page U.4.12* for information on relay settings.

```
Group 1

Relay Configuration

E87SSUP := N        ECSL    := N        ETOS    := 5        EBFL    := 6
E50     := N        E51     := N        EVOLT   := Y        EADVS   := N

.
.
.
Trip Logic

TR01    := 87BTR01 OR 87BTR04
ULTR01  := NA
.
.
.
Zone Config Group 1

Potential Transformer Ratio

PTR1    := 2000     PTR2    := 2000     PTR3    := 2000

Current Transformer Ratio

CTR01   := 600      CTR02   := 600      CTR03   := 600      CTR04   := 600
.
.
.
Global

General Global Settings

SID     := "Station A"
RID     := "Relay 1"
.
.
.
Output

Main Board

OUT101  := LOND_A OR LOND_B OR LOND_C
.
.
.
Protection 1

1: PLT01S := PCT02Q AND NOT DIFF_EN # DIFFERENTIAL ENABLED
.
.
.
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: 87Z1,"WEST_A"
.
.
.
28: TRIP18,"CANB_C"
```

Active Group Settings

Active Zone Configuration Settings

Global Settings

Output Settings

Protection Logic Settings

Alias Settings

Figure 3.11 Settings Section of the Event Report

CEVENT

The relay provides a Compressed ASCII event report for SCADA and other automation applications. The ACSELERATOR software uses Compressed ASCII commands to gather event report data. If you want to view the Compressed ASCII event report data, use a terminal to issue the **CEV** command. A sample of the report appears in *Figure 3.12*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII event report are similar to the event, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order. Contact your local Technical Service Center or the SEL factory for the latest inventory of the items and item order in the Compressed ASCII event report.

See *SEL Compressed ASCII Commands on page R.4.4* and *Section 7: ASCII Command Reference in the Reference Manual* for more information on the Compressed ASCII command set.

```
=>>CEV <Enter>
"FID","RID","SID","03E2"
"FID=SEL-487B-R102-V0-Z001001-D20030724","Relay 1","Station A","0F5F"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","0C6A"
4,21,2003,6,57,13,441,960,"04FA"
```

Report Header

```
"EVENT_NUM","FREQ","NFREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","SER_NUM","PRIM_
VAL","CTR_I01","CTR_I02","CTR_I03","CTR_I04","CTR_I05","CTR_I06","CTR_I07","CTR_
I08","CTR_I09","CTR_I10","CTR_I11","CTR_I12","CTR_I13","CTR_I14","CTR_I15","CTR_
I16","CTR_I17","CTR_I18","PTR_V01","PTR_V02","PTR_V03","EVENT","TIME_SOURCE","GR
OUP","TARGETS","MB_TRIGGER","MB_TRIP","TRIP_TERM","BZ_IN_ZONE1","BZ_IN_ZONE2","B
Z_IN_ZONE3","BZ_IN_ZONE4","BZ_IN_ZONE5","BZ_IN_ZONE6","I01","I01_DEG","I02","I02
_DEG","I03","I03_DEG","I04","I04_DEG","I05","I05_DEG","I06","I06_DEG","I07","I07
_DEG","I08","I08_DEG","I09","I09_DEG","I10","I10_DEG","I11","I11_DEG","I12","I12
_DEG","I13","I13_DEG","I14","I14_DEG","I15","I15_DEG","I16","I16_DEG","I17","I17
_DEG","I18","I18_DEG","V01","V01_DEG","V02","V02_DEG","V03","V03_DEG","BB17"
```

Summary Labels

```
10057,60.00,60,4,4,15,"0000000000","YES",600,600,600,600,600,600,600,600,600,600
,600,600,600,600,600,600,600,600,2000,2000,2000,"87BTR","OTHER",1,"TLED_1 TLED_6
 TLED_7 TLED_8","0000000000","0000000000","I07 I08 I09 I10 I11 I12 I16 I17 I18",
" "," "," ","BZ4","BZ5","BZ6",14964,178,14966,59,14968,-61,14969,179,14957,59,14
966,-61,22146,0,22138,-120,22135,120,14960,-179,14959,61,14973,-59,14967,-178,14
964,62,14968,-58,22140,2,22134,-117,22136,123,67.8,0,67.8,-120,67.8,121,"5D61"
```

Summary Data

```
"I01(A)","I02(A)","I03(A)","I04(A)","I05(A)","I06(A)","I07(A)","I08(A)","I09(A)"
,"I10(A)","I11(A)","I12(A)","I13(A)","I14(A)","I15(A)","I16(A)","I17(A)","I18(A)
","V01(kV)","V02(kV)","V03(kV)","IOP1","IRT1","IOP2","IRT2","IOP3","IRT3","IOP4"
,"IRT4","IOP5","IRT5","IOP6","IRT6","VDC1","TRIG","WEST_A WEST_B WEST_C EAST_A E
AST_B EAST_C LON_BF NEW_BF CAN_BF SEC_BF DIFF_EN BF_EN TNS LOND_A LOND_B LOND_C 
SEC2_A SEC2_B SEC2_C NEWY_A NEWY_B NEWY_C SEC1_A SEC1_B SEC1_C CANB_A CANB_B CAN
B_C","37E6"
```

Column Labels

```
861,-1146,277,872,-1142,266,439,-568,124,901,-1127,216,907,-1122,206,455,-558,94
,99.4,-126.8,26.2,0.00,0.80,0.00,0.80,0.00,0.79,0.00,0.79,0.00,0.80,0.00,0.79,28
.33, ,"0030000","2180"
829,339,-1162,820,352,-1159,401,185,-580,789,393,-1174,775,411,-1174,380,211,-58
4,89.3,42.2,-131.0,0.00,0.80,0.00,0.80,0.00,0.79,0.00,0.79,0.00,0.80,0.00,0.79,2
8.33, ,"0030000","21A5"
-862,1147,-276,-873,1142,-265,-438,568,-125,-902,1127,-216,-910,1122,-206,-459,5
58,-95,-99.4,126.8,-26.2,0.00,0.80,0.00,0.80,0.00,0.79,0.00,0.80,0.00,0.80,0.00,
0.79,28.32, ,"0030000","22B3"
-831,-342,1164,-818,-352,1161,-401,-185,582,-786,-394,1175,-771,-410,1177,-378,-
211,584,-89.3,-42.2,131.0,0.01,0.80,0.00,0.80,0.00,0.80,0.00,0.79,0.00,0.80,0.00
,0.79,28.33, ,"0030000","22D4"
.
.
.

2792,-5466,2663,93.0,-112.3,18.1,0.01,0.75,0.01,1.56,0.00,1.35,2.04,2.17,4.40,4.
41,2.35,2.52,28.32,">","1C301FF","2529"
```

Event Data

Trigger

```
-3399,301,3096,-3381,252,3142,5933,478,-6428,-3304,-47,3354,-3282,-131,3424,5721
,1056,-6813,72.3,41.1,-112.9,0.01,2.30,0.02,2.18,0.02,2.35,5.39,5.41,4.43,4.44,6
.01,6.02,28.32, ,"1C301FF","23E8"
6481,-10043,3496,6572,-10045,3431,-10565,15503,-4900,6862,-10098,3164,6956,-1011
5,3078,-11115,15543,-4341,-68.5,81.0,-11.7,0.03,4.90,0.02,6.70,0.03,3.60,10.74,1
0.74,13.72,13.73,6.91,6.92,28.32, ,"1C301FF","2784"
8983,2019,-10965,8901,2120,-11025,-13155,-3801,16970,8601,2731,-11307,8511,2906,
-11390,-12565,-4856,17455,-50.3,-30.7,80.7,0.04,7.55,0.03,6.84,0.03,7.69,14.88,1
4.88,14.23,14.24,15.79,15.80,28.32, ,"1C301FF","2815"
-10822,14336,-3423,-10940,14297,-3287,16439,-21057,4554,-11304,14107,-2692,-1141
7,14053,-2510,17099,-20708,3453,50.5,-64.3,13.1,0.05,9.39,0.04,9.64,0.05,7.66,18
.82,18.83,19.01,19.01,15.66,15.66,28.33, ,"1C301FF","28FE"
-10335,-4297,14572,-10217,-4394,14600,14840,6832,-21661,-9800,-4977,14729,-9677,
-5140,14756,14065,7815,-21866,45.2,21.5,-66.5,0.06,9.98,0.03,9.97,0.05,9.98,19.7
5,19.75,19.74,19.74,19.74,19.75,28.33,"*","1C301FF","2955"
10824,-14331,3424,10940,-14295,3285,-16437,21055,-4552,11304,-14104,2690,11413,-
```

Largest Current

```
.
.
.
"SETTINGS","02E1"
"
Group 1

Relay Configuration

E87SSUP := N        ECSL    := N        ETOS    := 5        EBFL    := 6
E50     := N        E51     := N        EVOLT   := Y        EADVS   := N

.
.
.

Trip Logic

TR01    := 87BTR01 OR 87BTR04
ULTR01  := NA
.
.
.
```

Active Group Settings

```
Zone Config Group 1

Potential Transformer Ratio

PTR1    := 2000     PTR2    := 2000     PTR3    := 2000

Current Transformer Ratio

CTR01   := 600      CTR02   := 600      CTR03   := 600      CTR04   := 600
CTR05   := 600      CTR06   := 600      CTR07   := 600      CTR08   := 600
.
.
.
```

Active Group Zone
Configuration Settings

```
Global

General Global Settings

SID     := Station A
RID     := Relay 1
.
.
.
```

Global Settings

```
Output

Main Board

OUT101  := LOND_A OR LOND_B OR LOND_C
.
.
.
```

Output Settings

```
Protection 1

1: PLT01S := PCT02Q AND NOT DIFF_EN # DIFFERENTIAL ENABLED
.
.
.
```

Active Protection
Logic Settings

```
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: 87Z1,WEST_A
.
.
.

28: TRIP18,CANB_C
","98DA"

=>>
```

Alias Settings

Figure 3.12 Sample Compressed ASCII Event Report

The order of the labels in the Column Labels data group matches the order of the Relay Word bits in the event report when read from left to right. For example, refer to the Column Labels data group and find the label TRIG. Look lower on the page at the Trigger data group, and identify the > symbol. The TRIG label in the Column Labels data group corresponds to the > symbol in the Event Data group. Next to the > symbol appears a hexadecimal number

(`1C301FF`). Each numeral of this hexadecimal number reports the status of four Relay Word bits in the event report. The first numeral (`1`) of the hexadecimal number `1C301FF` reports the status of the first four Relay Word bits in the event report, i.e., WEST_A, WEST_B, WEST_C, and EAST_A. Because each hexadecimal numeral represents four Relay Word bits, the binary number is 0001. Binary number 0001 tells us that of the four Relay Word bits in this group, only the fourth Relay Word bit (EAST_A) asserted, i.e., WEST_A = 0, WEST_B = 0, WEST_C = 0, and EAST_A = 1.

The next group of four Relay Word bits in the event report comprises EAST_B, EAST_C, LON_BF, and NEW_BF, represented by `C` in `1C301FF`. The binary equivalent of `C` is 1100, telling us that only the first two Relay Word bits (EAST_B and EAST_C) of the four Relay Word bits in the group asserted.

The first sample of Cycle [6] (see *Figure 3.8*) shows that elements EAST_A, EAST_B, and EAST_C (as well as other elements) are picked up.

Event Files Download

You can download the event file from the relay and save these files to a PC to keep it as a record or examine it later. Use a terminal emulation program with file transfer capability. For example:

Step 1. Type **FILE READ EVENTS E24_10007.TXT <Enter>** at an Access Level 1 prompt or higher to download a 24-samples/cycle event report with serial number 10007.

Step 2. Start the terminal download routine to store the file on your computer.

Use Y modem protocol.

Step 3. If you want the Compressed ASCII file, type **FILE READ EVENTS C24_10007.TXT <Enter>**.

In addition, you can use the ACSELERATOR software to download event files. See *Retrieving Event Report Data Files: Terminal Emulation Software on page U.4.36* and *Section 3: PC Software in the User's Guide* for more information on event report file download procedures.

Event Summary

You can retrieve a shortened version of stored event reports as event summaries. These short-form reports present vital information about a triggered event. The relay generates an event in response to power system faults and other trigger events (see *Triggering Data Captures and Event Reports on page A.3.3*). See *Figure 3.13* for a sample event summary.

```
Relay 1                                         Date: 03/30/2003  Time: 18:02:37.099
Station A                                       Serial Number: 2003004005

Event: 87BTR                                                   Time Source: OTHER
Event Number: 10057                                                   Group: 1
Targets: TLED_1 TLED_6 TLED_7 TLED_8

Fault:       I01   I02   I03   I04   I05   I06   I07   I08   I09   I10   I11
MAG(A)     14964 14966 14968 14969 14957 14966 22146 22138 22135 14960 14959
ANG(DEG)     178    59   -61   179    59   -61     0  -120   120  -179    61
             I12   I13   I14   I15   I16   I17   I18   V01   V02   V03
MAG(A/kV)  14973 14967 14964 14968 22140 22134 22136  67.8  67.8  67.8
ANG(DEG)     -59  -178    62   -58     2  -117   123     0  -120   121

Tripped Terminals
    I07         I08         I09         I10         I11         I12
    I16         I17         I18

Bus-Zones in Protection Zone 4
    BZ4

Bus-Zones in Protection Zone 5
    BZ5

Bus-Zones in Protection Zone 6
    BZ6
```

Report Header

Event Information

Fault Data

Terminals Tripped

Bus-Zones in the Protection Zone

Figure 3.13 Sample Event Summary Report

The event summary contains the following:

- Standard report header
  - Relay and terminal identification
  - Event date and time
- Event type
- Time source
- Event number
- Active settings group at trigger time
- Targets
- Fault currents and voltages
- Tripped terminals
- Bus-Zones in protection zone

Targets are displayed only if a rising edge of Relay Word bits 87BTR, SBFTR, or TRIP asserted before the end of the event report. When a trip occurs, the relay displays the aliases of the latched targeting bits asserted on the last row of the event. Current and voltage analog quantities in the summary are the values 1.25 cycles after the event trigger.

Table 3.9 defines the various event types in fault reporting priority. Fault event type 87BTR (busbar protection trip) has reporting priority over event type SBFTR (breaker failure). If more than one event type asserts, the relay reports only the highest priority event type. For example, you can trigger an event when there is no fault condition on the power system by using the **TRI** command. In this case, when there is no fault, the relay reports the event type as TRIG.

Table 3.9 Event Types

Event Type	Event Trigger
87BTR	Rising edge of Relay Word Bit 87BTR, the OR combination of a busbar protection trip output to any Terminal.
SBFTR	Rising edge of Relay Word Bit SBFTR, the OR combination of a breaker failure trip output to any Terminal.
TRIP	Rising edge of Relay Word Bit TRIP.
ER	The relay generates the event with elements in the SELOGIC control equation ER.
TRIG	The relay generates the event in response to the **TRI** command.

Viewing the Event Summary

Access the event summary from the communications ports or from the communications card. View and download history reports from Access Level 1 and higher. You can independently acknowledge a summary (with the **SUM ACK** command) at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve a complete set of summary reports.

To acknowledge and remove a summary, first use the **SUM N(EXT)** command to view that summary. Use the **SUM** command to retrieve event summaries by date or date range and by event number. (The relay labels each new event with a unique number as reported in the **HIS** command history report; see *Event History on page A.3.27*.)

Table 3.10 lists the **SUM** commands. See *SUMMARY on page R.7.41* for complete information on the **SUM** command.

Table 3.10 SUM Command

Command	Description
SUM	Return the most recent event summary.
SUM *n*	Return an event summary for event n[a].
SUM ACK	Acknowledge the oldest unacknowledged event summary on at the present communications port.
SUM NEXT	View the oldest unacknowledged event summary at the present communications port.

[a] Parameter n indicates event order or serial number; see Event Numbering on page A.3.7 for more information.

You can retrieve event summaries with the ACSELERATOR software. See *Analyze Events on page U.3.15* for information and examples.

CSUMMARY

The relay outputs a Compressed ASCII summary report for SCADA and other automation applications. Issue the **CSU** command to view the Compressed ASCII summary report. A sample of the summary report appears in *Figure 3.14*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII summary report are similar to those included in the summary report, although the relay reports the items in a special order.

See *SEL Compressed ASCII Commands on page R.4.4* and *Section 7: ASCII Command Reference in the Reference Manual* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03E2"
"Relay 1","Station A","FID=SEL-487B-R102-V0-Z001001-D20030724","0F59"
"EVENT_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","TIME_
SOURCE","GROUP","TARGETS","MB_TRIGGER","MB_TRIP","TRIP_TERM","BZ_IN_ZONE1","BZ_I
N_ZONE2","BZ_IN_ZONE3","BZ_IN_ZONE4","BZ_IN_ZONE5","BZ_IN_ZONE6","I01","I01_DEG"
,"I02","I02_DEG","I03","I03_DEG","I04","I04_DEG","I05","I05_DEG","I06","I06_DEG"
,"I07","I07_DEG","I08","I08_DEG","I09","I09_DEG","I10","I10_DEG","I11","I11_DEG"
,"I12","I12_DEG","I13","I13_DEG","I14","I14_DEG","I15","I15_DEG","I16","I16_DEG"
,"I17","I17_DEG","I18","I18_DEG","V01","V01_DEG","V02","V02_DEG","V03","V03_DEG"
,"822E"
10057,3,30,2003,18,2,37,99,600,"87BTR","OTHER",1,"TLED_1 TLED_6 TLED_7 TLED_8","
0000000000","0000000000","I07 I08 I09 I10 I11 I12 I16 I17 I18"," "," "," ","BZ4"
,"BZ5","BZ6",14964,178,14966,59,14968,-61,14969,179,14957,59,14966,-61,22146,0,2
2138,-120,22135,120,14960,-179,14959,61,14973,-59,14967,-178,14964,62,14968,-58,
22140,2,22134,-117,22136,123,67.8,0,67.8,-120,67.8,121,"4B06"
```

Report Header

Report Labels

Report Data

Figure 3.14 Sample Compressed ASCII Summary

Event History

The event history gives you a quick look at recent relay activity. The relay labels each new event with a unique number from 10000 to 42767. (At 42767, the top of the numbering range, the relay returns to 10000 for the next event number and then continues to increment.) See *Figure 3.15* for a sample event history.

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Event date and time
- Event type
- Time source
- Event number
- Active settings group at trigger time
- Targets
- Fault currents and voltages
- Tripped terminals
- Bus-Zones in protection zones

Figure 3.15 is a sample event history from a computer terminal.

```
=>>HIS <Enter>

Relay 1                                      Date: 05/06/2003  Time: 06:53:08.568
Station A                                    Serial Number: 2003004005

#       DATE        TIME      EVENT  GRP  TARGETS
10050 05/06/2003 06:52:59.807  87BTR   2   87_DIFF ZONE_2
.
.
.
10004 05/06/2003 06:51:20.646  ER      2
10003 05/06/2003 06:51:15.648  87BTR   1   87_DIFF ZONE_1
10002 05/06/2003 06:50:22.751  ER      1

10001 05/06/2003 06:50:17.758  87BTR   1   87_DIFF ZONE_1
10000 05/06/2003 06:46:22.656  TRIG    1
```

Event Number | Event Type | Active Group

Figure 3.15 Sample Event History

The event types in the event history are the same as the event types in the event summary. See *Table 3.5* for event types.

The event history report indicates events stored in relay nonvolatile memory. The relay places a blank row in the history report output; items that are above the blank row are available for viewing (use the **EVE** and **CEV** commands). Items that are below the blank row are no longer in relay memory; these events appear in the history report to indicate past power system performance. The relay does not ordinarily modify the numerical or time order in the history report. However, if an event report is corrupted (power was lost during storage, for example), the relay lists the history report line for this event after the blank row.

Viewing the Event History

Access the history report from the communications ports and communications cards.

Step 1. View and download history reports from Access Level 1 and higher.

Step 2. You can also clear or reset history data from Access Levels 1 and higher.

a. You can independently clear/reset history data at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete history reports.

b. You can also clear all history data from all ports (with the **HIS CA** and **HIS RA** commands).

Step 3. Use the **HIS** command from a terminal to obtain the event history.

Step 4. You can view event histories by date or by date range, or you can specify the number of the most recent events that the relay returns.

See *HISTORY on page R.7.17* for information on the **HIS** command. *Table 3.11* lists the **HIS** commands.

Table 3.11 HIS Command

Command	Description
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *k*	Return the *k* most recent event summaries with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *date1*	Return the event summaries on date *date1*.
HIS *date1 date2*	Return the event summaries from *date1* to *date2*, with *date1* at the bottom of the list and *date2* at the top of the list.
HIS C	Clear/reset all event data on the present port only.
HIS R	Clear/reset all event data on the present port only.
HIS CA	Clear event data for all ports.
HIS RA	Clear event data for all ports.

Step 5. You can use the ACSELERATOR software to retrieve the relay event history. See *Analyze Events on page U.3.15* for information and examples.

CHISTORY

NOTE: The **CHI A** option outputs compressed summary (**CSU**) information. This format displays the **CSU** labels, followed by **CSU** data for each record.

The relay outputs a Compressed ASCII history report for SCADA and other automation applications. Issue the **CHI** command to view the Compressed ASCII history report. A sample of the report appears in *Figure 3.16*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of each history in the Compressed ASCII history report. Items included in the Compressed ASCII history report are similar to those included in the history report.

See *SEL Compressed ASCII Commands on page R.4.4* and *Section 7: ASCII Command Reference in the Reference Manual* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03E2"
"Relay 1","Station A","FID=SEL-487B-R102-V0-Z001001-D20030724","0F59"
"REC_NUM","REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT
","GROUP","TARGETS","1818"
10057,1,3,30,2003,18,2,37,99,600,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","1038"
10056,2,3,30,2003,18,2,3,209,300,"TRIG",1," ","08D0"
10055,3,3,30,2003,18,0,36,494,0,"TRIG",1," ","08A7"
10054,4,3,30,2003,17,49,16,588,500,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","10A1
"
10053,5,3,30,2003,17,45,2,151,0,"TRIG",1," ","089E"
10052,6,3,30,2003,17,44,14,332,900,"ER",1," ","089B"
10051,7,3,30,2003,17,44,9,334,300,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","1061"
10050,8,3,30,2003,17,43,21,957,900,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","109B
"
10049,9,3,30,2003,17,36,29,576,700,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","10A9
"
10048,10,3,30,2003,17,29,16,320,400,"87BTR",1," ","0988"
10047,11,3,30,2003,17,23,18,689,900,"87BTR",1," ","099B"
```

Report Header
Report Labels
Report Data

Figure 3.16 Sample Compressed ASCII History Report

History File Download

You can also download the history report file from the relay.

Step 1. Use a terminal emulation program with file transfer capability.

Step 2. At an Access Level 1 prompt or higher type **FILE READ REPORTS HISTORY.TXT <Enter>**.

Step 3. Start the terminal download routine to store the file on your computer.

Step 4. If you want the Compressed ASCII file, type **FILE READ REPORTS CHISTORY.TXT <Enter>**.

In addition, you can use the ACSELERATOR software to download history files. See *Retrieving Event Report Data Files: Terminal Emulation Software on page U.4.36* for file download procedures.

Combined Event Report

Each SEL-487B provides event reports for analysis with software such as the SEL-5601 Analytic Assistant product. For stations with more than six terminals, the busbar protection requires three SEL-487B relays. Except for single-phase faults, all other faults involve at least two SEL-487B relays. For example, an A-phase to B-phase fault operates the differential element in the A-phase relay, as well as the differential element in the B-phase relay. For post-fault analysis, you need to consider two different event reports from two different relays.

With the SEL-5601 Analytic Assistant, you can display events from three different relays in one window to make the fault analysis easier and more meaningful. Because the three different relays time-stamp the events with values from their individual clocks, first you need to time-synchronize the three SEL-487B relays.

Time Synchronization

Each SEL-487B relay provides two IRIG-B connectors, labeled IN and OUT. Referring to the external source connections in *Figure 3.17*, connect the IRIG-B signals to the IN connection of Relay A to update the clock of Relay A. Connect the OUT connection of Relay A to the IN connector of Relay B to update the clock in Relay B. A similar connection between Relay B and Relay C updates the time in Relay C.

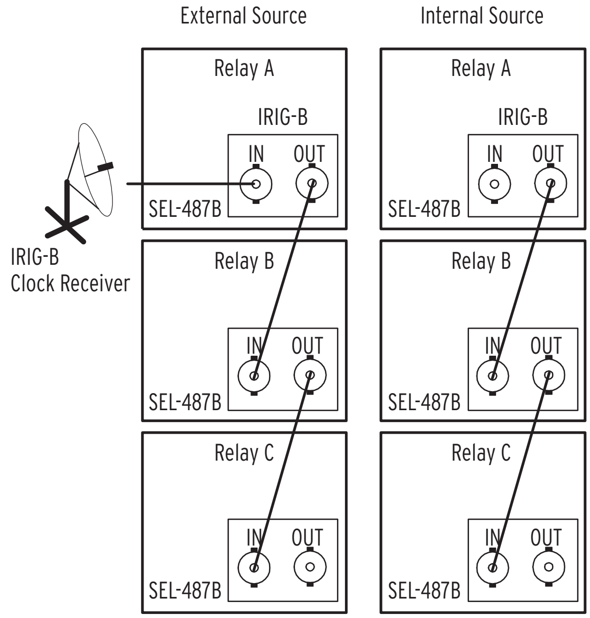

Figure 3.17 Time Synchronization Connections Between Three Relays

In the absence of an external IRIG-B signal, connect the relays as shown by the internal source connections in *Figure 3.17*. Connected this way, Relay B uses the clock of Relay A as time reference, and Relay C uses the clock of Relay B as time reference.

SEL-5601 Analytic Assistant

See *Section 3: PC Software in the User's Guide* for a full description of the use of the SEL-5601 Analytic Assistant.

SER (Sequential Events Recorder)

The SEL-487B SER (Sequential Events Recorder) gives you detailed information on relay states and relay element operation. The SER captures and time tags state changes of Relay Word bit elements and relay conditions. These conditions include power up, relay enable and disable, group changes, settings changes, memory overflow, diagnostic restarts, and SER automatic removal and reinsertion. The SEL-487B stores the latest 1000 SER entries to nonvolatile memory. *Figure 3.18* is a sample SEL-487B SER report.

The SER report contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
- SER number
- SER date and time
- Relay element or condition
- Element state

```
Relay 1                                    Date: 07/24/2003  Time: 18:39:05.882
Station A                                  Serial Number: 2003004005

FID=SEL-487B-R102-V0-Z001001-D20030724

#      DATE        TIME          ELEMENT            STATE
20   03/30/2003  18:00:34.277   Settings changed     Class T 1
.
.
.
1    03/30/2003  18:02:37.185   87BTR18              Deasserted
```

SER Number | Relay Element or Condition | Element State

Figure 3.18 Sample SER Report

In the SER report, the oldest information has the highest number. The newest information is always #1. When using a computer terminal you can order the positions of the SER records in the SER report. See *Table 3.12* or *SER on page R.7.30*.

Viewing the SER Report

The relay displays the SER records in ASCII and binary formats. For more information on binary SER messaging, see *Section 4: SEL Communications Protocols in the Reference Manual*.

Access the SER report from the communications ports and communications cards in Access Level 1 and higher. Clear or reset SER data from Access Levels 1, B, P, A, O, and 2. You can independently clear/reset SER data at each communications port (with the **SER CV** and **SER RV** commands) so that you and users at other ports (SCADA, Engineering, for example) can retrieve complete SER reports. You can also clear all SER data from all ports (with the **SER CA** command).

Use an ASCII terminal or the ACSELERATOR software to examine SER records. You can use the **SER** command to view the SER report by date, date range, SER number, or SER number range.

The relay labels each new SER record with a unique number. See *Table 3.12* or *Section 7: ASCII Command Reference in the Reference Manual* for more information on the **SER** command.

Table 3.12 SER Commands (Sheet 1 of 2)

Command	Description
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *m n*	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.

Table 3.12 SER Commands (Sheet 2 of 2)

Command	Description
SER *date1*	Return the SER records on date *date1*.
SER *date1 date2*	Return the SER records from *date1* at the top of the list to *date2* at the bottom of the list.
SER C and **SER R**	Clear SER records on the present port.
SER CA and **SER RA**	Clear SER data for all ports.
SER CV and **SER RV**	Clear viewed SER records on the present port.
SER D	List chattering SER elements that the relay has removed from the SER records.

You can retrieve SER records with the ACSELERATOR software. See *Viewing SER Records on page U.4.37* for information and examples. The latest 200 SER events are viewable on the front-panel display through the front-panel EVENTS MENU (see *Front-Panel Operations on page U.5.1 in the User's Guide*).

CSER

The relay outputs a Compressed ASCII SER report for SCADA and other automation applications. Issue the **CSE** command to view the Compressed ASCII SER report. A sample of the SER report appears in *Figure 3.19*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

See *SEL Compressed ASCII Commands on page R.4.4* and *CSER on page R.7.9* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-487B-R102-V0-Z001001-D20030724","0e49"
"#","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","ELEMENT","STATE","0FC8"
1,3,30,2003,18,2,37,185,"87BTR18","Deasserted","0B33"
2,3,30,2003,18,2,37,185,"87BTR17","Deasserted","0B33"
3,3,30,2003,18,2,37,185,"87BTR12","Deasserted","0B2F"
4,3,30,2003,18,2,37,185,"87BTR11","Deasserted","0B2F"
```

Report Header

SER Data

Figure 3.19 Sample Compressed ASCII SER Report

SER File Download

You can also download the SER data as a file from the relay.

Step 1. Use a terminal emulation program with file transfer capability.

Step 2. At an Access Level 1 prompt or higher type **FILE READ REPORTS SER.TXT <Enter>**.

Step 3. Start the terminal download routine to store the file on your computer.

Step 4. If you want the Compressed ASCII file, type **FILE READ REPORTS CSER.TXT <Enter>**.

See *Downloading an SER Report File on page U.4.39* for SER file download procedures.

Setting SER Points and Reporting Names

You program the relay elements that trigger an SER record. You can select from as many as 250 elements. These triggers, or points, can include control input and control output state changes, element pickups and dropouts, and so on. You can also change the names of the elements and set reporting names for the element clear and set states.

Use the **SET R** command from a terminal, or use the ACSELERATOR software Report branch of the Settings tree view to enter SER Points.

Step 1. Use the text-edit line mode settings method to enter or delete SER elements (see *Text-Edit Mode Line Editing on page U.4.18*).

Step 2. To set an SER element, enter the five items of this comma-delimited string (all but the first parameter are optional):

Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

Reporting names can contain any printable ASCII character. See *Viewing SER Records on page U.4.37* for examples of entering SER data.

The relay defaults to the element name when you do not provide a reporting name. The defaults for the set and clear states are Asserted and Deasserted, respectively. By default, SER Points are not configured for HMI alarm display. The relay always creates an SER record for power-up, relay enable and relay disable, any group change and settings change, diagnostic restart, and memory overflow. For a setting example, see *Viewing SER Records*.

Automatic Deletion and Reinsertion

The SER also includes an automatic deletion and reinsertion function. The relay automatically deletes oscillating SER items from SER recording. This function prevents overfilling the SER buffer with chattering information. To use the automatic deletion and reinsertion function, proceed with the following steps:

Step 1. Set Report setting ESERDEL (Enable SER Delete) to Y to enable this function.

Step 2. Select values for the setting SRDLCNT (SER Delete Count) and the setting SRDLTIM (SER Delete Time) that mask the chattering SER element.

The relay removes an item from all SER recordings once a point has changed state more than SRDLCNT times in an SRDLTIM period. Once deleted from SER recording, the relay ignores the item for a 10 • SRDLTIM period.

At the end of this period, the relay checks the chatter criteria and, if the point does not exceed the criteria, the relay automatically reinserts the item into SER recording.

Use the **SER D** command to see a list of deleted SER points (see *SER on page R.7.30*).

Section 4
SEL Communications Processor Applications

Overview

This section describes applications where the SEL-487B Relay is applied in a system integration architecture that includes the SEL-20xx family (SEL-2020, SEL-2030, SEL-2032) of communications processors. This section contains the following topics:

- Introduction to the SEL communications processor family
- SEL-487B and SEL communications processor architecture
- Example SEL-487B with SEL communications processor Application

For detailed application examples using the SEL Communications Processors, see the SEL library of Application Guides on our website at www.selinc.com.

SEL Communications Processor

SEL offers the SEL-2020, SEL-2030, and SEL-2032 Communications Processors, powerful tools for system integration and automation.

The SEL-2020, SEL-2030, and SEL-2032 hardware are similar, except that the SEL-2020 does not support network protocol cards. Both the SEL-2030 and SEL-2032 support as many as two network protocol cards. The SEL-2032 supports relay SER time tagging of data used for DNP; the SEL-2020 and the SEL-2030 do not. The SEL-20xx family provides a single point of contact for integration networks with a star topology as shown in *Figure 4.1*.

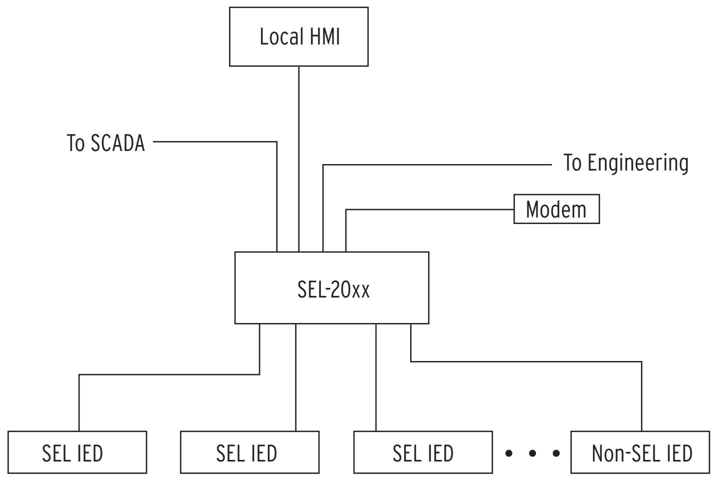

Figure 4.1 SEL-20xx Star Integration Network

In the star topology network in *Figure 4.1* the SEL communications processors offer the following substation integration functions:

- Collection of real-time data from SEL and non-SEL IEDs
- Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Distribution of IRIG-B time synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Automated dial-out on alarms

The SEL communications processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure 4.2*. In this multitiered system, the lower-tier SEL communications processors forward data to the upper-tier SEL communications processor that serves as the central point of access to substation data and station IEDs.

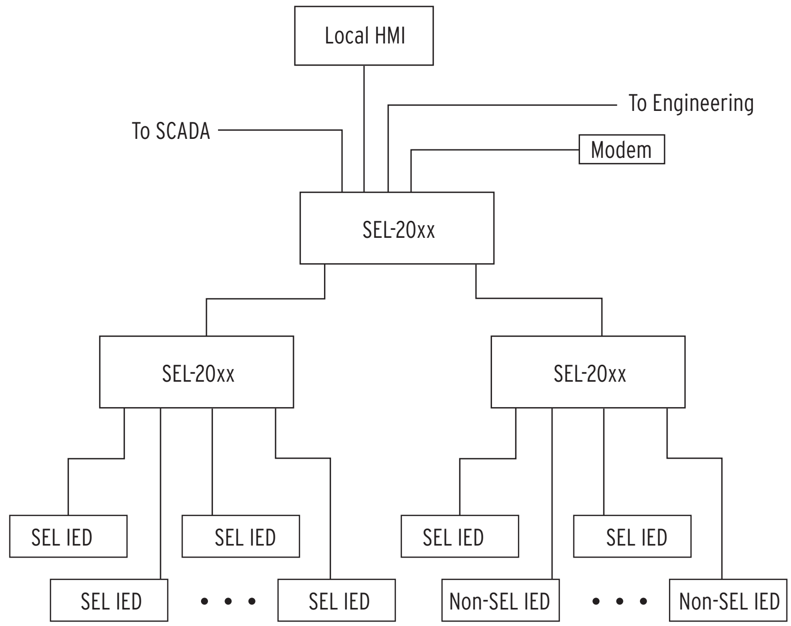

Figure 4.2 Multitiered SEL-20xx Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. The SEL-20xx family of communications processors provides an integration solution with MTBF (mean time between failures) that is 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure the SEL-20xx family with a system of communication-specific keywords and data movement commands rather than programming in C or another general-purpose computer language. The SEL communications processors offer the protocol interfaces listed in *Table 4.1*.

Table 4.1 SEL-2020, SEL-2030, and SEL-2032 Communications Processor Protocol Interfaces

Protocol	Connect to
DNP3 Level 2 Slave	DNP3 masters (serial)
Modbus® RTU Protocol	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus®[a]	Modbus Plus peers with global data and Modbus Plus masters
DNP3 Level 2 Slave (Ethernet)[b]	DNP3 masters (Ethernet)
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol peers

[a] SEL-2030 and SEL-2032 only, requires SEL-2711 Modbus Plus protocol card.
[b] SEL-2030 and SEL-2032 only, requires SEL-2701 Ethernet Processor.

SEL Communications Processors and SEL-487B Architecture

You can apply the SEL Communications Processors and the SEL-487B in a limitless variety of applications that integrate, automate, and improve station operation. Most of the system integration architectures utilizing the SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-487B and an SEL-20xx is shown in *Figure 4.1*. In this architecture, the SEL communications processor collects data from the SEL-487B and other station IEDs. The SEL-20xx acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The SEL communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the utilization efficiency on each link. A system that uses the SEL communications processor to provide a protocol interface to an RTU will have a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting the SEL communications processor directly to the SCADA master and eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface; so you can install, test, and even upgrade the system in the future without disturbing protective relays and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

NOTE: The communications processor Ethernet card supports components of UCA2 as a subset of IEC 61850.

The SEL communications processor equipped with an SEL-2701 can provide a UCA2 interface to SEL-487B relays and other serial IEDs. The SEL-2701 and SEL communications processor offer a significant cost savings because you can use existing IEDs or purchase less expensive IEDs. For full details on applying the SEL-2701 and SEL communications processor see the *SEL-2701 Ethernet Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the SEL-2701 or a serial port connection. This versatility will accommodate the channel that is available between the station and the engineering center. SEL software, including the ACSELERATOR QuickSet® SEL-5030 Software Program, can use either a serial port connection or an Ethernet network connection from an engineering workstation to the relays in the field.

Enhancing Multidrop Networks

You can also use the SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure 4.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI multidrop network. In the example, there are two Ethernet networks, the SCADA LAN and the Engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI (Human Machine Interface).

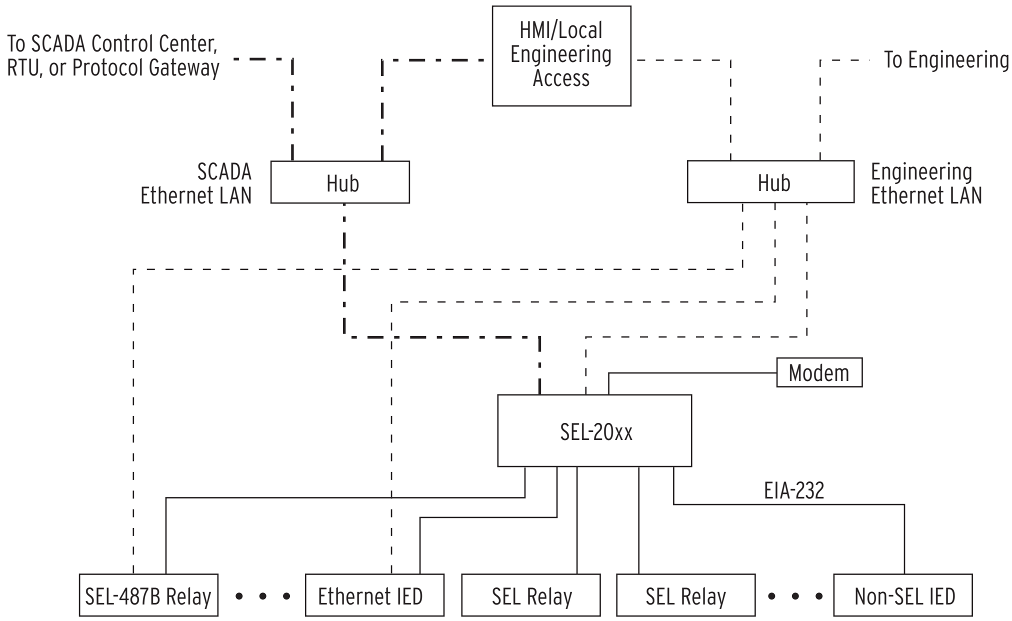

Figure 4.3 Enhancing Multidrop Networks With the SEL-20xx

In this example, the SEL-20xx provides the following enhancements when compared to a system that employs only the multidrop network:

- Ethernet access for IEDs with serial ports
- Backup engineering access through the dial-in modem
- IRIG-B time signal distribution to all station IEDs
- Integration of IEDs without Ethernet
- Single point of access for real-time data for SCADA, HMI, and other uses
- Significant cost savings by use of existing IEDs with serial ports
- Cost savings by installing Ethernet network interfaces in the SEL communications processor rather than in each relay

SEL Communications Processor Example

This example demonstrates the data and control points available in the SEL communications processor when you connect an SEL-487B. The station layout is shown in *Figure 4.5*. The busbar voltage is 230 kV, and the highest expected current on any feeder is 2000 A. The physical configuration used in this example is shown in *Figure 4.4*.

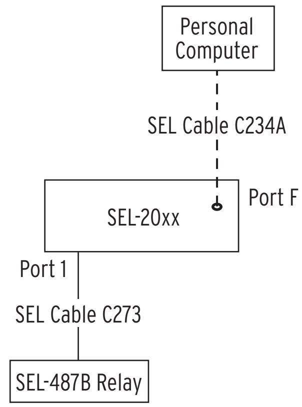

Figure 4.4 Example SEL-487B and SEL-20xx Configuration

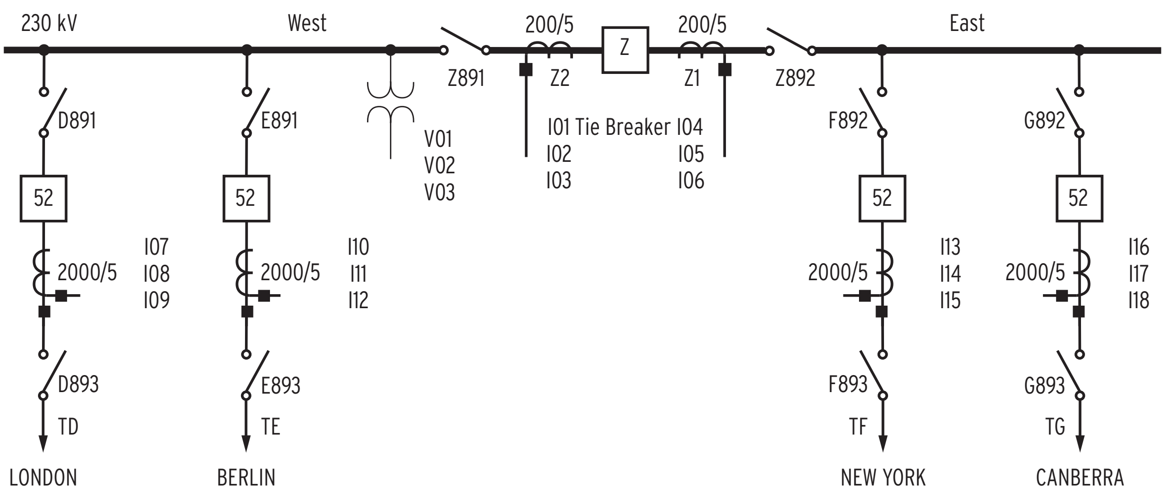

Figure 4.5 Substation Layout Showing Four Feeders and a Tie Breaker

Table 4.2 shows the port settings for Port 1 of the SEL communications processor.

Table 4.2 SEL Communications Processor Port 1 Settings (Sheet 1 of 2)

Setting Name	Setting	Description
DEVICE	S	Connected device is an SEL device
CONFIG	Y	Allow autoconfiguration for this device
PORTID	Relay 1	Name of connected relay[a]
BAUD	19200	Channel speed of 19200 bits per second[a]
DATABIT	8	Eight data bits[a]
STOPBIT	1	One stop bit

Table 4.2 SEL Communications Processor Port 1 Settings (Sheet 2 of 2)

Setting Name	Setting	Description
PARITY	N	No parity
RTS_CTS	Y	Hardware flow control enabled
TIMEOUT	5	Idle timeout that terminates transparent connections of 5 minutes

[a] Automatically collected by the SEL Communications Processor during autoconfiguration.

Data Collection

The SEL communications processor is configured to collect data from the SEL-487B using the list in *Table 4.3*.

Table 4.3 SEL Communications Processor Data Collection Automessages

Message	Data Collected
20METER	Selected SEL-487B automation math variables (AMVs)
20METER2	Binary METER database region[a]
20TARGET	Selected Relay Word bit elements
20TARGET2	Binary TARGET database region[a]
20STATUS	Relay status similar to the **CST** command
20STATUS2	Binary STATUS database region[a]
20HISTORY	History data similar to the **CHI** command
20HISTORY2	Binary HISTORY database region[a]
20EVENTL	Event data similar to the **CEV L** command
20LOCAL2	Binary LOCAL database region[a]
20ANALOGS2	Binary ANALOGS database region[a]
20STATE2	Binary STATE database region[a]
20D12	Binary D1 270x DNP database region[a]

[a] For detailed information regarding the database regions, see Communications Card Database on page R.3.23.

In this example, we only consider the 20METER and 20TARGET functions. *Table 4.4* shows the automessage (SET A) settings for the SEL communications processor.

Table 4.4 SEL Communications Processor Port 1 Automatic Messaging Settings (Sheet 1 of 2)

Setting Name	Setting	Description
AUTOBUF	Y	Save unsolicited messages
STARTUP	ACC*n*OTTER*n*	Automatically log on at Access Level 1
SEND_OPER	Y	Send Fast Operate messages for remote bit and breaker bit control
REC_SER	N	Automatic Sequential Event Recorder data collection disabled
NOCONN	NA	No SELOGIC control equation entered to selectively block connections to this port
MSG_CNT	2	Two automessages
ISSUE1	P00:00:01.0	Issue Message 1 every second
MESG1	20METER	Collect metering data

Table 4.4 SEL Communications Processor Port 1 Automatic Messaging Settings (Sheet 2 of 2)

Setting Name	Setting	Description
ISSUE2	P00:00:01.0	Issue Message 2 every second
MESG2	20TARGET	Collect Relay Word bit data
ARCH_EN	N	Archive memory disabled
USER	0	No USER region registers reserved

Table 4.5 shows the map of regions in the SEL communications processor for data collected from the SEL-487B.

Table 4.5 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Relay metering data
D2	Binary	TARGET	Relay Word bit data
D3–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

Table 4.6 shows the list of meter data available in the SEL-20xx and the location and data type for the memory areas within D1 (Data Region 1). The type field indicates the data type and size. The type “int” is a 16-bit integer. The type “float” is a 32-bit IEEE® floating point number. Because the number of terminals differs from substation to substation, the SEL-487B provides 21 automation math variables (AMV001 through AMV021) instead of dedicated meter values. This flexibility makes it possible to assign meter values to suit the substation. The communications processor treats these as vector quantities.

Table 4.6 SEL Communications Processor METER Region Map (Sheet 1 of 2)

Item	Starting Address	Type
_YEAR	2000h	int
DAY_OF_YEAR	2001h	int
TIME(ms)	2002h	int
MONTH	2003h	char
DATE	2004h	char
YEAR	2005h	char
HOUR	2006h	char
MIN	2007h	char
SECONDS	2008h	char
MSEC	2009h	int
AMV001	200Ah	float
AMV002	200Ch	float
AMV003	200Eh	float
AMV004	2010h	float
AMV005	2012h	float

Table 4.6 SEL Communications Processor METER Region Map (Sheet 2 of 2)

Item	Starting Address	Type
AMV006	2014h	float
AMV007	2016h	float
AMV008	2018h	float
AMV009	201Ah	float
AMV010	201Ch	float
AMV011	201Eh	float
AMV012	2020h	float
AMV013	2022h	float
AMV014	2024h	float
AMV015	2026h	float
AMV016	2028h	float
AMV017	202Ah	float
AMV018	202Ch	float
AMV019	202Eh	float
AMV020	2030h	float
AMV021	2032h	float

In the example, we assign the current from one phase in each terminal, one phase voltage from the PT, and the differential currents from each differential zone to eight automation math variables in the SEL-487B. *Figure 4.5* shows the analog channel assignment of each terminal. For example, current channels I07, I08, and I09 are assigned to Terminal LONDON. Assuming balanced conditions, we measure one phase from each terminal and one phase from the potential transformer. *Figure 4.6* shows the assignment of alias names to analog quantities (see *Appendix B: Analog Quantities in the Reference Manual* for a list of the available analog quantities).

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  > <Enter>
62:
?  I01FM,TIE_BKR <Enter>
63:
?  I07FM,LONDON <Enter>
64:
?  I10FM,BERLIN <Enter>
65:
?  I13FM,NEW_YRK <Enter>
66:
?  I16FM,CANBERRA <Enter>
67:
?  V01FM,VOLTAGE <Enter>
68:
?  IOP1F,DIFF_W <Enter>
69:
?  IOP4F,DIFF_E <Enter>
70:
?  END <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.6 Assigning Alias Names to the Analog Quantities

Figure 4.7 shows the assigning of the selected analog quantities to the automation math variables.

```
=>>SET A <Enter>
Automation 1

1:
?  AMV001:=LONDON <Enter>
2:
?  AMV002:=BERLIN <Enter>
3:
?  AMV003:=TIE_BKR <Enter>
4:
?  AMV004:=NEW_YRK <Enter>
5:
?  AMV005:=CANBERRA <Enter>
6:
?  AMV006:=VOLTAGE <Enter>
7:
?  AMV007:=DIFF_W <Enter>
8:
?  AMV008:=DIFF_E <Enter>
9:
?  END <Enter>
Automation 1

1: AMV001 := LONDON
2: AMV002 := BERLIN
3: AMV003 := TIE_BKR
4: AMV004 := NEW_YRK
5: AMV005 := CANBERRA
6: AMV006 := VOLTAGE
7: AMV007 := DIFF_W
8: AMV008 := DIFF_E

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 4.7 Assigning Selected Analog Quantities to the Automation Math Variables

Table 4.7 lists the Relay Word bit data available in the SEL-20xx TARGET region.

Table 4.7 SEL Communications Processor TARGET Region (Sheet 1 of 3)

	Relay Word Bits (in Bits 7–0)							
Address	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
2804h	TEST	FMTEST	STEST	STCSET	STFAIL	STWARN	STRSET	STGSET
2805h	EN	TRIPLED	*	*	*	*	*	*
2806h	TLED_1	TLED_2	TLED_3	TLED_4	TLED_5	TLED_6	TLED_7	TLED_8
2807h	TLED_9	TLED_10	TLED_11	TLED_12	TLED_13	TLED_14	TLED_15	TLED_16
2808h	52AL03	52A03	52CL02	52AL02	52A02	52CL01	52AL01	52A01
2809h	52A06	52CL05	52AL05	52A05	52CL04	52AL04	52A04	52CL03
280Ah	*	*	ZONE6	ZONE5	ZONE4	ZONE3	ZONE2	ZONE1
280Bh	*	*	*	*	ZSWOAL	ZSWOIP	ZSWO	RZSWOAL
280Ch	*	87ST	87ST6	87ST5	87ST4	87ST3	87ST2	87ST1
280Dh	*	CSL1	ACTRPT1	ACTRP1	CBCLST1	CBCLS1	CB52T1	CB52A1
280Eh	*	CSL2	ACTRPT2	ACTRP2	CBCLST2	CBCLS2	CB52T2	CB52A2
280Fh	TOS08	TOS07	TOS06	TOS05	TOS04	TOS03	TOS02	TOS01
2810h	TOS16	TOS15	TOS14	TOS13	TOS12	TOS11	TOS10	TOS09
2811h	*	*	*	*	*	*	TOS18	TOS17
2812h	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
2813h	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
2814h	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
2815h	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
2816h	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
2817h	*	IN107	1N106	IN105	IN104	IN103	IN102	IN101
2818h	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
2819h	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
281Ah	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
281Bh	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
281Ch	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
281Dh	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317
281Eh	IN408	IN407	IN406	IN405	IN404	IN403	IN402	IN401
281Fh	IN416	IN415	IN414	IN413	IN412	IN411	IN410	IN409
2820h	IN424	IN423	IN422	IN421	IN420	IN419	IN418	IN417
2821h	IN508	IN507	IN506	IN505	IN504	IN503	IN502	IN501
2822h	IN516	IN515	IN514	IN513	IN512	IN511	IN510	IN509
2823h	IN524	IN523	IN522	IN521	IN520	IN519	IN518	IN517
2824h	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01
2825h	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09
2826h	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
2827h	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25
2828h	PSV40	PSV39	PSV38	PSV37	PSV36	PSV35	PSV34	PSV33

Table 4.7 SEL Communications Processor TARGET Region (Sheet 2 of 3)

	Relay Word Bits (in Bits 7–0)							
Address	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
2829h	PSV48	PSV47	PSV46	PSV45	PSV44	PSV43	PSV42	PSV41
282Ah	PSV56	PSV55	PSV54	PSV53	PSV52	PSV51	PSV50	PSV49
282Bh	PSV64	PSV63	PSV62	PSV61	PSV60	PSV59	PSV58	PSV57
282Ch	PLT08	PLT07	PLT06	PLT05	PLT04	PLT03	PLT02	PLT01
282Dh	PLT16	PLT15	PLT14	PLT13	PLT12	PLT11	PLT10	PLT09
282Eh	PCT08Q	PCT07Q	PCT06Q	PCT05Q	PCT04Q	PCT03Q	PCT02Q	PCT01Q
282Fh	PCT16Q	PCT15Q	PCT14Q	PCT13Q	PCT12Q	PCT11Q	PCT10Q	PCT09Q
2830h	PST08Q	PST07Q	PST06Q	PST05Q	PST04Q	PST03Q	PST02Q	PST01Q
2831h	PST16Q	PST15Q	PST14Q	PST13Q	PST12Q	PST11Q	PST10Q	PST09Q
2832h	PCN08Q	PCN07Q	PCN06Q	PCN05Q	PCN04Q	PCN03Q	PCN02Q	PCN01Q
2833h	PCN16Q	PCN15Q	PCN14Q	PCN13Q	PCN12Q	PCN11Q	PCN10Q	PCN09Q
2834h	ASV008	ASV007	ASV006	ASV005	ASV004	ASV003	ASV002	ASV001
2835h	ASV016	ASV015	ASV014	ASV013	ASV012	ASV011	ASV010	ASV009
2836h	ASV024	ASV023	ASV022	ASV021	ASV020	ASV019	ASV018	ASV017
2837h	ASV032	ASV031	ASV030	ASV029	ASV028	ASV027	ASV026	ASV025
2838h	ASV040	ASV039	ASV038	ASV037	ASV036	ASV035	ASV034	ASV033
2839h	ASV048	ASV047	ASV046	ASV045	ASV044	ASV043	ASV042	ASV041
283Ah	ASV056	ASV055	ASV054	ASV053	ASV052	ASV051	ASV050	ASV049
283Bh	ASV064	ASV063	ASV062	ASV061	ASV060	ASV059	ASV058	ASV057
283Ch	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
283Dh	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
283Eh	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
283Fh	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
2840h	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
2841h	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
2842h	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*
2843h	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
2844h	SALARM	HALARM	BADPASS	CCALARM	CCOK	*	*	*
2845h	*	*	TIRIG	TUPDH	*	*	*	*
2846h	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
2847h	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201
2848h	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
2849h	OUT408	OUT407	OUT406	OUT405	OUT404	OUT403	OUT402	OUT401
284Ah	OUT508	OUT507	OUT506	OUT505	OUT504	OUT503	OUT502	OUT501
284Bh	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED
284Ch	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
284Dh	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
284Eh	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
284Fh	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
2850h	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*

Table 4.7 SEL Communications Processor TARGET Region (Sheet 3 of 3)

	Relay Word Bits (in Bits 7–0)							
Address	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
2851h	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
2852h	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*
2853h	CCIN25	CCIN26	CCIN27	CCIN28	CCIN29	CCIN30	CCIN31	CCIN32
2854h	CCIN17	CCIN18	CCIN19	CCIN20	CCIN21	CCIN22	CCIN23	CCIN24
2855h	CCIN09	CCIN10	CCIN11	CCIN12	CCIN13	CCIN14	CCIN15	CCIN16
2856h	CCIN01	CCIN02	CCIN03	CCIN04	CCIN05	CCIN06	CCIN07	CCIN08
2857h	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
2858h	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
2859h	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
285Ah	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
285Bh	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
285Ch	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
285Dh	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
285Eh	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
285Fh	FSERP1	FSERP2	FSERP3	FSERPF	*	*	*	*

NOTE: An asterisk (*) indicates reserved for future use.

Control Points

The SEL communications processor can automatically pass control messages, called Fast Operate messages, to the SEL-487B. You must enable Fast Operate messages using the FASTOP setting in the SEL-487B port settings for the port connected to the communications processor. You must also enable Fast Operate messages in the communications processor by setting the automessage setting SEND_OPER equal to Y.

When you enable Fast Operate functions, the SEL communications processor automatically sends messages to the relay for changes in remote bits RB1–RB16 or breaker bits BR1 and BR2 on the corresponding SEL communications processor port. In this example, if you set RB1 on Port 1 in the communications processor, it automatically sets RB01 in the SEL-487B.

Breaker bits BR1 through BR16 operate differently than remote bits. There are no breaker bits in the SEL-487B. For Circuit Breaker 1, when you set BR1, the SEL communications processor sends a message to the SEL-487B that asserts the manual open command bit OC1 for one processing interval. If you clear BR1, the communications processor sends a message to the connected relay that asserts the close command bit CC1 for one processing interval. Because there is no breaker close functionality (no CC*nn* bits) bits in the SEL-487B, breakers cannot be closed using the clear breaker function. If you are using the default settings, OC1 opens Circuit Breaker 1.

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Section 5
Direct Network Communications

Overview

This section describes applications in which the SEL-487B Relay connects directly to a communications network via an optional Ethernet card or a serial port connection. This section contains the following topics:

- ➤ Serial Port Networking
- ➤ Protocol Card Networking
- ➤ Direct Networking Example

Direct Network Communication

You can establish direct network communication with the SEL-487B either by serial port or through an optional protocol card. The protocols available on the serial ports are DNP3 and the SEL suite of ASCII and binary protocols. The protocol card presently available for the SEL-487B is an Ethernet card with FTP, Telnet, DNP3, and IEC 61850 protocols. This is a factory-installed option available at the time of purchase of a new SEL-487B or as a factory-installed conversion to an existing relay.

The SEL-487B includes a protocol card slot. This slot supports an SEL standard interface for network protocol cards. Communication between the SEL-487B and an installed protocol card is automatic; you do not need any configuration or driver software. You can access any configuration settings you need for protocol parameters or network operation through the SEL-487B. Each protocol card contains a processor responsible for network interface operation.

Unlike a protocol card installed in a computer, a protocol card installed in the SEL-487B is responsible for all network message and protocol processing. This means that network traffic volumes and network failures do not affect protection processing.

Because SEL relays have more than one port, you can establish direct networking and a communications processor star network simultaneously. Combine a member of the SEL-20xx family of communications processors (SEL-2020, SEL-2030, or SEL-2032) with a direct networking application to add the following system capabilities:

- ➤ Distribution of IRIG-B time synchronization signal
- ➤ Single point of access for IEDs through an Ethernet network or serial connection
- ➤ Nonvolatile logging of data collected from several IEDs

- ➤ Single point for central substation database access
- ➤ Single point of access for Fast SER (Sequential Events Recorder) data

See *Section 4: SEL Communications Processor Applications* for more information regarding use of the SEL communications processors with the SEL-487B.

Serial Networking

The protocols available on the SEL-487B serial ports are either SEL protocols or standard protocols. While the standard protocols offer connectivity without a specific SEL support in other integration products, the SEL protocols offer features not included in standard protocols. These features provide additional capabilities that can significantly enhance your application.

SEL Protocols

SEL protocols are described in detail in *Section 4: SEL Communications Protocols in the Reference Manual*. SEL protocols include Fast Meter, Fast Operate, Fast SER, MIRRORED BITS® communications, and SEL ASCII.

DNP3

This section describes the serial networking features of DNP3. The DNP3 Ethernet interface is discussed briefly in *Ethernet Card on page A.5.4*

DNP3 is a protocol that provides an interface for retrieving SCADA data. The DNP User's Group is responsible for maintaining and distributing the DNP3 specifications.

NOTE: In order to use DNP3 features, including virtual terminal connections, your DNP3 master device must support the required standard DNP3 objects and operations.

The serial DNP3 settings and operation are described in *Section 5: DNP3 Communications in the Reference Manual*. The serial DNP3 interface has the capabilities summarized in *Table 5.1*.

Table 5.1 DNP3 Feature Summary

Feature	Application
DNP event data reporting	More efficient polling through event collection or unsolicited data
Time tagged events	Time-stamped SER data
Control output relay blocks	Operator-initiated control through remote bits
Write analog output	Change the active protection settings group
Time synchronization	Set the relay time from the master station or automatically request time synchronization from the master
Custom mapping	Increase communication efficiency by organizing data and reducing available data to what you need for your application
Modem support	Reduce the cost of the communications channel by either master dialing to relay or relay dialing to master
Virtual terminal	Establish an engineering connection across a DNP3 network
TEST DNP command	Test DNP3 interface without disturbing protection

You can build a DNP3 network using either a multidrop or star topology. Each DNP3 network has a DNP3 master and DNP3 remotes or slaves. *Figure 5.1* shows the DNP3 multidrop network topology while *Figure 5.2* shows the DNP3 star network topology.

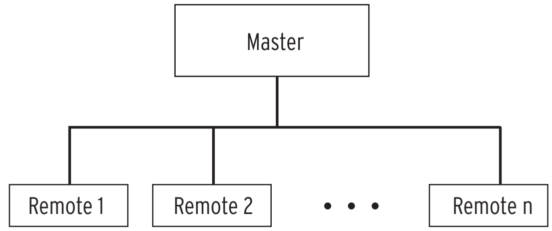

Figure 5.1 DNP3 Multidrop Network Topology

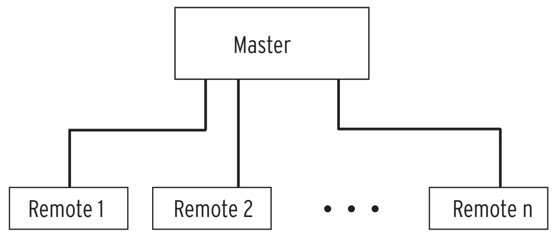

Figure 5.2 DNP3 Star Network Topology

DNP3 multidrop networks that are used within substations often use an EIA-485 physical layer. The multidrop network is vulnerable to the failure of a single transmitter. If any one transmitter fails in a state that disrupts signals on the network, the network will fail. The DNP3 star network topology eliminates the network transmitters and other single points of failure related to the physical medium.

If you are planning either a DNP3 star or network topology, you should consider the benefits of including an SEL Communications Processor in your design. A network with a communications processor is shown in *Figure 5.3*. A DNP3 network that includes a communications processor has a lower data latency and shorter scan time than comparable networks through two primary mechanisms. First, the communications processor collects data from all remotes in parallel rather than one-by-one. Second, the master can collect all data with one message and response, drastically reducing message overhead.

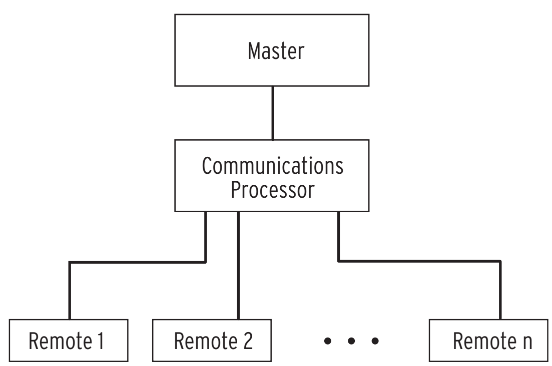

Figure 5.3 DNP3 Network With Communications Processor

In the communications processor DNP3 network you can also collect data from devices that do not have DNP3 protocol. The communications processor can collect data and present it to the master as DNP3 data regardless of the protocol between the communications processor and the remote device.

Ethernet Card

The SEL-487B Ethernet card is an optional protocol card that you can add to the SEL-487B in the field or purchase as a factory-installed option. In order to exchange data over this interface, you must choose a data exchange protocol that operates over the Ethernet network link. The Ethernet card supports FTP, Telnet, HTTP, DNP LAN/WAN, FTP, and IEC 61850 data exchange protocols.

You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security. Work with a networking professional to design your substation Ethernet network.

Ethernet

The SEL-487B Ethernet card provides Ethernet networking with the popular physical and data-link standards listed in *Table 5.2*.

Table 5.2 Ethernet Connection Options

Name	Connector	Media
10BASE-T/100BASE-TX selectable	RJ-45	CAT 5 cable (Category 5 twisted pair)
10BASE-F	Standard ST	Multimode fiber-optic cable
100BASE-FX	Standard ST	Multimode fiber-optic cable

FTP

Use FTP (File Transfer Protocol) to access data stored in files in the SEL-487B. FTP is a standard TCP/IP protocol for exchanging files. A free FTP application is included with most web browser software. You can also obtain a free or inexpensive FTP application from the Internet.

When you connect to the SEL-487B Ethernet card, you will find files stored in directories. At the root or top level, you will find three directories, one for the Ethernet card and two for the SEL-487B. One SEL-487B directory contains snapshots of data regions within the SEL-487B database. The other SEL-487B directory contains the files and subdirectories included in the virtual file interface described in *Section 4: SEL Communications Protocols in the Reference Manual*.

Files associated with the Ethernet card are in the SEL-2702 directory. This directory contains the file DIAGNOSTICS.TXT, which contains a log of Ethernet card system failures. The time and date of the diagnostics file correspond to the time and date of the last system failure event. The SEL-2702 directory may also contain custom mapping files for the DNP LAN/WAN protocol.

The relay generates certain files at the time that they are requested, so that the file you retrieve contains the latest information. For example, when you request the file SER.TXT, the SEL-487B creates and sends to you a file that contains SER information up until the moment that you requested the file.

If the IEC 61850 protocol is installed and enabled, the following files will be found in the root directory:

- ➤ CID (Configured IED Description) file—contains the IEC 61850 SCL configuration for the SEL-487B
- ➤ ERR.TXT file—contains any errors encountered during the CID file download
- ➤ CFG.XML file—contains the Ethernet card and SEL-487B configuration information

Telnet

Use Telnet to connect to the SEL-487B ASCII interface and work with the relay. Telnet is a terminal connection across a TCP/IP network that operates in a manner very similar to a direct serial port connection to one of the relay ports. As with FTP, Telnet is a part of TCP/IP. A free Telnet application is included with most computer operating systems, or you can obtain low-cost or free Telnet applications on the Internet.

When you connect with Telnet and log on to the relay, you can use all of the ASCII and Compressed ASCII commands described in *Section 7: ASCII Command Reference in the Reference Manual* to configure and interact with the relay. You can also use the SEL binary Fast Meter and Fast Operate commands described in *Section 4: SEL Communications Protocols in the Reference Manual*.

HTTP

The SEL-2702 Ethernet Card supports HTML web pages when used with the SEL-487B. These web pages allow you to view relay read-only data, including settings, metering, event history, event reports, relay status, and relay configuration. This is enabled via the EHTTP settings (see *Table 8.75 on page R.8.39*). Up to four simultaneous connections are allowed. No data is allowed to be written to the relay via the HTML web page interface.

To connect to the web server, use a web browser and go to the configured IP address (IPADDR) and port number (HPNUM setting). This will initially display a login screen, as shown in *Figure 5.4*. The Username is always ACC. The password is the relay's access level one password.

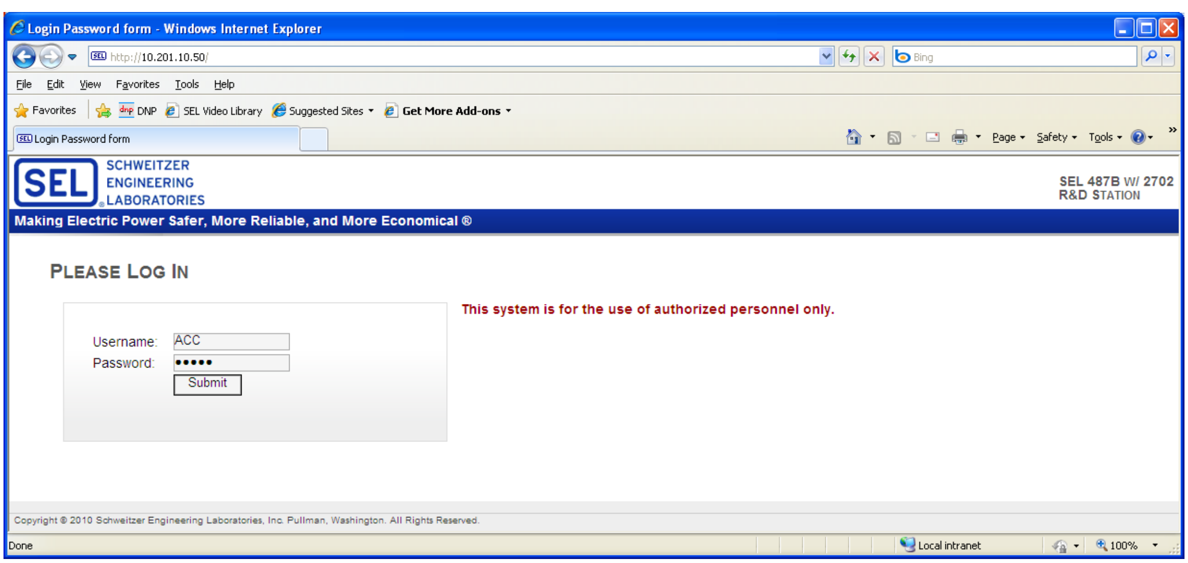

Figure 5.4 Web Server Login Screen

Once you are logged in to the relay, you will see a menu of choices, as shown in *Figure 5.5*. Select items from the menu to see the respective data displayed on the screen.

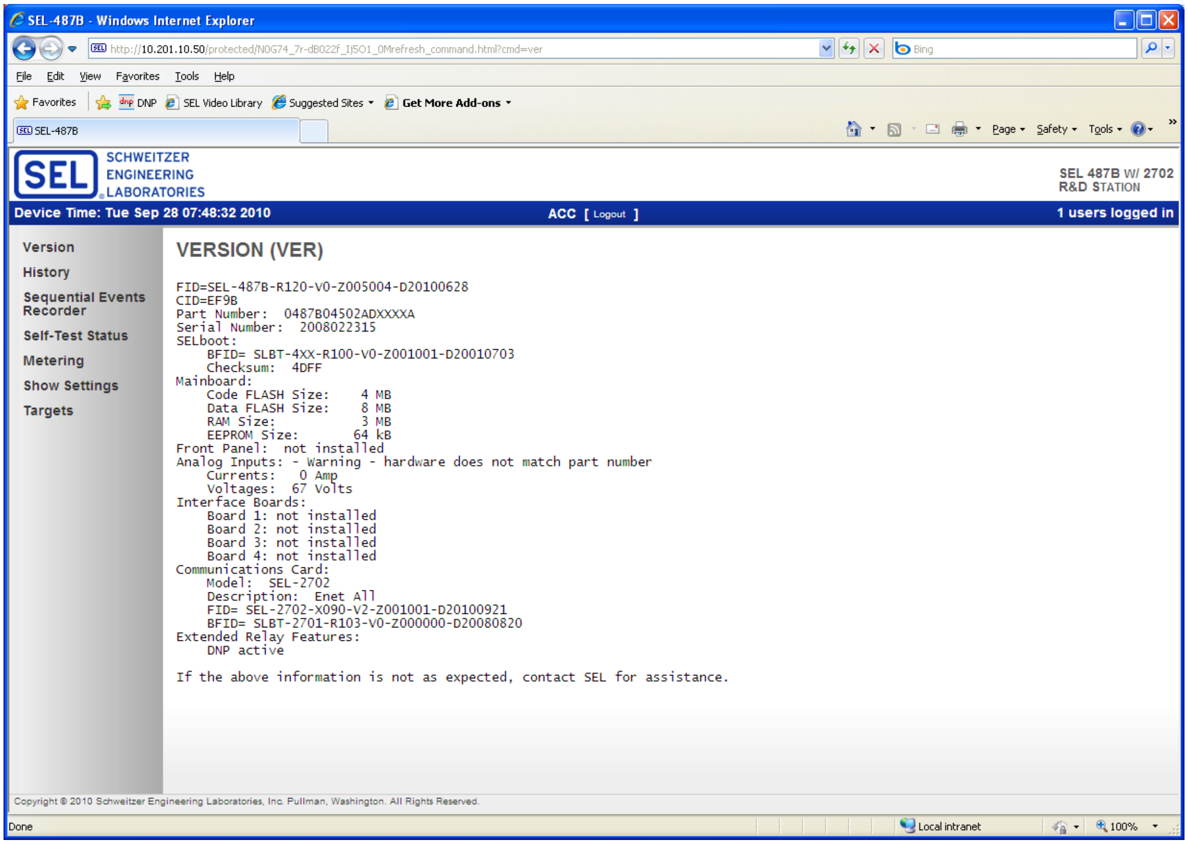

Figure 5.5 Web Server Default Menu Screen

Event reports are accessed from the history screen. Each listed event that has an event report will contain a link to that event report. An example of this is shown in *Figure 5.6*.

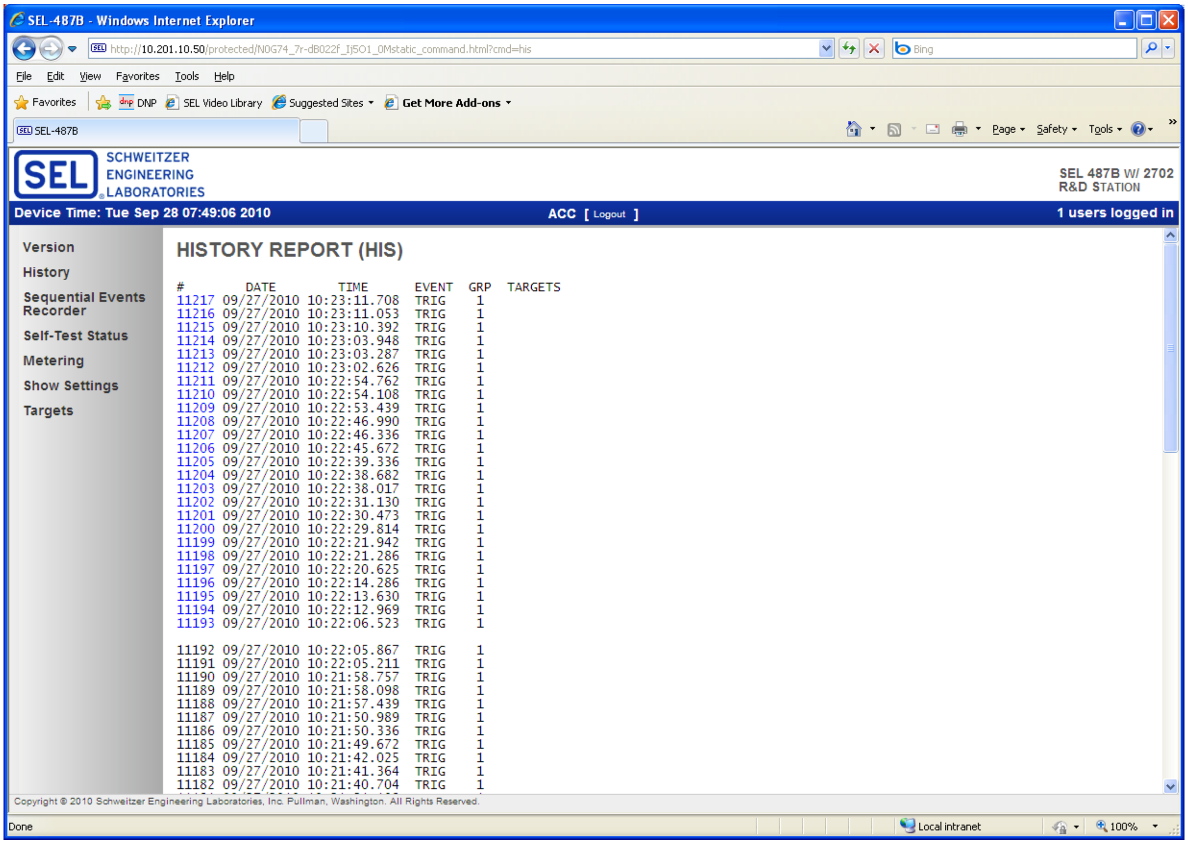

Figure 5.6 Event History Screen With Links to Event Reports

IEC 61850

The IEC 61850 standard is a superset of UCA2 and contains most of the UCA2 specification plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards.

UCA2 utilized GOMSFE to present data from station IEDs as a series of objects called models or bricks. The IEC working group incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

The GOOSE object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network.

MMS provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506. MMS supports complex named objects and flexible services that enable the mapping to IEC 61850 in a straightforward manner. It was for this reason that the UCA users group utilized MMS for UCA from the start, and why the IEC chose to keep it for IEC 61850.

See *Section 6: IEC 61850 Communications in the Reference Manual* for important information regarding IEC 61850.

DNP3

Installation of the Ethernet card in an SEL-487B relay provides a high performance DNP3 Level 2 slave network interface designed for operation in a substation environment.

The DNP LAN/WAN interface has the capabilities summarized in *Table 5.3*.

Table 5.3 DNP LAN/WAN Feature Summary

Feature	Key Features
DNP Event data reporting	More efficient polling through event collection or unsolicited data
Time tagged events	Time-stamped SER data directly from the SEL-487B, not an intermediate device
Control output relay blocks	Operator-initiated control through remote bits
Custom mapping	Increase communication efficiency by organizing and/or reducing available data to what is needed with 5 custom data maps for up to 10 different sessions
Analog deadband settings per session	Deadbands may be set to different values per session depending on desired application

Customized DNP3 data within the SEL-487B relay is available to any of ten DNP3 master sessions configured in the Ethernet card. Configuration and implementation of DNP LAN/WAN is entirely independent of any serial DNP3 settings that might exist in the SEL-487B relay.

See *Section 5: DNP3 Communications* in the Reference Manual for information on configuring and using DNP LAN/WAN for the SEL-487B.

SEL Software

The SEL-487B configuration software, ACSELERATOR QuickSet® SEL-5030 software, can connect to, configure, and control an SEL-487B with an Ethernet card. You can use ACSELERATOR QuickSet to choose a connection type and provide the required information for a network connection. With this capability, you can configure and control SEL-487B relays from a local substation LAN (local area network) or from an engineering workstation across a WAN (wide area network). The ACSELERATOR Architect® software will be included with your purchase of the IEC 61850 option. The ACSELERATOR Architect SEL-5032 software enables protection and integration engineers to design and commission IEC 61850 substations containing SEL IEDs.

Other SEL software includes Ethernet network connection capabilities, so you can use an Ethernet network for engineering connections to SEL protection and integration products. Check the documentation of your specific software for more information on Ethernet network connection capabilities.

Direct Networking Example

This direct networking example demonstrates direct networking to the SEL-487B using the Ethernet card. *Figure 5.7* shows the Ethernet network topology.

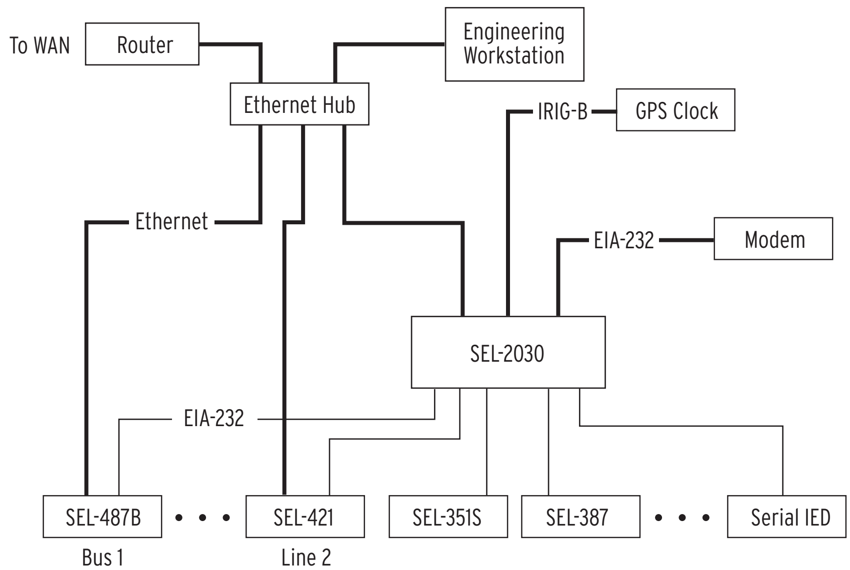

Figure 5.7 Example Direct Networking Topology

Application

In this application, all IEDs connect to the Ethernet network. The SEL-487B and SEL-421 relays and the SEL-2030 each have an Ethernet card installed. In this example, the Ethernet network is used primarily for an engineering connection to the devices in the substation either across the WAN or from the local computer. The engineer can use FTP to collect settings, oscillography, and other file data directly from the SEL-487B and SEL-421 relays. The engineer can also use Telnet to establish a terminal connection to the SEL-487B and SEL-421 relays or through the SEL-2030 to one of the serial IEDs in order to configure these devices or obtain diagnostic information.

There is a serial cable from the SEL-2030 to the SEL-487B and SEL-421 relays. This cable provides IRIG-B time synchronization from the SEL-2030 that is synchronized by the GPS clock attached to the SEL-2030. The SEL-2030 provides its output synchronization signal from its internal clock, so that loss of the signal from the GPS will not result in a loss of synchronization between substation devices as they will all be synchronized to the SEL-2030 clock. During long periods of loss of synchronization, the SEL-2030 clock drift will become noticeable, but all substation devices will remain synchronized relative to each other and the SEL-2030 clock. The serial cables also allow the SEL-2030 to provide a single point for dial-in communications with the substation IEDs avoiding the high cost of high bandwidth connections (for example, ISDN or DSL) for this backup to the Ethernet network engineering connection.

Settings

This example focuses on the relay labeled Bus 1 shown in *Figure 5.7*. Port 5 settings for the SEL-487B configure the Ethernet card. Port 5 settings for this example are shown in *Table 5.4*.

Table 5.4 SEL-487B Port 5 Direct Networking Settings (Sheet 1 of 2)

Setting Name	Setting	Description
TIMEOUT	5	Port inactivity time-out in minutes (drops to Access Level 0 on Telnet connections when this expires)
AUTO	N	Automessage disabled because engineering connection will not require unsolicited messages from SEL-2030
FASTOP	N	Fast Operate messages disabled because they are not required on engineering connection
TERTIM1	1	Length of time the channel must be idle before checking for the termination string in seconds
TERSTRN	\005	Transparent communication termination string default of **<Ctrl+E>**
TERTIM2	0	Length of time the channel must be idle before accepting the termination string in seconds
IPADDR	10.201.0.112	IP network address
SUBNETM	255.255.0.0	IP network subnet mask
DEFRTR	10.201.0.1	Default router
ETCPKA	N	Disable TCP keep-alive functionality (IEC 61850 only)
KAIDLE	10	Length of time to wait with no detected activity before sending a keep-alive packet (must be greater than or equal to KAINTV)
KAINTV	1	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet (must be less than or equal to KAIDLE)
KACNT	6	Maximum number of keep-alive packets to send
NETPORT	A	Primary network port selected to Port A
FAILOVR	N	Automatic fail-over disabled, forcing network operation on Port A only
FTIME	5	Fail over time-out; not used in this application
NETASPD	A	Automatically detect network speed on Port A
NETBSPD	A	Automatically detect network speed on Port B; not used in this application
FTPSERV	Y	FTP sessions enabled
FTPCBAN	FTP SERVER:	FTP connect banner
FTPIDLE	5	FTP connection time-out in minutes
FTPANMS	N	Anonymous log on disabled so that passwords are required for all FTP users
FTPAUSR	“”	Host user from which anonymous FTP client inherits access rights; not used in this application
T1CBAN	HOST TERMINAL SERVER:	Host Telnet connect banner
T1INIT	N	Telnet session from Ethernet card enable; not used in this application
T1RECV	Y	Telnet session to SEL-487B enable
T1PNUM	23	Host Telnet TCP/IP port

Table 5.4 SEL-487B Port 5 Direct Networking Settings (Sheet 2 of 2)

Setting Name	Setting	Description
T2CBAN	CARD TERMINAL SERVER:	Ethernet card Telnet connect banner
T2RECV	Y	Telnet session to Ethernet card enable
T2PNUM	1024	Ethernet card Telnet TCP/IP port
TIDLE	5	Telnet connection time-out in minutes

FTP Session

Figure 5.9 is a screen capture of an FTP session with the relay. The FTP client used for this example is included with the Windows NT® operating system and accessible through a command prompt window. The operator connects to the relay, moves to the SETTINGS directory, and collects the Port 5 settings. *Figure 5.10* shows a portion of the Port 5 settings in the SET_P5.TXT file.

Telnet Session

This section contains screen captures of a Telnet session with the Bus 1 SEL-487B. The Telnet application shown is included with the Windows NT operating system. *Figure 5.8* shows the log on dialog box and the entries required to connect to the SEL-487B.

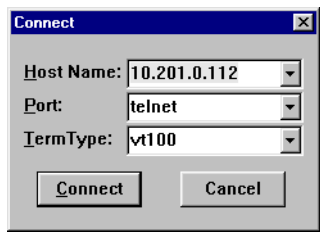

Figure 5.8 Telnet Connection Dialog Box

Figure 5.11 is a screen capture of a Telnet session with the relay. The operator connects to the relay and displays the Port 5 settings. Only a portion of the Port 5 settings are shown.

```
C:\>ftp 10.201.0.112 <Enter>

Connected to 10.201.0.112.
220 FTP SERVER:
User (10.201.0.112:(none)): 2AC <Enter>
331 User name okay, need password.
Password:
230 User logged in, proceed.

ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
SEL-487B
SEL-2702
DD01_SEL_487B
CFG.TXT
226 Closing data connection.
42 bytes received in 0.00 seconds (42000.00 Kbytes/sec)

ftp> cd SEL-487B <Enter>
250 CWD  requested file action okay, completed.

ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
CFG.TXT
EVENTS
REPORTS
SETTINGS
226 Closing data connection.
36 bytes received in 0.08 seconds (0.45 Kbytes/sec)
ftp> cd SETTINGS <Enter>
250 CWD  requested file action okay, completed.
```

```
ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
ERR.TXT
SET_A1.TXT
SET_A10.TXT
SET_A2.TXT
SET_A3.TXT
SET_A4.TXT
SET_A5.TXT
SET_A6.TXT
SET_A7.TXT
SET_A8.TXT
SET_A9.TXT
SET_ALL.TXT
SET_D1.TXT
SET_F1.TXT
SET_G1.TXT
SET_L1.TXT
SET_L2.TXT
SET_L3.TXT
SET_L4.TXT
SET_L5.TXT
SET_L6.TXT
SET_O1.TXT
SET_P1.TXT
SET_P2.TXT
SET_P3.TXT
SET_PF.TXT
SET_R1.TXT
SET_S1.TXT
SET_S2.TXT
SET_S3.TXT
SET_S4.TXT
SET_S5.TXT
SET_S6.TXT
SET_T1.TXT
SET_Z1.TXT
SET_Z2.TXT
SET_Z3.TXT
SET_Z4.TXT
SET_Z5.TXT
SET_Z6.TXT
226 Closing data connection.
419 bytes received in 0.73 seconds (0.57 Kbytes/sec)

ftp> get SET_P5.TXT <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
226 Closing data connection.
2392 bytes received in 1.58 seconds (1.51 Kbytes/sec)

ftp> QUIT <Enter>
221 Goodbye.
C:\>
```

Figure 5.9 Example FTP Session

```
[INFO]
RELAYTYPE=487B
FID=SEL-487B-R102-V0-Z001001-D20030724
BFID=SLBT-4XX-R100-V0-Z001001-D20010703
PARTNO=0487B061X2XBDXXXH
[IOBOARDS]
IO1, , , 24, 8, 0, 0, 1
[COMCARDS]
SEL-2702, SEL-2702-R100-V0-Z000000-D20060501, SLBT-2702-R100-V0-Z000000-D20060425, 1
[P5]
"TIMEOUT",5
"AUTO",Y
"FASTOP",N
"TERTIM1",1
"TERSTRN","\005"
"TERTIM2",0
"IPADDR","10.200.90.10"
"SUBNETM","255.255.0.0"
"DEFRTR","10.200.0.1"
"NETPORT","B"
"FAILOVR","Y"
"FTIME",5
"NETASPD","A"
"NETBSPD","A"
"FTPSERV","Y"
"FTPCBAN","SEL-2701 FTP SERVER:"
"FTPIDLE",5
"FTPANMS","Y"
"FTPAUSR","2AC"
"T1CBAN","HOST TERMINAL SERVER:"
"T1INIT","Y"
"T1RECV","Y"
"T1PNUM",23
"T2CBAN","SEL-2702 TERMINAL SERVER:"
"T2RECV","Y"
"T2PNUM",1024
"TIDLE",5
```
Remaining settings not shown

Figure 5.10 Partial Contents of SET_P5.TXT

```
HOST TERMINAL SERVER:

Bus 1                                   Date: 01/19/2001  Time: 15:35:57.644
Station A                                 Serial Number: 00000001

=ACC <Enter>

Password: ?***** <Enter>

Relay 1                                   Date: 01/19/2001  Time: 15:36:12.856
Station A                                 Serial Number: 00000001

Level 1

=>2AC <Enter>

Password: ?**** <Enter>

Bus 1                                   Date: 01/19/2001  Time: 15:36:16.887
Station A                                 Serial Number: 00000001

Level 2

=>>SHO P 5 <Enter>

Port 5

SEL Protocol Settings

TIMEOUT := 5        AUTO    := N        FASTOP  := N        TERTIM1 := 1
TERSTRN := "\005"
TERTIM2 := 0

Protocol Card Settings

IPADDR  := "10.201.0.112"
SUBNETM := "255.255.0.0"
DEFRTR  := "10.201.0.1"
NETPORT := "A"
FAILOVR := "N"
FTIME   := 5
NETASPD := "A"
NETBSPD := "A"
FTPSERV := "Y"
FTPCBAN := "SEL-2702 FTP SERVER:"
FTPIDLE := 5
FTPANMS := "N"
FTPAUSR := ""
T1CBAN  := "HOST TERMINAL SERVER:"
T1INIT  := "N"
T1RECV  := "Y"
T1PNUM  := 23
T2CBAN  := "SEL-2702 TERMINAL SERVER:"
T2RECV  := "Y"
T2PNUM  := 1024     TIDLE   := 5
Settings HOST1-CTRLB64 Not Shown

=>>QUIT <Enter>

Host connection terminated, terminating Network connection.
```

Figure 5.11 Example Telnet Session

Appendix B
Analog Quantities

Overview

This section contains a table of the analog quantities available within the SEL-487B Relay. For information on using analog quantities in protection and automation, see the SEL-487B *Applications Handbook*.

Analog Quantities

Use this section as a reference for analog quantities. *Table B.1* groups the analog quantities by function; *Table B.2* groups the analog quantities alphabetically.

Table B.1 Analog Quantities Sorted by Function (Sheet 1 of 3)

Label	Description	Units
Current		
I*nn*FIM[a]	Phase filtered instantaneous current magnitude	A (sec)
I*nn*FIA[a]	Phase filtered instantaneous current angle	degrees
I*nn*FM[a]	Phase one-cycle average current magnitude	A (pri)
I*nn*FA[a]	Phase one-cycle average current angle	degrees
IOP*k*[b]	Zone *k* operating current	pu
IOPCZ1	Check Zone 1 operating current	pu
IRT*k*[b]	Zone *k* restraint current	pu
IRTCZ1	Check Zone 1 operating current	pu
IOP*k*F[b]	Zone *k* one-cycle average operating current	pu
IOPCZ1F	Check Zone 1 one-cycle average operating current	pu
IRT*k*F[b]	Zone *k* one-cycle average restraint current	pu
IRTCZ1F	Check Zone 1 one-cycle average restraint current	pu
Voltage		
V*mm*FIM[c]	Phase filtered instantaneous voltage magnitude	V (sec)
V*mm*FIA[c]	Phase filtered instantaneous voltage angle	degrees
V*mm*FM[c]	Phase one-cycle average voltage magnitude	kV (pri)
V*mm*FA[c]	Phase one-cycle average voltage angle	degrees
V1FIM	Positive-sequence filtered instantaneous voltage magnitude, V1	V (sec)
3V2FIM	Negative-sequence filtered instantaneous voltage magnitude, 3V2	V (sec)

Table B.1 Analog Quantities Sorted by Function (Sheet 2 of 3)

Label	Description	Units
3V0FIM	Zero-sequence filtered instantaneous voltage magnitude, 3V0	V (sec)
DC1	Filtered dc monitor voltage	V
DC1PO	Average positive-to-ground dc voltage	V
DC1NE	Average negative-to-ground dc voltage	V
DC1RI	AC ripple of dc voltage (peak-to-peak)	V
DC1MIN	Minimum dc voltage	V
DC1MAX	Maximum dc voltage	V
Database Structure		
RA001–RA256	Remote analogs from Ethernet card	N/A
Date and Time		
TODMS	Time of day in milliseconds (0–86399999)	ms
THR	Hour (0–23)	hours
TMIN	Minute (0–59)	minutes
TSEC	Seconds (0–59)	seconds
TMSEC	Milliseconds (0–999)	ms
DDOW	Day of the week (Encoded value: 1=Sun, 2=Mon, 3=Tue, 4=Wed, 5=Thu, 6=Fri, 7=Sat)	n/a
DDOM	Day of the month (1–31)	n/a
DDOY	Day of the year (1–366)	n/a
DMON	Month (1–12)	n/a
DYEAR	Year (2000–2200)	n/a
MIRRORED BITS®		
MB1A–MB7A	MIRRORED BITS® communications Channel A received analog values	n/a
MB1B–MB7B	MIRRORED BITS® communications Channel B received analog values	n/a
SELOGIC® and Automation Elements		
PMV01–PMV64	Protection SELOGIC® control equation math variable	n/a
PCT01PU–PCT16PU	Protection conditioning timer pickup time	cycles
PCT01DO–PCT16DO	Protection conditioning timer dropout time	cycles
PST01ET–PST32ET	Protection sequencing timer elapsed time	cycles
PST01PT–PST32PT	Protection sequencing timer preset time	cycles
PCN01CV–PCN32CV	Protection counter current value	n/a
PCN01PV–PCN32PV	Protection counter preset value	n/a
AMV001–AMV256	Automation SELOGIC® control equation math variable	n/a
AST01ET–AST32ET	Automation sequencing timer elapsed time	seconds

Table B.1 Analog Quantities Sorted by Function (Sheet 3 of 3)

Label	Description	Units
AST01PT–AST32PT	Automation sequencing timer preset time	seconds
ACN01CV–ACN32CV	Automation counter current value	n/a
ACN01PV–ACN32PV	Automation counter preset value	n/a
Setting Group		
ACTGRP	Active group setting	n/a

[a] nn = 01-18
[b] k = 1-6
[c] mm = 01-03

Table B.2 Analog Quantities Sorted Alphabetically (Sheet 1 of 2)

Label	Description	Units
3V0FIM	Zero-sequence filtered instantaneous voltage magnitude, 3V0	V (sec)
3V2FIM	Negative-sequence filtered instantaneous voltage magnitude, 3V2	V (sec)
ACN01CV–ACN32CV	Automation counter current value	n/a
ACN01PV–ACN32PV	Automation counter preset value	n/a
ACTGRP	Active group setting	n/a
AMV001–AMV256	Automation SELOGIC® control equation math variable	n/a
AST01ET–AST32ET	Automation sequencing timer elapsed time	seconds
AST01PT–AST32PT	Automation sequencing timer preset time	seconds
DC1	Filtered dc monitor voltage	V
DC1MAX	Maximum dc voltage	V
DC1MIN	Minimum dc voltage	V
DC1NE	Average negative-to-ground dc voltage	V
DC1PO	Average positive-to-ground dc voltage	V
DC1RI	AC ripple of dc voltage (peak-to-peak)	V
DDOM	Day of the month (1–31)	n/a
DDOW	Day of the week (encoded value: 1=Sun, 2=Mon, 3=Tue, 4=Wed, 5=Thu, 6=Fri, 7=Sat)	n/a
DDOY	Day of the year (1–366)	n/a
DMON	Month (1–12)	n/a
DYEAR	Year (2000–2200)	n/a
I*nn*FA[a]	Phase one-cycle average current angle	degrees
I*nn*FIA[a]	Phase filtered instantaneous current angle	degrees
I*nn*FIM[a]	Phase filtered instantaneous current magnitude	A (sec)
I*nn*FM[a]	Phase one-cycle average current magnitude	A (pri)
IOP*k*[b]	Zone *k* operating current	pu

Table B.2 Analog Quantities Sorted Alphabetically (Sheet 2 of 2)

Label	Description	Units
IOPCZ1	Check Zone 1 operating current	pu
IOP*k*F[b]	Zone *k* one-cycle average operating current	pu
IOPCZ1F	Check Zone 1 one-cycle average operating current	pu
IRT*k*[b]	Zone *k* restraint current	pu
IRTCZ1	Check Zone 1 restraint current	pu
IRT*k*F[b]	Zone *k* one-cycle average restraint current	pu
IRTCZ1F	Check Zone 1 one-cycle average restraint current	pu
MB1A–MB7A	MIRRORED BITS communications Channel A received analog values	n/a
MB1B–MB7B	MIRRORED BITS communications Channel B received analog values	n/a
PCN01CV–PCN32CV	Protection counter current value	n/a
PCN01PV–PCN32PV	Protection counter preset value	n/a
PCT01DO–PCT16DO	Protection conditioning timer dropout time	cycles
PCT01PU–PCT16PU	Protection conditioning timer pickup time	cycles
PMV01–PMV64	Protection SELOGIC control equation math variable	n/a
PST01ET–PST32ET	Protection sequencing timer elapsed time	cycles
PST01PT–PST32PT	Protection sequencing timer preset time	cycles
RA001–RA256	Remote analogs from Ethernet card	n/a
THR	Hour (0–23)	hours
TMIN	Minute (0–59)	minutes
TMSEC	Milliseconds (0–999)	ms
TODMS	Time of day in milliseconds (0–86399999)	ms
TSEC	Seconds (0–59)	seconds
V1FIM	Positive-sequence filtered instantaneous voltage magnitude, V1	V (sec)
V*mm*FA[c]	Phase one-cycle average voltage angle	degrees
V*mm*FIA[c]	Phase filtered instantaneous voltage angle	degrees
V*mm*FIM[c]	Phase filtered instantaneous voltage magnitude	V (sec)
V*mm*FM[c]	Phase one-cycle average voltage magnitude	kV (pri)

[a] nn = 01–18.
[b] k = 1–6.
[c] mm = 01–03.

Glossary

9U The designation of the vertical height of a device in rack units. Nine rack units, 9U, total approximately 400 mm (15.75 inches).

7U The designation of the vertical height of a device in rack units. Seven rack units, 7U, total approximately 311 mm (12.25 inches).

A Abbreviation for amps or amperes; unit of electrical current flow.

a contact A normally open auxiliary contact that closes when the device is closed and opens when the device is open.

ABS Operator An operator in math SELOGIC® control equations that provides absolute value.

AC Ripple The peak-to-peak ac component of a signal or waveform. In the station dc battery system, monitoring ac ripple provides an indication of whether the substation battery charger has failed.

Acceptance Testing Testing that confirms that the relay meets published critical performance specifications and requirements of the intended application. This involves testing protection elements and logic functions when qualifying a relay model for use on the utility system.

Access Level A relay command level with a specified set of relay information and commands. All access levels, except for Access Level 0, require the correct password.

Access Level 0 The least secure and most limited access level; not password protected. You must enter a password from this level to go to a higher level.

Access Level 1 The default access level for the relay front panel, used to monitor (view) relay information.

Access Level 2 The most secure access level, from which you have total relay functionality and control of all settings types.

Access Level A A relay command level used to access all Access Level 1 and Access Level B (Breaker) functions, plus Alias, Automation, Global, Front Panel, Report, Port, and DNP settings.

Access Level B A relay command level used for Access Level 1 functions, plus circuit breaker control and data.

Access Level O A relay command level used to access all Access Level 1 and Access Level B (Breaker) functions, plus Alias, Output, Global, Front Panel, Report, Port, and DNP settings.

Access Level P A relay command level used to access all Access Level 1 and Access Level B (Breaker) functions, plus Protection, Global, Group, Front Panel, Report, Port, Alias, Zone configuration, and DNP settings.

ACSELERATOR Architect® SEL-5032 Software
ACSELERATOR Architect is an add-on to the ACSELERATOR Suite that utilizes the IEC 61850 Substation Configuration Language to configure SEL IEDs.

ACSELERATOR QuickSet® SEL-5030 Software
A Windows®-based program that simplifies settings and provides analysis support.

ACSI
Abstract Communications Service Interface for the IEC 61850 protocol. Defines a set of objects, a set of services to manipulate and access those objects, and a base set of data types for describing objects.

Active Settings Group
The settings group that the SEL-487B is presently using from among six settings groups available in the relay.

Active Zone
A zone is active when any I*qq*BZ*p*V (*qq* = 01–18, *p* = 1–6) Relay Word bit asserts. For example, Zone 1 becomes active when Relay Word bit I01BZ1V asserts.

Advanced Settings
Settings for customizing protection functions; these settings are hidden unless you set EADVS := Y.

Alias
An alternative name assigned to Relay Word bits, analog quantities, default terminals, and bus-zone names.

Analog Quantities
Variables represented by such fluctuating measurable quantities as temperature, frequency, current, and voltage.

AND Operator
Logical AND. An operator in Boolean SELOGIC control equations that requires fulfillment of conditions on both sides of the operator before the equation is true.

ANSI Standard Device Numbers
A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include the following:

27	Undervoltage Element
50	Overcurrent Element
51	Inverse Time-Overcurrent Element
52	AC Circuit Breaker
59	Overvoltage Element
86	Breaker Failure Lockout
89	Disconnect

These numbers are frequently used within a suffix letter to further designate their application. The suffix letters used in this instruction manual include the following:

P	Phase Element
N	Neutral/Ground Element
Q	Negative-Sequence Element

Anti-Aliasing Filter
A low pass filter that blocks frequencies too high for the given sampling rate.

ASCII
Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The SEL-487B uses ASCII text characters to communicate, through front- and rear-panel EIA-232 serial ports and virtual serial ports.

ASCII Terminal A terminal without built-in logic or local processing capability that can only send and receive information.

Assert To activate. To fulfill the logic or electrical requirements needed to operate a device. To set a logic condition to the true state (logical 1) of that condition. To apply a closed contact to an SEL-487B input. To close a normally open output contact. To open a normally closed output contact.

AT Modem Command Set Dialing String Standard The command language standard that Hayes Microcomputer Products, Inc. developed to control auto-dial modems from an ASCII terminal (usually EIA-232 connected) or a PC (personal computer) containing software allowing emulation of such a terminal.

Autoconfiguration The ability to determine relay type, model number, metering capability, port ID, baud rate, passwords, relay elements, and other information that an IED (e.g., SEL-2020/2030/2032 Communications Processor) needs to automatically communicate with relays.

Automatic Messages Messages including status failure and status warning messages that the relay generates at the serial ports and displays automatically on the front-panel LCD.

Automation Variables Variables that are included in automation SELOGIC control equations.

AX-S4 MMS "Access for MMS" is an IEC 61850, UCA2, and MMS client application produced by SISCO, Inc., for real-time data integration in Microsoft Windows-based systems supporting OPC and DDE. Included with AX-S4 MMS is the interactive MMS Object Explorer for browser-like access to IEC 61850 / UCA2 and MMS device objects.

b contact A normally closed auxiliary contact that opens when the device is closed and closes when the device is open.

Bandpass Filter A filter that passes frequencies within a certain range and blocks all frequencies outside this range.

Bit Label The identifier for a particular bit.

Bit Value Logical 0 or logical 1.

Boolean Logic Statements Statements consisting of variables that behave according to Boolean logic operators, such as AND, NOT, and OR.

Breaker Auxiliary Contact An electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A Form A breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed and opens when the breaker is open. A Form B breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

Breaker-and-a-Half Configuration A switching station arrangement of three circuit breakers per two circuits; the two circuits share one of the circuit breakers.

Breaker Differential Differential zone of protection configured exclusively across the tie breaker; the breaker differential protects only the area between the two tie-breaker CTs.

Buffered Report IEC 61850 IEDs can issue buffered reports of internal events (caused by trigger options data-change, quality-change, and data-update). These event reports can be sent immediately or buffered (to some practical limit) for transmission, such that values of data are not lost due to transport flow control constraints or loss of connection. Buffered reporting provides sequence-of-events (SOE) functionality.

Busbar Electrical junction of two or more primary circuits. For a single busbar, there could be multiple bus-zones; there can be more bus-zones than busbars, but not more busbars than bus-zones.

Buscoupler (see also Tie Breaker) Equipment with at least a current transformer and circuit breaker, connecting two busbars when the circuit breaker is closed. Disconnects of other terminals at the station (feeders, lines, etc.) are normally arranged in parallel with the buscoupler. Closing two or more disconnects of the other terminals bypasses the buscoupler, forming a connection without a circuit breaker between two or more busbars.

Busbar Protection Element Each of the six busbar protection elements comprise a differential element, a directional element, and a fault detection logic.

Bus Sectionalizer (see also Buscoupler) Equipment with at least a current transformer and circuit breaker, connecting two busbars when the circuit breaker is closed.

Bus-Zone-to-Bus-Zone Connection Variable SELOGIC variable stating the conditions when the relay merges two zones to form a single protection zone.

Bus-Zone (see also Protection Zone) Area of protection formed by a minimum of two terminals.

Category A collection of similar relay settings.

Checksum A method for checking the accuracy of data transmission, involving summation of a group of digits and comparison of this sum to a previously calculated value.

Check Zone Protection zone formed by two or more terminals where the differential calculation is independent of the status of the disconnect auxiliary contacts.

CID Checksum identification of the firmware.

CID File IEC 61850 Configured IED Description file. XML file that contains the configuration for a specific IED.

Circuit Breaker Failure Logic This logic within the SEL-487B detects and warns of failure or incomplete operation of a circuit breaker in clearing a fault or in performing a trip or close sequence.

Class The first level of the relay settings structure, including Global, Group, Breaker Monitor, Port, Report, Front Panel, DNP settings, Protection SELOGIC control equations, Automation SELOGIC control equations, and Output SELOGIC control equations.

Commissioning Testing Testing that serves to validate all system ac and dc connections and confirm that the relay, auxiliary equipment, and SCADA interface all function as intended with your settings. Perform such testing when installing a new protection system.

Common Data Class IEC 61850 grouping of data objects that model substation functions. Common Data Classes include Status information, Measured information, Controllable status, Controllable analog, Status settings, Analog settings, and Description information.

Common Inputs Relay control inputs that share a common terminal.

Communications Protocol A language for communication between devices.

Comparison Boolean SELOGIC control equation operation that compares two numerical values. Compares floating-point values, such as currents, total counts, and other measured and calculated quantities.

Computer Terminal Emulation Software Software such as Microsoft® HyperTerminal® or ProComm Plus® that can be used to send and receive ASCII text messages and files via a computer serial port.

COMTRADE Abbreviation for Common Format for Transient Data Exchange.

Conditioning Timers Timers for conditioning Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state.

Contact Input See Control Input.

Contact Output See Control Output.

Control Input Relay input for monitoring the state of external circuits. Connects auxiliary relay and circuit breaker contacts to the control inputs.

Control Output Relay output that affects the state of other equipment. Connects control outputs to circuit breaker trip and close coils, breaker failure auxiliary relays, communications-assisted tripping circuits, and SCADA systems.

Coordination Timer A timer that delays an overreaching element so that a downstream device has time to operate.

COS Operator Operator in math SELOGIC control equations that provides the cosine function.

Counter Variable or device such as a register or storage location that either records or represents the number of times an event occurs.

CT Current transformer.

CT Subsidence Current Subsidence current appears as a small exponentially decaying dc current with a long time constant. This current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load.

CTR Current transformer ratio.

Current Transformer Saturation CT condition when the CT does not reproduce the primary current with the specified accuracy.

Data Attribute In the IEC 61850 protocol, the name, format, range of possible values, and representation of values being communicated.

Data Bit A single unit of information that can assume a value of either logical 0 or logical 1 and can convey control, address, information, or frame check sequence data.

Data Class In the IEC 61850 protocol, an aggregation of classes or data attributes.

Data Label The identifier for a particular data item.

Data Object In the IEC 61850 protocol, part of a logical node representing specific information (status or measurement, for example). From an object-oriented point of view, a data object is an instance of a data class.

DC Offset A dc component of fault current that results from the physical phenomenon preventing an instantaneous change of current in an inductive circuit.

DCE Devices Data communication equipment devices (modems).

Deadband The range of variation an analog quantity can traverse before causing a response.

Deassert To deactivate. To remove the logic or electrical requirements needed to operate a device. To clear a logic condition to its false state (logical 0). To open the circuit or open the contacts across an SEL-487B input. To open a normally open output contact. To close a normally closed output contact.

Debounce Time The time that masks the period when relay contacts continue to move after closing; debounce time covers this indeterminate state.

Default Data Map The default map of objects and indices that the SEL-487B uses in DNP protocol.

Differential Element Using the busbar as reference, the differential element calculates the difference between current towards the busbars and away from the busbars.

Directional Element The directional element compares the direction of current at the reference terminal to the direction of current at all other terminals in each protection zone.

Disconnect (Isolator) Mechanical switch that isolates primary equipment such as circuit breakers from the electrical system.

DNP (Distributed Network Protocol) Manufacturer-developed, hardware-independent communications protocol primarily intended for SCADA applications; owned and controlled by the DNP User's Group (www.dnp.org).

Dropout Time The time measured from the removal of an input signal until the output signal deasserts. You can set the time, in the case of a logic variable timer, or the dropout time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

DTE Devices Data terminal equipment (computers, terminals, printers, relays, etc.).

DTT (Direct Transfer Trip) A communications-assisted tripping scheme. A relay at one end of a line sends a tripping signal to the relay at the opposite end of the line.

Dumb Terminal See ASCII terminal.

Dynamic Zone Selection The process by which the currents from the CTs are assigned to or removed from the differential calculations as a function of the boolean value (logical 0 or logical 1) of a particular SELOGIC equation.

EEPROM Electrically Erasable Programmable Read-Only Memory. Nonvolatile memory where relay settings, event reports, SER records, and other nonvolatile data are stored.

EHV Extra high voltage. Voltages greater than 230 kV.

EIA-232 Electrical definition for point-to-point serial data communications interfaces, based on the standard EIA/TIA-232. Formerly known as RS-232.

EIA-485 Electrical standard for multidrop serial data communications interfaces, based on the standard EIA/TIA-485. Formerly known as RS-485.

Electrical Operating Time Time between trip or close initiation and an open phase status change.

Electromechanical Reset Setting of the relay to match the reset characteristics of an electromechanical overcurrent relay.

End-Zone Fault A fault between the circuit breaker and the CT of a terminal.

ESD (Electrostatic Discharge) The sudden transfer of charge between objects at different potentials caused by direct contact or induced by an electrostatic field.

Ethernet A network physical and data link layer defined by IEEE® 802.2 and IEEE 802.3.

Event History A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; fault location; maximum fault phase current; active group at the trigger instant; and targets.

Event Report A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or ASCII **TRI** command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary A shortened version of stored event reports. An event summary includes items such as event date and time, event type, time source, etc. The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

EXP Operator Math SELOGIC control equation operator that provides exponentiation.

F_TRIG Falling-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a falling edge.

Fail-Safe Refers to an output that is open during normal relay operation and closed when relay power is removed or if the relay fails. Configure alarm outputs for fail-safe operation.

Falling Edge Transition from logical 1 to logical 0.

Fast Meter SEL binary serial port command used to collect metering data with SEL relays.

Fast Operate SEL binary serial port command used to perform control with SEL relays.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash Memory A type of nonvolatile relay memory used for storing large blocks of nonvolatile data.

Fault Detection Logic Logic that distinguishes between internal and external faults.

Float High The highest charging voltage supplied by a battery charger.

Float Low The lowest charging voltage supplied by a battery charger.

Form C Output An output with both an a output and b output sharing a common post.

Free-Form Logic Custom logic creation and execution order.

Free-Form SELogic Control Equations Free-form relay programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

FTP File transfer protocol.

Function In IEC 61850, task(s) performed by the substation automation system, i.e., by application functions. Generally, functions exchange data with other functions. Details are dependent on the functions involved.

Functions are performed by IEDs (physical devices). A function may be split into parts residing in different IEDs but communicating with each other (distributed function) and with parts of other functions. These communicating parts are called logical nodes.

Function Code A code that defines how you manipulate an object in DNP3 protocol.

Functional Component Portion of an IEC 61850 Logical Node dedicated to a particular function including status, control, and descriptive tags.

Fundamental Frequency The component of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Global Settings General settings including those for relay and station identifiers, number of breakers, number of disconnects, date format, nominal system frequency, enables, station dc monitoring, control inputs, settings group selection, and data reset controls.

GOMSFE Generic Object Model for Substation and Feeder Equipment; a system for presenting and exchanging IED data.

GOOSE IEC 61850 Generic Object Oriented Substation Event. GOOSE objects can quickly and conveniently transfer status, controls, and measured values among peers on an IEC 61850 network.

GPS Global Positioning System. Source of position and high-accuracy time information.

GUI Graphical user interface.

Hexadecimal Address An address reference represented as a base-16 value. Hexadecimal number representation is typically indicated by a 0x prefix or an h suffix.

HMI Human machine interface.

Local HMI: the LCD display on each of the SEL-487B relays.

System HMI: the display connected to the SEL-2030 that dynamically shows the station linking arrangement.

Station HMI: the equipment from which station-wide data acquisition and control are performed.

HV High voltage. System voltage greater than or equal to 100 kV and less than 230 kV.

I01–I18 Input phase currents.

ICD File IEC 61850 IED Capability Description file. XML file that describes IED capabilities, including information on logical node and GOOSE support.

IEC 61850 Internationally standardized method of communications and integration conceived with the goal of supporting systems of multivendor IEDs networked together to perform protection, monitoring, automation, metering, and control.

IED Intelligent electronic device.

IGBT Insulated gate bipolar junction transistor.

Inboard CT (bushing CT) Current transformer physically positioned in such a way that the CT is bypassed when the feeder is on transfer.

Input Conditioning The establishment of debounce time and assertion level.

Instance A subdivision of a relay settings class. Group settings have several subdivisions (Group 1–Group 6), while the Global settings class has one instance.

IP Address An identifier for a computer or device on a TCP/IP network. Networks using the TCP/IP protocol route messages based on the IP address of the destination. The format of an IP address is a 32-bit numeric address written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

IRIG-B A time code input that the relay can use to set the internal relay clock.

Jitter Time, amplitude, frequency, or phase-related abrupt, spurious variations in duration, magnitude, or frequency.

L/R Circuit inductive/resistive ratio.

Latch Bits Nonvolatile storage locations for binary information.

LED Light-emitting diode. Used as indicators on the relay front panel.

Left-Side Value LVALUE. Result storage location of a SELOGIC control equation.

Line Impedance The phasor sum of resistance and reactance in the form of positive-sequence, negative-sequence, and zero-sequence impedances of the protected line.

LMD SEL distributed port switch protocol.

LN Operator Math SELOGIC control equation operator that provides natural logarithm.

Local Bits The Relay Word bit outputs of local control switches that you access through the SEL-487B front panel. Local control switches replace traditional panel mounted control switches.

Lockout Relay An auxiliary relay that prevents operation of associated devices until it is reset either electrically or manually.

Logical 0 A false logic condition, dropped out element, or deasserted control input or control output.

Logical 1 A true logic condition, picked up element, or asserted control input or control output.

Logical Node In IEC 61850, the smallest part of a function that exchanges data. A logical node (LN) is an object defined by its data and methods. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function.

Low-Level Test Interface An interface that provides a means for interrupting the connection between the relay input transformers and the input processing module and allows inserting reduced-scale test quantities for relay testing.

MAC Address The Media Access Control (hardware) address of a device connected to a shared network medium, most often used with Ethernet networks.

Maintenance Testing Testing that confirms that the relay is measuring ac quantities accurately and verifies correct functioning of auxiliary equipment, scheme logic, and protection elements.

Math Operations Calculations for automation or extended protection functions.

Math Operators Operators that you use in the construction of math SELOGIC control equations to manipulate numerical values.

Maximum Dropout Time The maximum time interval following a change of input conditions between the deassertion of the input and the deassertion of the output.

Mechanical Operating Time Time between trip initiation or close initiation and the change in status of an associated circuit breaker auxiliary 52A normally open contacts.

MIRRORED BITS® Communications Patented relay-to-relay communications protocol that sends internal logic status, encoded in a digital message, from one relay to the other. Eliminates the need for some communications hardware.

MMS Manufacturing Messaging Specification, a data exchange protocol used by IEC 61850 and UCA.

MOD Motor-operated disconnect.

MOV Metal-oxide varistor.

Negation Operator A SELOGIC control equation math operator that changes the sign of the argument. The argument of the negation operation is multiplied by –1.

Negative Sequence Use the following expression to calculate the negative-sequence voltage:

$$3V_2 = V_A + a^2V_B + aV_C$$

where a = 1 ∠ 120°

NEMA National Electrical Manufacturers' Association.

Nonvolatile Memory Relay memory that persists over time to maintain the contained data even when the relay is de-energized.

NOT Operator A logical operator that produces the inverse value.

OR Operator Logical OR. A Boolean SELOGIC control equation operator that compares two Boolean values and yields either a logical 1 if either compared Boolean value is logical 1 or a logical 0 if both compared Boolean values are logical 0.

OSI Open Systems Interconnect. A model for describing communications protocols. Also an ISO suite of protocols designed to this model.

Outboard CT Current transformer physically positioned in such a way that the CT remains in circuit when the feeder is on transfer.

Overlap Configuration Configuration of the tie-breaker protection whereby the area between the tie-breaker CTs are part of two bus-zones, i.e., a fault between the tie-breaker CTs is common to two bus-zones.

Override Values Test values you enter in Fast Meter and DNP storage.

Parentheses Operator Math operator. Use paired parentheses to control the execution of operations in a SELOGIC control equation.

PC Personal computer.

Phase Overcurrent Element Elements that operate by comparing the phase current applied to the secondary current inputs with the phase overcurrent setting. The relay asserts these elements when any combination of the phase currents exceeds phase current setting thresholds.

Pickup Time The time measured from the application of an input signal until the output signal asserts. You can set the time, as in the case of a logic variable timer, or the pickup time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

Port Settings Communications port settings such as Data Bits, Speed, and Stop Bits.

Positive-Sequence Use the following expression to calculate the positive-sequence voltage:

$$3V_1 = V_A + aV_B + a^2V_C$$

Where a = 1 ∠ 120°

Primitive Name The mnemonic current labels (I01, I02 through I18), voltage labels (V01, V02 and V03) and bus-zone labels (BZ1, BZ2 through BZ6).

Protection and Automation Separation Segregation of protection and automation processing and settings.

Protection Settings Group Individual scheme settings for as many as six different schemes (or instances).

Protection-Disabled State Suspension of relay protection element and trip/close logic processing and de-energization of all control outputs.

Protection Zone (also see Bus-Zone) Area of protection formed by a minimum of one bus-zone. A protection zone can include more than one bus-zone. For example, merging two bus-zones results in a single protection zone. When no bus-zones are merged, a protection zone and a bus-zone have the same meanings.

PT Potential transformer. Also referred to as a voltage transformer or VT.

PTR Potential transformer ratio.

Qualifier Code Specifies type of range for DNP3 objects. With the help of qualifier codes, DNP master devices can compose the shortest, most concise messages.

R_TRIG Rising-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a rising edge.

RAM Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data.

Relay Word Bit A single relay element or logic result. A Relay Word bit can equal either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted control input or control output. Logical 0 represents a false logic condition, dropped out element, or deasserted control input or control output. Use Relay Word bits in SELOGIC control equations.

Remapping The process of selecting data from the default map and configuring new indices to form a smaller data set optimized to your application.

Remote Bit A Relay Word bit with a state that is controlled by serial port commands, including the **CONTROL** command, a binary Fast Operate command, DNP binary output operation, or an IEC 61850 control operation.

Report Settings Event report and Sequential Events Recorder settings.

Retrip A subsequent act of attempting to open the contacts of a circuit breaker after the failure of an initial attempt to open these contacts.

Rising Edge Transition from logical 0 to logical 1, or the beginning of an operation.

RMS Root-mean-square. This is the effective value of the current and voltage measured by the relay, accounting for the fundamental frequency and higher order harmonics in the signal.

RTU Remote Terminal Unit.

RXD Received data.

SCADA Supervisory control and data acquisition.

SCD File IEC 61850 Substation Configuration Description file. XML file that contains information on all IEDs within a substation, communications configuration data, and a substation description.

SCL IEC 61850 Substation Configuration Language. An XML-based configuration language that supports the exchange of database configuration data among different software tools that can be from different manufacturers. There are four types of SCL files used within IEC 61850: CID, ICD, SCD, and SSD.

Self-Description A feature of the IEC 61850 protocol. A master device can request a description of all of the Logical Nodes and data within the IED.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates detection of an out-of-tolerance condition. The SEL-487B has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as a control output) using a logical combination of relay element outputs and fixed logic outputs.

SELOGIC Expression Builder A rules-based editor within the ACSELERATOR software for programming SELOGIC control equations.

SELOGIC Math Variables Math calculation result storage locations.

Sequencing Timers Timers designed for sequencing automated operations.

Sequential Events Recorder A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a list that you set in the relay. SER provides a useful way to determine the order and timing of events of a relay operation.

SER Sequential Events Recorder or the relay serial port command to request a report of the latest 1000 sequential events.

Settle/Settling Time Time required for an input signal to result in an unvarying output signal within a specified range.

Single-CT Application Tie breaker with only one CT available for busbar protection.

Single Relay Application Stations with as many as 18 per-phase CTs require only one SEL-487B. Stations with more than 18 and as many as 54 per-phase CTs require three SEL-487B relays.

SIN Operator Operator in math SELOGIC control equations that provides the sine function.

SQRT Operator Math SELOGIC control equation operator that provides square root.

SSD File IEC 61850 System Specification Description file. XML file that describes the single-line diagram of the substation and the required logical nodes.

Status Failure A severe out-of-tolerance internal operating condition. The relay issues a status failure message and enters a protection-disabled state.

Status Warning Out-of-tolerance internal operating conditions that do not compromise relay protection, yet are beyond expected limits. The relay issues a status warning message and continues to operate.

Strong Password A mix of valid password characters in a six-character combination that does not spell common words in any portion of the password. Valid password characters are numbers, upper- and lowercase alphabetic characters, period (.), and hyphen (-).

Subnet Mask The subnet mask divides the local node IP address into two parts, a network number and a node address on that network. A subnet mask is four bytes of information and is expressed in the same format as an IP address.

Subsidence Current See CT subsidence current.

Telnet An Internet protocol for exchanging terminal data that connects a computer to a network server and allows control of that server and communication with other servers on the network.

Terminal Any equipment with at least a current transformer and a circuit breaker.

Terminal-to-Bus-Zone Connection Variable SELOGIC variable stating the conditions when the relay considers the current input from a particular terminal in the differential calculations of a particular bus-zone.

Thermal Withstand Capability The capability of equipment to withstand a predetermined temperature value for a specified time.

Three-Phase Fault A fault involving all three phases of a three-phase power system.

Three-Pole Trip A circuit breaker operation that occurs when the circuit breaker opens all three poles at the same time.

Three-Relay Application Stations with more than 18 and as many as 54 per-phase CTs require three SEL-487B relays. Stations with as many as 18 per-phase CTs require only one SEL-487B.

Tie Breaker See buscoupler and bus sectionalizer.

Time Delay on Pickup The time interval between initiation of a signal at one point and detection of the same signal at another point.

Time Dial A control that governs the time scale of the time-overcurrent characteristic of a relay. Use the time-dial setting to vary relay operating time.

Time-Delayed Tripping Tripping that occurs after expiration of a predetermined time.

Time-Overcurrent Element An element that operates according to an inverse relationship between input current and time, with higher current causing faster relay operation.

Torque Control A method of using one relay element to supervise the operation of another.

Total Clearing Time The time interval from the beginning of a fault condition to final interruption of the circuit.

TXD Transmitted data.

UCA2 Utility Communications Architecture version 2. A network-independent protocol suite that serves as an interface for individual intelligent electronic devices.

Unbalanced Fault All faults that do not include all three phases of a system.

Unbuffered Report IEC 61850 IEDs can issue immediate unbuffered reports of internal events (caused by trigger options data-change, quality-change, and data-update) on a "best efforts" basis. If no association exists, or if the transport data flow is not fast enough to support it, events may be lost.

User ST Region in GOOSE for user-specified applications.

V01, V02, V03 Voltage input terminals.

Virtual Terminal Connection A mechanism that uses a virtual serial port to provide the equivalent functions of a dedicated serial port and a terminal.

VT Voltage transformer. Also referred to as a potential transformer or PT.

Warm Start The reset of a running system without removing and restoring power.

Wye A phase-to-neutral connection of circuit elements, particularly voltage transformers or loads. To form a wye connection using transformers, connect the nonpolarity side of each of three voltage transformer secondaries in common (the neutral), and take phase to neutral voltages from each of the remaining three leads. When properly phased, these leads represent the A-phase-, B-phase-, and C-phase-to-neutral voltages. This connection is frequently called four-wire wye, alluding to the three phase leads plus the neutral lead.

XML Extensible Markup Language. This specification developed by the W3C (World Wide Web Consortium) is a pared-down version of SGML designed especially for web documents. It allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data among applications and organizations.

Zero Sequence Use the following expression to calculate the zero-sequence voltage:

$$3V_0 = V_A + V_B + V_C$$

Z-Number That portion of the relay FID string that identifies the proper ACSELERATOR software relay driver version and HMI driver version when creating or editing relay settings files.

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Page numbers appearing in bold mark the location of the topic's primary discussion.

A=Applications Handbook   U=User's Guide   R=Reference Manual

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SEL-487B Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (complete relay monitoring and control)
AACCESS	Go to Access Level A (automation control)
ACCESS	Go to Access Level 1 (monitor relay)
BACCESS	Go to Access Level B (monitor relay and control circuit breakers)
BNAME	ASCII names of all relay status bits (Fast Meter)
CASCII	Generate the Compressed ASCII response configuration message
CEVENT	**EVENT** command for the Compressed ASCII response
CHISTORY	**HISTORY** command for the Compressed ASCII response
COMM *c*	Display relay-to-relay MIRRORED BITS® communications data (*c* = A is channel A; *c* = B is channel B; *c* = M is either enabled single channel)
CONTROL *nn*	Set, clear, or pulse an internal remote bit (*nn* is the remote bit number from 01–96)
COPY *m n*	Copy settings between instances in the same class (*m* and *n* are instance numbers; for example: *m* = 1 is Group 1; *n* = 2 is Group 2)
CSER	**SER** command for the Compressed ASCII response
CSTATUS	**STATUS** command for the Compressed ASCII response
CSUMMARY	**SUMMARY** command for the Compressed ASCII response
DATE	Display and set the date
DNAME X	ASCII names of all relay digital I/O (Fast Meter)
DNP	Access or modify serial port DNP3 settings (similar to **SHOW D** and **SET D**)
EVENT	Display and acknowledge event reports
FILE	Transfer data between the relay and external software
GROUP	Display the active group number or select the active group
HELP	Display available commands or command help at each access level
HISTORY	View event summaries/histories; clear event data
ID	Display the firmware id, user id, device code, part number, and configuration information
LOOPBACK	Connect MIRRORED BITS data from transmit to receive on the same port
MAP 1	Analyze the communications card database
METER	Display metering data and internal relay operating variables
OACCESS	Go to Access Level O (output control)
OPEN *n*	Open the circuit breaker (*n* = 1–18)
PACCESS	Go to Access Level P (protection control)
PASSWORD	Change relay passwords
PORT	Connect to a remote relay via MIRRORED BITS® virtual terminal (for port number *p* = 1–3 and F), or to the Ethernet card (port *p* = 5)
PULSE OUT*nnn*	Pulse a relay control output (OUT*nnn* is a control output number)
QUIT	Reduce access level to Access Level 0 (exit relay control)
SER	View Sequential Events Recorder reports
SET[c]	Enter relay settings
SHOW[c]	Display relay settings

Command[a, b]	Description
SNS	Display Sequential Events Recorder settings name strings (Fast SER)
STATUS	Report or clear relay status and SELOGIC® control equation errors
SUMMARY	View summary event reports
TARGET	Display relay elements for a row in the Relay Word table
TEST DB	Display or place values in the communications card database (useful for Ethernet protocol read tests)
TEST DNP	Display or place values in the serial port DNP3 object map
TEST FM	Display or place values in metering database (Fast Meter)
TIME	Display and set the internal clock
TRIGGER	Initiate a data capture and record an event report
VERSION	Display the relay hardware and software configurations
VIEW 1	View data from the communications card database
ZONE	Display the terminal and bus names associated with all active protective zones

[a] See Section 7: ASCII Command Reference in the Reference Manual.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.
[c] See the table below for **SET/SHOW** options.

SET/SHOW Command Options

Option	Setting Type	Description
[S] ***n***	Group Settings 1–6	Particular application settings
A ***n***	Automation Logic Block 1–10	Automation SELOGIC control equations
D	DNP3	Direct Network Protocol remapping (serial port only)
F	Front Panel	Front-panel HMI settings
G	Global	Relay-wide settings
L ***n***	Protection Logic Group 1–6	Protection SELOGIC control equations
O	Outputs	Output SELOGIC control equations
P ***n***	Port 1–3, F, 5	Communications port settings
R	Report	Event report and SER settings
T	Alias	Alias names for analog quantities and Relay Word bits
Z ***n***	Zone Configuration Group 1–6	Zone configuration settings

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