BE1-FLEX

Protection, Automation, and Control System

Instruction Manual

12570 Route 143 • Highland, Illinois 62249-1074 USA
Tel +1 618.654.2341 • Fax +1 618.654.2351
www.basler.com • info@basler.com

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Preface

This instruction manual provides information about the installation and operation of the BE1-FLEX Protection, Automation, and Control System. To accomplish this, the following information is provided:

- General information
- Quick start
- Mounting and hardware configuration
- Circuit configuration and connections
- BESTCOMS*Plus*® software
- Protection and control functions
- Reporting and alarms
- Communications and security
- Testing and troubleshooting
- Specifications

An optional instruction manual (Basler Electric part number 9579200991) for the BE1-FLEX includes Modbus® Protocol, Distributed Network Protocol (DNP), and IEC 61850 Protocol.

Conventions Used in this Manual

Important safety and procedural information is emphasized and presented in this manual through warning, caution, and note boxes. Each type is illustrated and defined as follows.

Warning!
Warning boxes call attention to conditions or actions that may cause personal injury or death.

Caution
Caution boxes call attention to operating conditions that may lead to equipment or property damage.

Note
Note boxes emphasize important information pertaining to installation or operation.

Basler Electric
12570 State Route 143
Highland IL 62249-1074 USA
www.basler.com
info@basler.com
Tel: +1 618.654.2341
Fax: +1 618.654.2351

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Warning!

READ THIS MANUAL. Read this manual before installing, operating, or maintaining the BE1-FLEX. Note all warnings, cautions, and notes in this manual as well as on the product. Keep this manual with the product for reference. Only qualified personnel should install, operate, or service this system. Failure to follow warning and cautionary labels may result in personal injury or property damage. Exercise caution at all times.

Caution

Installing previous versions of firmware may result in compatibility issues causing the inability to operate properly and may not have the enhancements and resolutions to issues that more recent versions provide. Basler Electric highly recommends using the latest version of firmware at all times. Using previous versions of firmware is at the user's risk and may void the warranty of the unit.

Basler Electric does not assume any responsibility to compliance or noncompliance with national code, local code, or any other applicable code. This manual serves as reference material that must be well understood prior to installation, operation, or maintenance.

For terms of service relating to this product and software, see the *Commercial Terms of Products and Services* document available at www.basler.com/terms.

This publication contains confidential information of Basler Electric Company, an Illinois corporation. It is loaned for confidential use, subject to return on request, and with the mutual understanding that it will not be used in any manner detrimental to the interests of Basler Electric Company and used strictly for the purpose intended.

It is not the intention of this manual to cover all details and variations in equipment, nor does this manual provide data for every possible contingency regarding installation or operation. The availability and design of all features and options are subject to modification without notice. Over time, improvements and revisions may be made to this publication. Before performing any of the following procedures, contact Basler Electric for the latest revision of this manual.

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

Revision History

A historical summary of the changes made to this instruction manual is provided below. Revisions are listed in reverse chronological order.

Visit www.basler.com to download the latest hardware, firmware, and BESTCOMS*Plus*® revision histories.

Instruction Manual Revision History

Manual Revision and Date	Change
L, Dec 2025	• Added screw size, ferrule length, and strip length information. • Added information on fast current detector dropout time. • Minor text edits throughout manual.
K, Jun 2025	• Changed mentions of BESTwave to BESTdata. • Updated specs for fast current detector. • Updated troubleshooting of targets and alarms reset. • Added FCC requirements.
J, Mar 2025	• Added specs for Control Power Monitor and updated China RoHS table in *Specifications*. • Minor text edits throughout manual.
I	• This revision letter not used.
H, Jul 2024	• Updated grounding recommendation for RS-485 cable in *Communications*. • Updated RoHS 2 and added IEC 62055-27 in *Specifications*.
G, May 2024	• Updated Control Timer and Trip/ReTrip descriptions of the 50BF element. • Updated Communications in the *Troubleshooting* chapter. • Added Maritime Recognition in the *Specifications* chapter.
F, Dec 2023	• Added China RoHS in *Specifications*. • Minor text edits throughout manual.
E, Jul 2023	• Added description of circuit frequency calculation. • Updated Breaker Status logic block and descriptions. • Added description of BESTlogic*Plus* processing sequence. • Updated description of alarms. • Updated Isolation specifications. • Minor text edits throughout manual.
D, Feb 2023	• Added description of HMIC Editor in the *HMI* chapter. • Added Protocol Package 2 to the style chart in the *Introduction* chapter. • Added description of HSR and PRP in the *Communications* chapter. • Added Differential Compensation Methodology in the *Phase Differential* (87) chapter. • Minor text edits throughout manual.

Manual Revision and Date	Change
C, Aug 2022	• Added Hardware Slot Numbers at the top of style chart. • Added top dimension on side view in Mounting section. • Added information on circuit board pin labeling. • Added a note about EMI suppression. • Updated figures for Typical Connections. • Added a note about HMIC files. • Updated Security Access Levels description. • Updated Fault Reporting description. • Added description of IN-1 Thresh Alarm. • Other minor improvements and edits throughout manual.
B, Jan 2022	• Added Zone Configuration settings descriptions for the 87 element. • Added Nominal Voltage specs for voltage inputs. • Added UKCA Compliance spec. • Other clarifications throughout manual.
A, Jun 2021	• Changed K constant values to “0” in the *Timing Characteristics* chapter. • Updated weight and added shipping weight in the *Specifications* chapter.
—, May 2021	• Initial release.

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1 • Introduction

The BE1-FLEX Protection, Automation, and Control System is designed to be configurable for nearly any Power System application. The BE1-FLEX can cover a wide application spectrum as it can be configured for any combination of functions available. The large configurable touchscreen provides an application specific user interface. To support unknown future needs, the BE1-FLEX can simply turn on extra functions not common for an application, change or upgrade boards, field upgrade non-hardware style options, and securely update firmware all without needing to remove it from the installation.

The BE1-FLEX provides flexible, reliable, and economical protection, automation, control, monitoring, and measurement functions for distribution feeder, transformer, main-tie-main, generator, bay control, bus, capacitor bank, intertie, and other protection applications. It can also be configured to a wide variety of non-protection applications as it can be set to exclude all protection functions or only desired functions. Automation control, multi-breaker synchronization and other functions are possible. The BE1-FLEX offers hundreds of elements for protection, automation, and control described later in this chapter. System metering, status information, and fault locating are available at the BE1-FLEX front panel and through its communication ports. The capabilities of the BE1-FLEX make it suitable for retrofit, new, and future applications.

The BE1-FLEX is expandable and provides extreme flexibility. Circuit boards can be added or removed to configure it in any manner deemed necessary to fit the application. The BE1-FLEX accommodates multiple boards in a wide variety including current and voltage sensing boards, input/output and auxiliary boards, communications boards, and power supply boards.

A front-panel USB port or optional rear Ethernet ports enable local and remote communication between the BE1-FLEX and a PC operating with BESTCOMS*Plus*® software. BESTCOMS*Plus* software simplifies the commissioning process by providing a graphical interface for setting the BE1-FLEX and configuring a protection, automation, and control scheme for your application. Through BESTCOMS*Plus*, all BE1-FLEX settings and logic can be retained in a file for printing or uploading to other BE1-FLEX systems. Oscillography and sequential events records can be retrieved from a BE1-FLEX, viewed, and printed.

Front-panel features include a large touchscreen display and LED indicators that display system parameters, BE1-FLEX settings, and BE1-FLEX status. The touchscreen enables navigation through the menu, changes to settings, resetting of targets (with password access), and direct access to controls and switches.

Applications

The capabilities of the BE1-FLEX make it ideally suited for a wide variety of applications. A few applications with specific requirements that can be met by the BE1-FLEX are noted below:

- Generator specific protection and control elements including loss of field, out of step, stator ground protection, and sync check or synchronizer
- Generator focused protection including reverse power, negative-sequence, overexcitation, and differential
- Transformer applications where differential protection is required
- Bus Differential with low or high breaker and segmentation counts
- Monitoring the through fault currents that may lead to transformer damage
- Complete control of the circuit breaker connecting the transformer to the distribution bus
- Applications where bus protection is provided by a high-speed overcurrent blocking scheme on the transformer bus mains instead of a dedicated bus differential circuit
- Applications requiring an interface between the protection and control package and the process control systems
- Low burden to extend the linear range of CTs
- Coordinated protection with other BE1-FLEX systems on both ac and dc sides of a rectifier

- The flexibility provided by wide setting ranges, multiple setting groups, and multiple coordination curves in one unit
- The economy and space savings provided by a multifunction, multiphase unit. This one unit can provide all of the protection, control, metering, and local and remote indication functions required for typical applications.
- Directional control and fault recording
- High-speed Ethernet communications and protocol support
- The capabilities of a digital multifunction relay
- The small size and limited behind-panel projection facilitates modernizing protection and control systems in existing equipment
- Detection of low ground current levels (SEF option)
- Settings Templates with logic schemes for feeder, generator, intertie, transformer, and custom applications

Features

The BE1-FLEX system includes many features for the protection, monitoring, and control of power system equipment. These features include protection, automation, control, metering, reporting, and alarm functions. A highly flexible programmable logic system called BESTlogic™*Plus* allows the user to apply the available functions with complete flexibility and customize the system to meet the requirements of the protected power system. Programmable I/O, extensive communication features, and an advanced user interface provide easy access to the features provided.

The following information summarizes the capabilities of this multifunction device. Each feature, along with its setup and use, is described in detail in the later chapters of this manual.

General Features

- Seven-inch touchscreen with customizable HMI (Human-Machine Interface)
- Advanced cybersecurity secure device access settings
- Multi-breaker automation and control with Trip Circuit Monitoring and Breaker Monitoring
- Multi-circuit protection, monitoring and control
    - Up to 28 CT (pending configuration)
    - Up to 16 VT (pending configuration)
- Contact input and output capabilities
    - Up to 72 contact inputs (pending configuration)
    - Up to 48 outputs (pending configuration)
- Auxiliary analog inputs
    - 4 to 20 mA, 0 to 10 V, 50 to 100 mV, and RTD
- Field upgradable hardware
- Field upgradable software
- NTP and IRIG-B synchronized clock with battery backup
- USB, RS-485, copper Ethernet and fiber Ethernet ports with multi-protocol support
- Advanced recording
    - All targets and alarms
    - 30+ million data point Oscillography (COMTRADE format) with Fault Summary
    - 8,000-record Sequence of Events (SoE)
    - Security audit log

- Load profile
- Transformer Damage (51TF)
- Diagnostic log
- Demand
- Power quality
- Energy

Protection and Control

The BE1-FLEX includes protection elements that monitor voltage, current, power, phase angle, frequency, temperature, impedance, and more to provide protection against faults and abnormal operating conditions. Control elements make the BE1-FLEX capable of controlling complex configurations common in multi-breaker management schemes.

Any combination of elements can be enabled, any number of any specific element, up to the maximum total capacity as shown by BESTCOMS*Plus* software. A user can enable many elements for all schemes and then disable the ones not being used for a particular application, allowing a single map to be used for the whole system. In addition, the BE1-FLEX has the ability to adapt to any future system requirement without device replacement.

- Voltage
  - Overexcitation (24), Sync Check (25), Undervoltage (27), Negative-Sequence Voltage (47), Overvoltage (59), Zero-Sequence Voltage (59N), Vector Jump (78V)
- Frequency
  - Underfrequency (81U), Overfrequency (81O), Rate-of-Change-of-Frequency (81R, ROCOF)
- Current
  - Undercurrent (37), Negative-Sequence Overcurrent (46), Single Phase, Three Phase, Neutral, Ground and Unbalance Instantaneous Overcurrent with 2nd and 5th Harmonic Inhibit (50, 50P, 50N, 50G, 50U), Breaker Failure (50BF), Single Phase, Three Phase, Neutral, Ground and Unbalance Inverse Overcurrent (51, 51P, 51N, 51G, 51U), Voltage Controlled and Restrained Overcurrent (51V), Overcurrent Through-Fault Counter (51TF), Directional Overcurrent (67), DC Overcurrent (76), Phase Differential (87), Flux Balance Differential (87FB), Neutral Differential (87N)
- Power
  - Underpower (32U), Overpower (32O), Loss of Excitation (40Q), Power Factor (55)
- Impedance
  - Neutral Distance (21N), Phase Distance (21P), Loss of Excitation (40Z), Out of Step (78OOS)
- Other Protection
  - Resistance Temperature Detector (49RTD), Control Power Monitor
  - Configurable Protection (with math functions: plus, minus, multiply, and divide) of circuit metering, power quality, energy, demand, and other parameters
- Control
  - Breaker control (101), Automatic Synchronizer (25A), Virtual Switches (43), Fuse Loss (60FL), Logic Timers (62), Recloser (79), Lockout (86).

BESTlogic™*Plus* Programmable Logic

Each BE1-FLEX protection, automation, and control function is implemented in an independent function element. Every function block is equivalent to its single function, discrete device counterpart so it is immediately familiar to the protection engineer. Programming with BESTlogic*Plus* is equivalent to choosing the devices required by your protection, automation, and control scheme and then drawing schematic diagrams to connect the inputs and outputs to obtain the desired operating logic.

Custom logic settings allow you to tailor the BE1-FLEX functionality to match the needs of the operation's practices and power system requirements.

Style Code and Style Configurator

The Style Configurator on the Basler website allows users to select the number of desired components and an abbreviated, yet complete, ordering code is generated. The BE1-FLEX recognizes both long style numbers and the codes. Shortened codes reduce typographical errors and simplify the style build. The online tool ensures only valid style numbers are created.

BE1-FLEX electrical characteristics and operational features are defined by a combination of letters and numbers that make up the style number. The style number describes the options included in a specific device and appears on labels located on the front panel and inside the case. Upon receipt of a BE1-FLEX, be sure to check the style number against the requisition and the packing list to ensure that they agree. The style chart is shown in Figure 1-1.

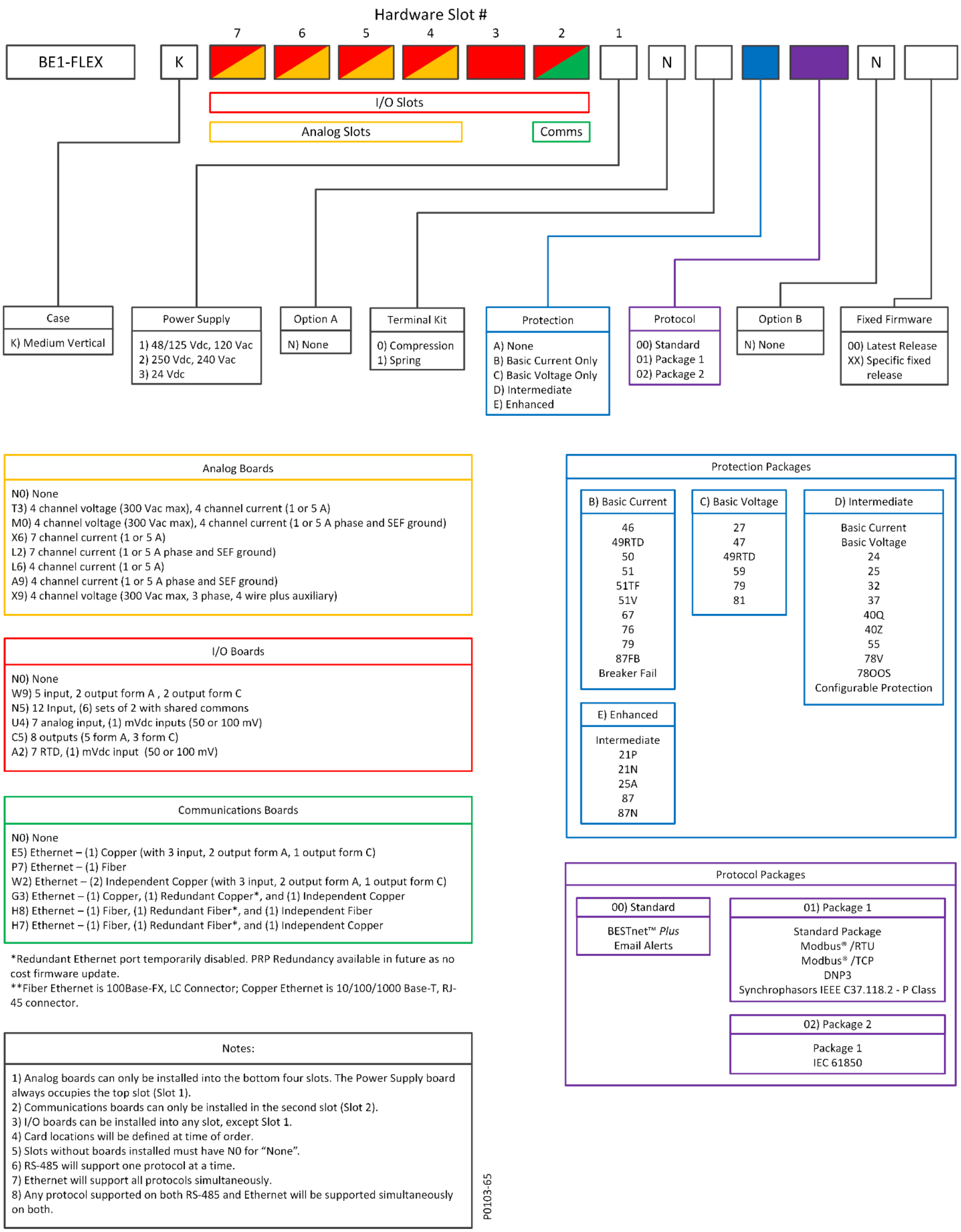


Figure 1-1. Style Chart

2 • Quick Start

This chapter provides basic installation and setup information about the BE1-FLEX. Upon receipt of the BE1-FLEX, check the model and style number against the requisition and packing list for agreement. If there is evidence of shipping damage, file a claim with the carrier, and notify the Basler Electric Regional Sales Office, your sales representative, or a sales representative at Basler Electric, Highland, Illinois.

If the BE1-FLEX is not installed immediately, store it in the original shipping carton in a moisture- and dust-free environment.

Note
Do not connect a USB cable between the PC and the BE1-FLEX until BESTCOMS*Plus*® is installed. Connecting a USB cable before setup is complete may result in errors.

Maintenance

Preventive maintenance consists of periodic replacement of the backup battery and periodically checking that the connections between the BE1-FLEX and the system are clean and tight. The front cover should be removed only when replacing the backup battery for the real-time clock. Ensure that the BE1-FLEX is powered off and taken out of service before removing the front cover. BE1-FLEX units are manufactured using state-of-the-art, surface-mount technology. As such, Basler Electric recommends that no repair procedures be attempted by anyone other than Basler Electric personnel. Rear accessed boards and displays are designed for field changes by following proper ESD limiting procedures.

Storage

This device contains long-life aluminum electrolytic capacitors. For devices that are not in service (spares in storage), the life of these capacitors can be maximized by energizing the device for 30 minutes once per year.

Install BESTCOMSPlus® Software

BESTCOMS*Plus* software is built on the Microsoft® .NET Framework. The setup utility that installs BESTCOMS*Plus* on your PC also installs the BE1-FLEX plugin and the required version of .NET Framework (if not already installed). BESTCOMS*Plus* operates with systems using Windows® 7 SP1, Windows 8.1, Windows 10 version 1607 (Anniversary Edition) or later, and Windows 11. System recommendations for the .NET Framework and BESTCOMS*Plus* are listed in Table 2-1.

Table 2-1. System Recommendations for BESTCOMS*Plus* and the .NET Framework

System Type	Component	Recommendation
32/64 bit	Processor	2.0 GHz
32/64 bit	RAM	1 GB (minimum), 2 GB (recommended)
32 bit	Hard Drive	200 MB (if .NET Framework is already installed on PC)
		4.5 GB (if .NET Framework is not already installed on PC)
64 bit	Hard Drive	200 MB (if .NET Framework is already installed on PC)
		4.5 GB (if .NET Framework is not already installed on PC)

To install BESTCOMS*Plus*, a Windows user must have Administrator rights.

1. Download BESTCOMS*Plus* from www.basler.com.
2. Click the installation button for BESTCOMS*Plus*. The setup utility installs BESTCOMS*Plus*, the .NET Framework (if not already installed), the USB driver, and the BE1-FLEX plugin for BESTCOMS*Plus* on your PC.

When BESTCOMS*Plus* installation is complete, a Basler Electric folder is added to the Windows programs menu. This folder is accessed by clicking the Windows Start button and then accessing the Basler Electric folder in the Programs menu. The Basler Electric folder contains an icon that starts BESTCOMS*Plus* when clicked.

Connect and Power Up the BE1-FLEX

The BE1-FLEX plugin is a module that runs inside the BESTCOMS*Plus* shell. The BE1-FLEX plugin contains specific operational and logic settings for only BE1-FLEX protection systems.

USB Connection

The USB driver was copied to your PC during BESTCOMS*Plus* installation and is installed automatically after powering the BE1-FLEX. USB driver installation progress is shown in the Windows Taskbar area. Windows will notify you when installation is complete. Connect a USB cable between the PC and your BE1-FLEX system.

Note
In some instances, the Found New Hardware Wizard will prompt you for the USB driver. If this happens, direct the wizard to the following folder: C:\Program Files\Basler Electric\USB Connect Driver\

If the USB driver does not install properly, refer to the *Troubleshooting* chapter.

Apply Operating Power

The nominal power supply values are listed next to the Power Supply terminals on the rear of the device. See Figure 2-1. Power Supply ratings on Style Number label are as built and may no longer be valid if a Power Supply board has been field updated.

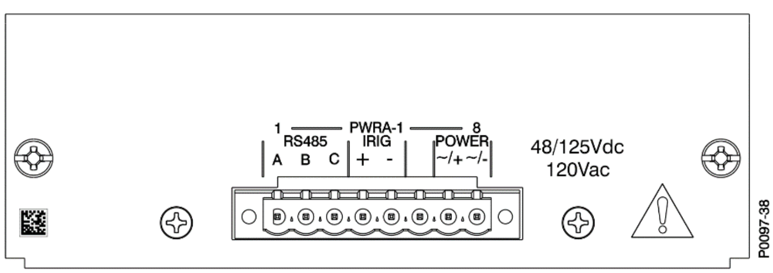


Figure 2-1. Power Supply Board, Rear View Example

Connect rear terminals labeled **POWER ~+** and **~–** to a power supply. Apply operating power consistent with the nominal power supply values listed on the Power Supply board. Wait until the boot sequence is complete.

Start BESTCOMSPlus®

To start BESTCOMS*Plus*, click the Start button, point to Programs, Basler Electric, and then click the BESTCOMS*Plus* icon. During initial startup, the BESTCOMS*Plus* Select Language screen is displayed

(Figure 2-2). You can choose to have this screen displayed each time BESTCOMS*Plus* is started, or you can select a preferred language and this screen will be bypassed in the future. Click OK to continue. This screen can be accessed later by selecting Tools and Select Language from the menu bar.

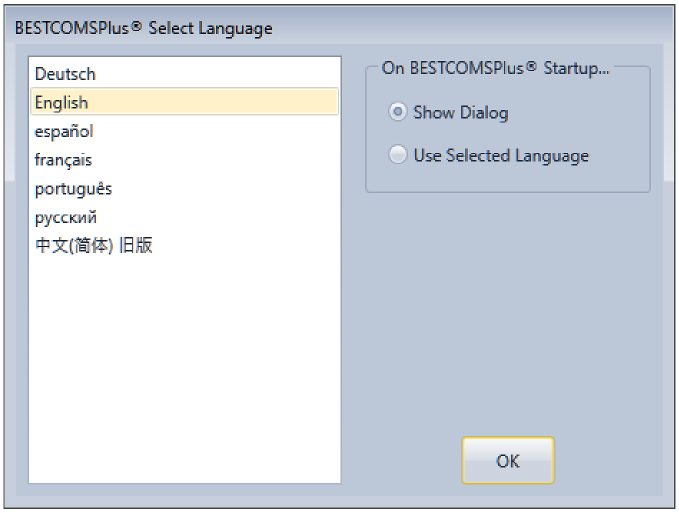


Figure 2-2. BESTCOMS*Plus* Select Language Screen

The BESTCOMS*Plus* platform window opens. Select New Connection from the Communication pull-down menu and select BE1-FLEX. See Figure 2-3. The BE1-FLEX Connection screen shown in Figure 2-4 appears.

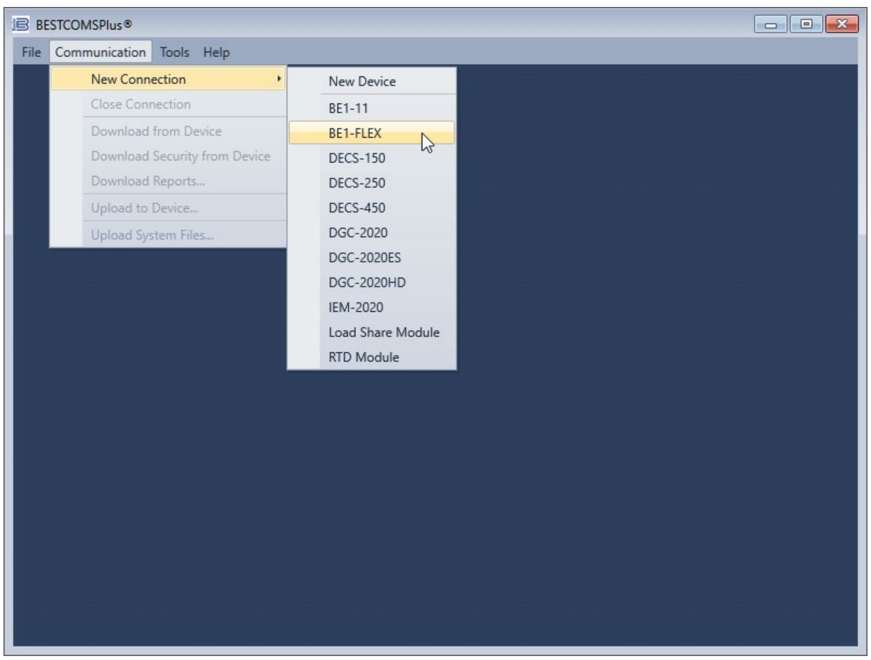


Figure 2-3. Communication Pull-Down Menu

Select USB Connection and then click the Connect button.

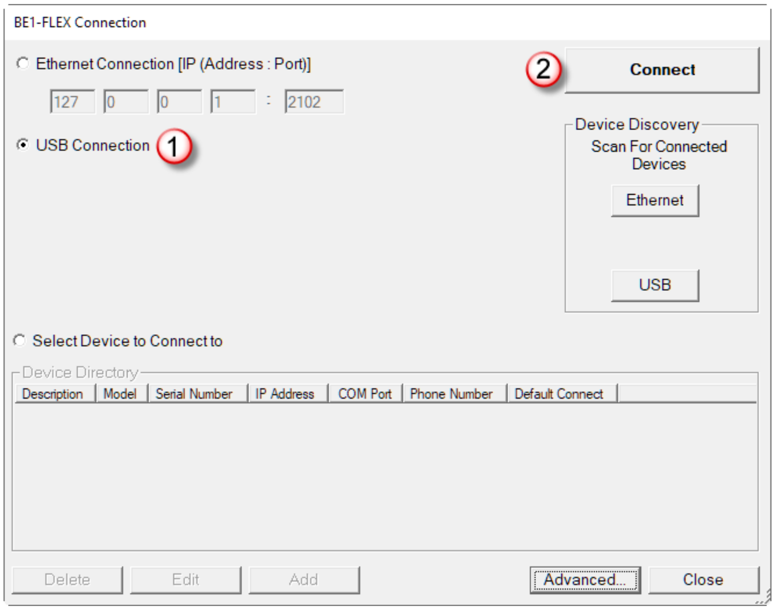


Figure 2-4. BE1-FLEX Connection Screen

Programming the BE1-FLEX

This section contains an introduction to BESTCOMS*Plus*, explains summary screens, and gives an example of settings elements and programming logic.

Introduction to BESTCOMS*Plus*®

BESTCOMS*Plus* is a Windows®-based, PC application that provides a user-friendly, graphical user interface (GUI) for use with Basler Electric communicating products. The name BESTCOMS*Plus* is an acronym that stands for Basler Electric Software Tool for Communications, Operations, Maintenance, and Settings.

BESTCOMS*Plus* provides the user with a point-and-click means to set and monitor the BE1-FLEX. The capabilities of BESTCOMS*Plus* make the configuration of one or several BE1-FLEX Protection, Automation, and Control Systems fast and efficient. A primary advantage of BESTCOMS*Plus* is that a settings scheme can be created, saved as a file, and then uploaded to the BE1-FLEX at the user's convenience.

BESTCOMS*Plus* uses plugins allowing the user to manage several different Basler Electric products. The BE1-FLEX plugin opens inside the BESTCOMS*Plus* main shell.

BESTlogic™*Plus* Programmable Logic is used to program BE1-FLEX logic for protection elements, inputs, outputs, alarms, etc. This is accomplished by the drag-and-drop method. The user can drag elements, components, inputs, and outputs onto the program grid and make connections between them to create the desired logic scheme.

BESTCOMS*Plus* also allows for downloading industry-standard COMTRADE files for analysis of stored oscillography data. Detailed analysis of the oscillography files can be accomplished using BESTdata software. BESTdata software is free and available at www.basler.com.

Figure 2-5 illustrates the typical user interface components of the BE1-FLEX plugin with BESTCOMS*Plus*.

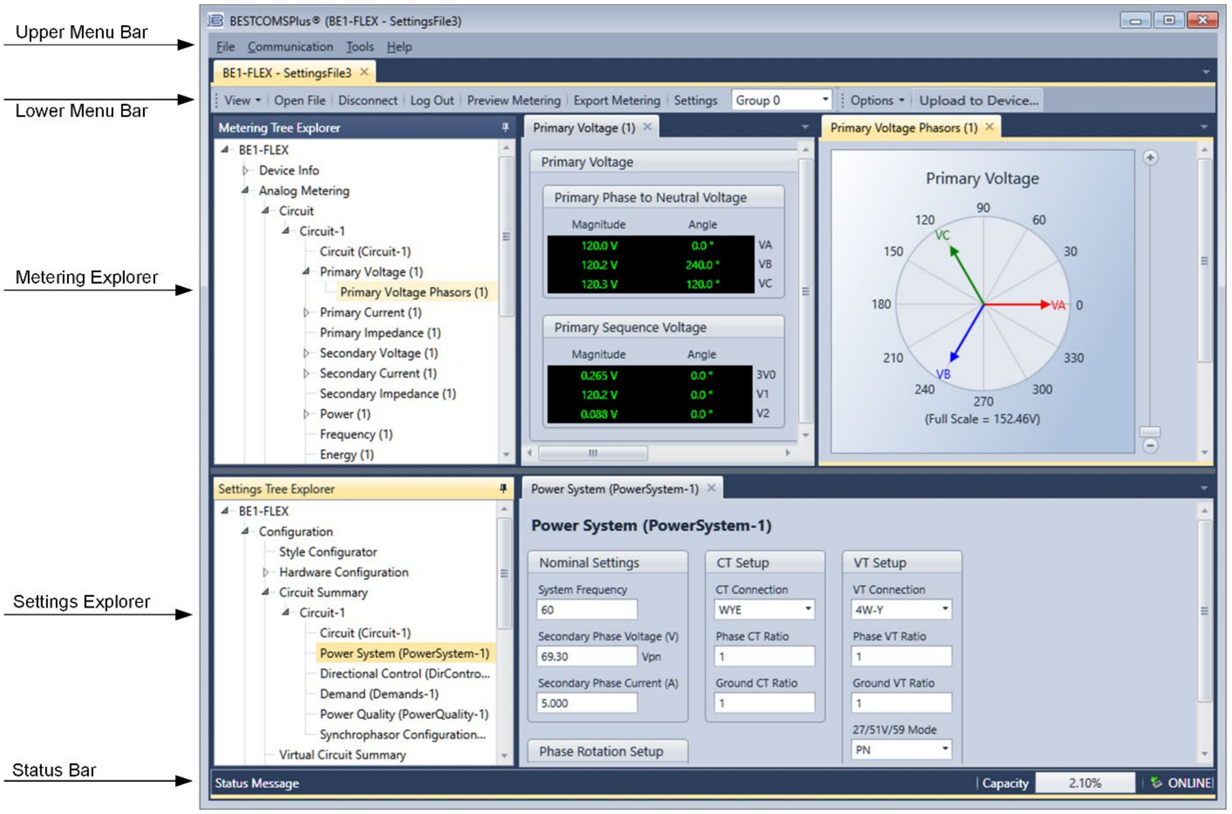


Figure 2-5. BESTCOMS*Plus* Typical User Interface Components

Click the View drop-down button to switch between the Settings Explorer and Metering Explorer or split the view between both. The Settings Info Panel displays settings ranges. A BESTspace™ workspace can be opened, saved, or set as default. See Figure 2-6.

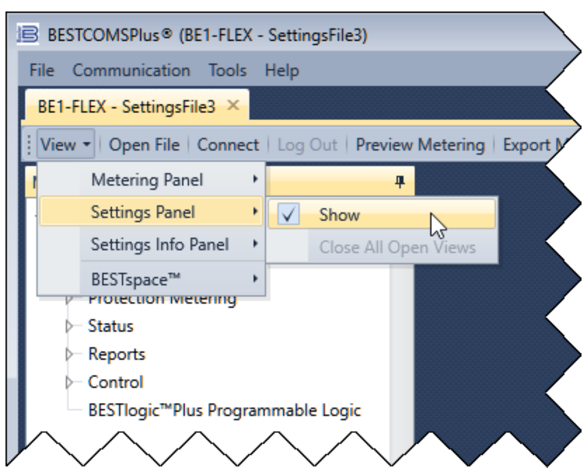


Figure 2-6. View Drop-Down Button

Summary Screens

Summary screens provide an overview of the system setup. The legend on the right provides interpretation for the various indicated colors. The current state of functions is indicated by the color of the adjacent indicator. If the function is enabled, the color is green. If the function is disabled only by a setting (such as zero), the color is yellow. If the function is disabled only by a mode, the color is blue. If the function is disabled by both a setting and mode, the color is gray. The BE1-FLEX Summary screen is available by clicking BE1-FLEX in the Settings Explorer as shown in Figure 2-7. Filtered summary screens are also available for most folders in the BE1-FLEX Settings Explorer by similarly clicking on the folder in the settings tree.

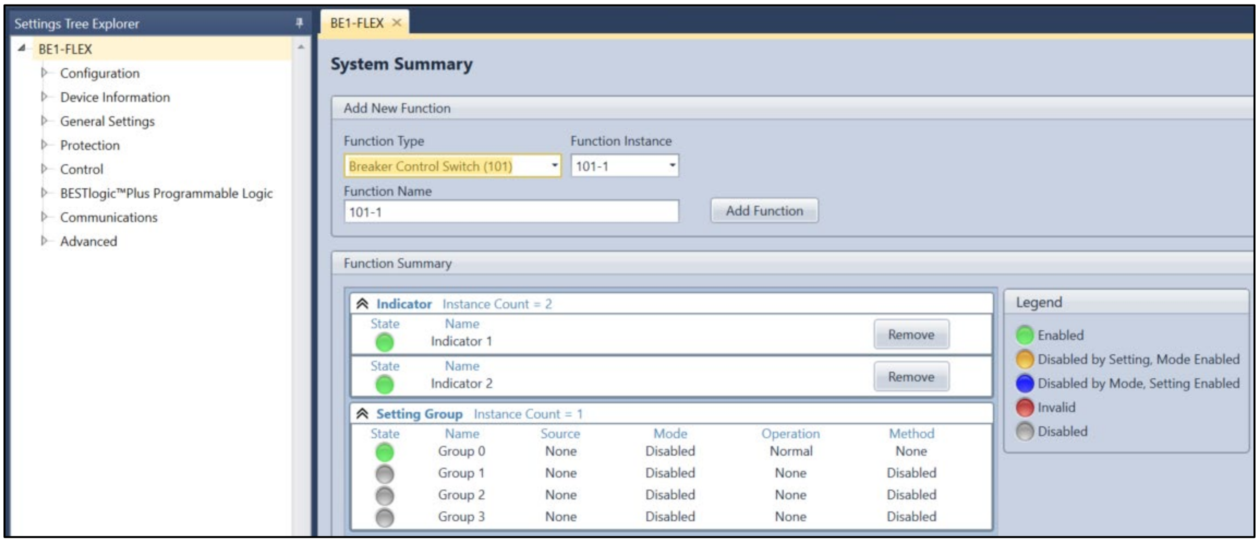


Figure 2-7. BE1-FLEX Summary Screen

Settings Methodology

To eliminate unnecessary features on a configured device, the BE1-FLEX is originally shipped without any protection and control functions enabled. This allows devices to be set up with only the functions desired and deletion of unwanted settings is not required. Settings templates on www.basler.com and auto-generation features in BESTCOMS*Plus* expedite setup for typical applications. The Programming Example below walks through a fully manual configuration.

BE1-FLEX setup is completed in several stages. Core components are listed below and followed by the walk through. Components with near limitless counts available are referenced as Instances throughout the device. Additional features not discussed below can be viewed in the Settings Explorer and described in their respective instruction manual chapters.

1. Download from Device (extract Setting and Logic).
2. Map hardware to configuration settings such as CT/PTs to Circuits, Circuits to Breaker, and I/O to Input/Output Instances.
3. Configure Instances, such as CT Ratios and Power System settings for a Circuit Instance.
4. Utilize Instances in functions such as Protection and Control Instances, typically as a Source selection.
5. Configure BESTlogic*Plus.*
6. Save File and Upload to Device.

Programming Example

This example demonstrates how to configure a “Feeder” relay by programing a 50 ground instantaneous overcurrent element and a directional phase 51 time overcurrent element (which the user nomenclature calls a “67P-Reverse”). System nominal quantities for the example are 69.3 pn volts secondary, 5 amps, a phase CT of 2000/5 (400 ratio), Ground CT of 250/5 (50 ratio), and 4160/69.3V (60 ratio) 4 wire-WYE VTs. The 50 ground element is set for a 5.62 amp pickup with a 30 second time delay and the 51 with a pickup of 9 amps, 3.7 time dial, curve V2. Additionally, the Trip output is wired to hardware output 2 from hardware slot 3 and includes a Normally Closed Alarm on slot 3, output 4. This example uses a BE1-FLEX-000050 style code (BE1-FLEX-K-T3N0N0N0-W9-E5-1N0-D01N-00 style number).

Step 1: Start BESTCOMS*Plus* and select New Connection, BE1-FLEX from the Communication pull-down menu to connect to the device. See Figure 2-3.

Step 2: The BE1-FLEX Connection screen appears. See Figure 2-4. Select USB Connection and click Connect.

Step 3: Select Download from Device and select Settings and Logic from the Communication pull-down menu. This copies all settings, logic, and device information from the BE1-FLEX to BESTCOMS*Plus*.

Step 4: Click on the View drop-down button and de-select Show Metering Panel and Show Setting Information. See Figure 2-6. This maximizes the settings workspace.

Step 5: Skip this step if not using DC voltage wetted Contact Sense inputs. In the Settings Explorer, click the “>” next to BE1-FLEX. This expands the sub menus in the tree. Click Hardware Configuration and select Hardware Info for each slot with DC wetted inputs. Select the appropriate sensing level from the Card Setting dropdown. See Figure 2-8.

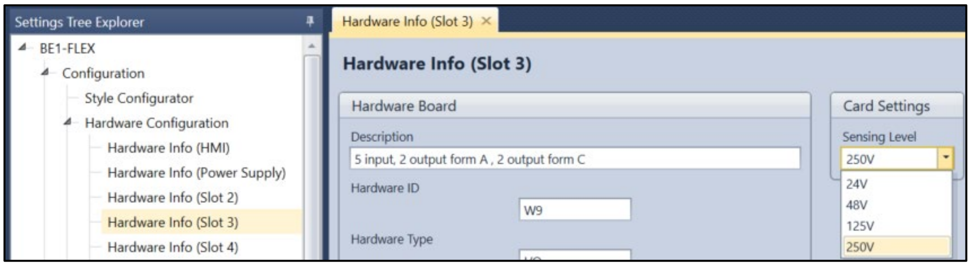


Figure 2-8. Hardware Info (Slot) Screen

Step 6: In the Settings Explorer, click the “>” next to BE1-FLEX. This expands the sub menus in the tree. Now select Circuit Summary. Edit Function Name to “Feeder” and select Add Function. See Figure 2-9.

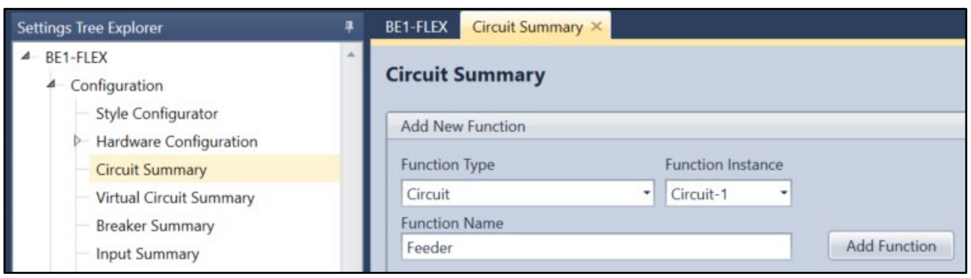


Figure 2-9. Circuit Summary Screen

Step 7: Click the Yellow state button (Figure 2-10) on the newly created Circuit, then Edit Circuit from the Circuit view (Figure 2-11). The Circuit Editor screen (Figure 2-12) will appear. Select Current Phase and Ground Hardware slot 7. BESTCOMS*Plus* will populate Current hardware channels I1-3 to IA, IB, and IC respectively. Hardware I4 to IG Ground will also be configured. Select Voltage Phase Hardware Slot 7. BESTCOMS*Plus* will populate VA, VB, and VC inputs. The voltages in this Quick Start example are for metering and example. Press Ok.

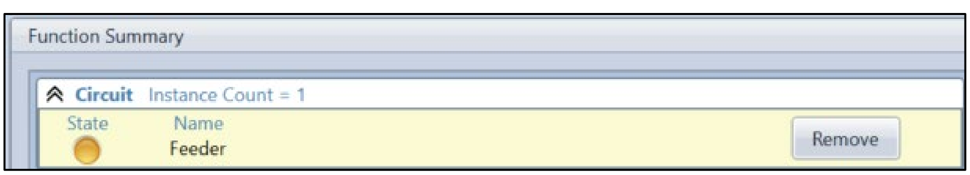


Figure 2-10. Function Summary Screen

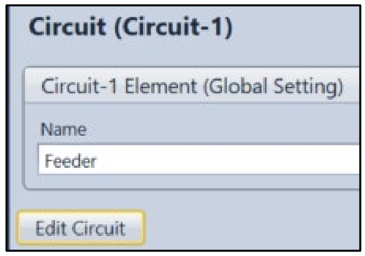


Figure 2-11. Edit Circuit Screen

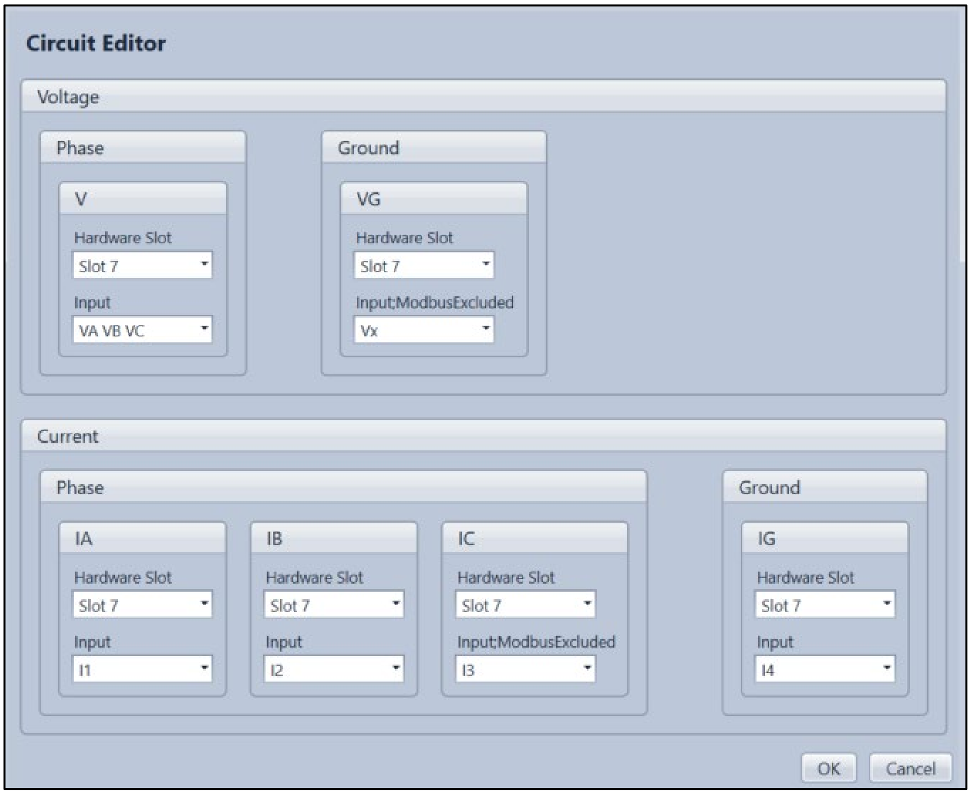


Figure 2-12. Circuit Editor Screen

Step 8: Under Circuit, Power System enter (confirm) settings for Secondary Phase Voltage (69.3 V) and Secondary Phase Current (5 A). Set Phase CT Ratio to 400, Ground CT Ratio to 50, VT Connection to 4W-Y, and Phase VT Ratio to 60. See Figure 2-13. Update Directional Control parameters from the Directional Control screen if using 67 functions and default settings are not valid.

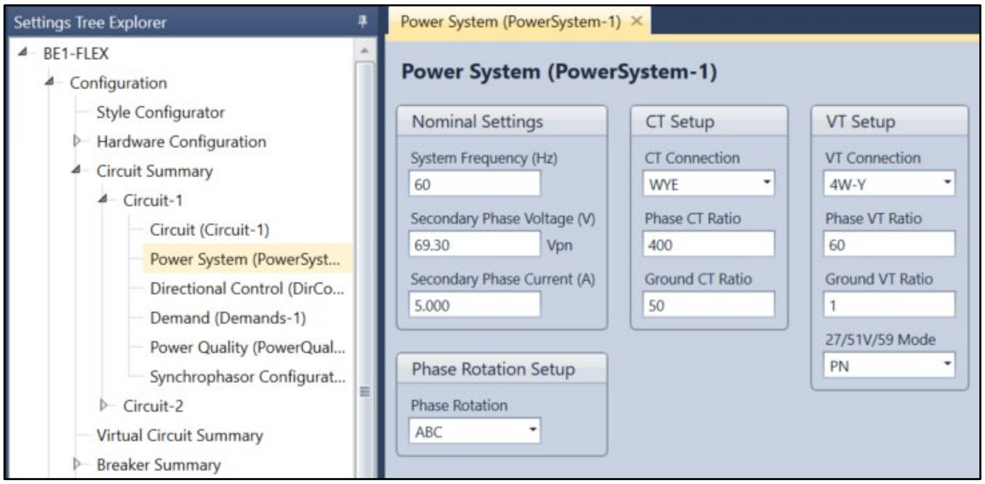


Figure 2-13. Power System Screen

Step 9: Select Output Summary from the Configuration branch. Edit Function Name to “Trip”. Select Add Function. Add a second output named “Alarm”. See Figure 2-14.

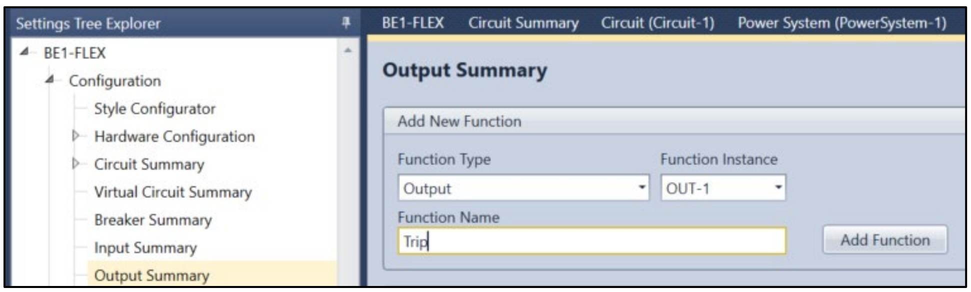


Figure 2-14. Output Summary Screen

Step 10: Click the Yellow state button (Figure 2-15) on the newly created Output Trip Instance. Map hardware output 2 in slot 3 as shown in Figure 2-16. Repeat for Alarm output with slot 3, output 4 as shown in Figure 2-17. These outputs are now utilized as Output Instances OUT-1 and OUT-2 and named “Trip” and “Alarm”.

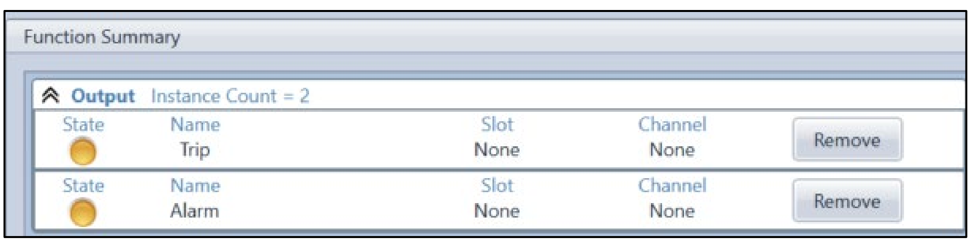


Figure 2-15. Function Summary Screen

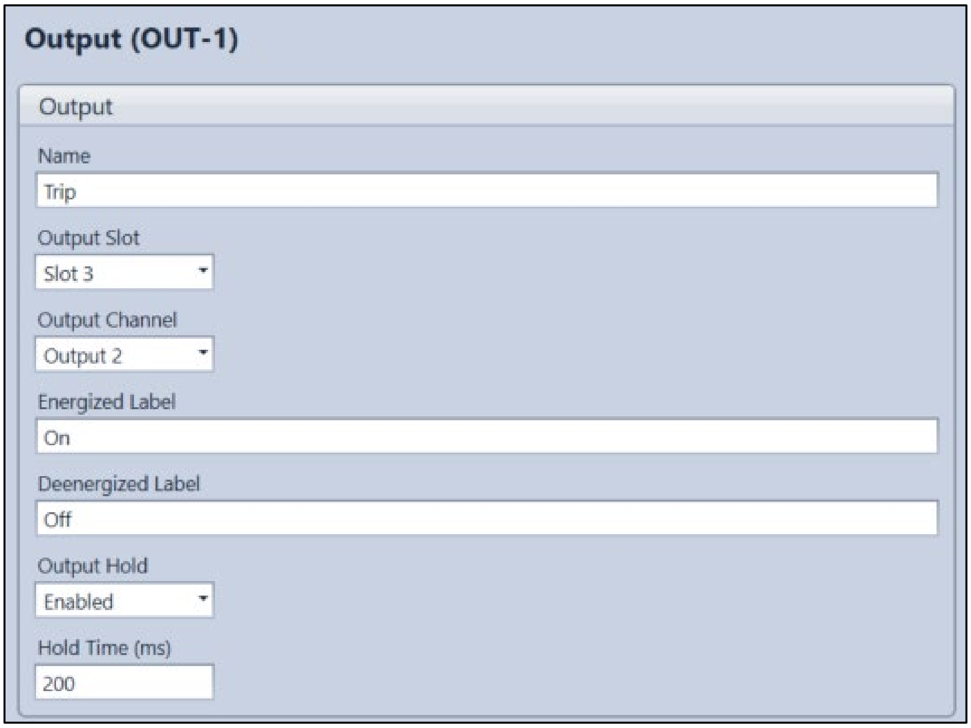


Figure 2-16. Output 1 Screen

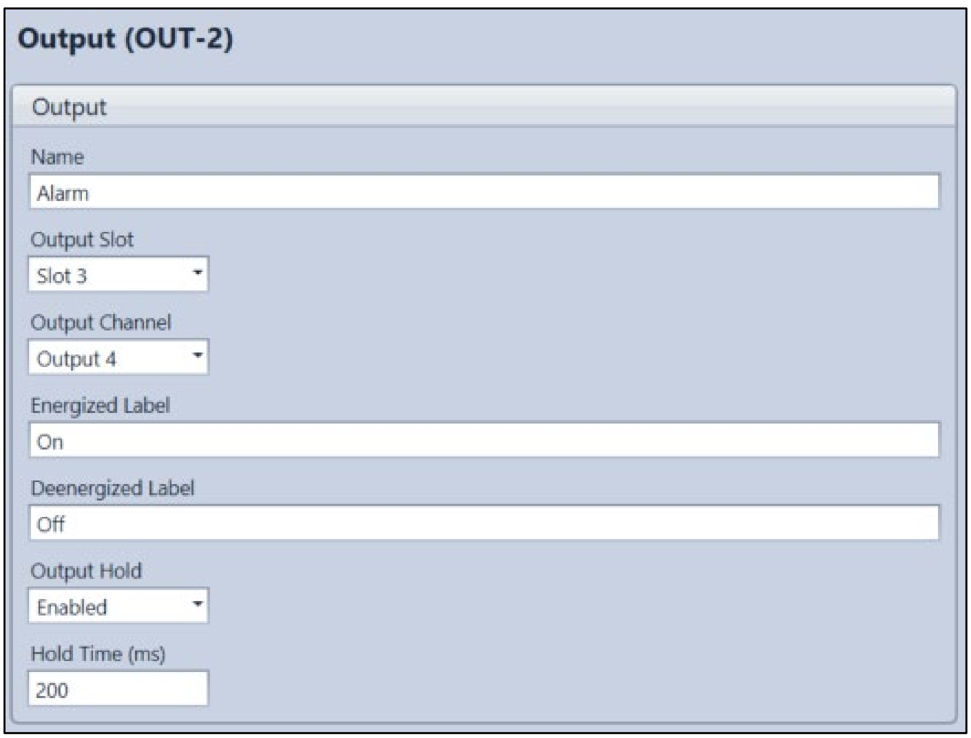


Figure 2-17. Output 2 Screen

Step 11: In the Settings Explorer, click Protection. Use the Function Type dropdown to select Instantaneous Overcurrent (50). Enter “50 Ground” into the Function Name field and click Add Function. Repeat for Function Type Inverse Overcurrent (51), Function Name “67P-Reverse”, click Add Function. See Figure 2-18.

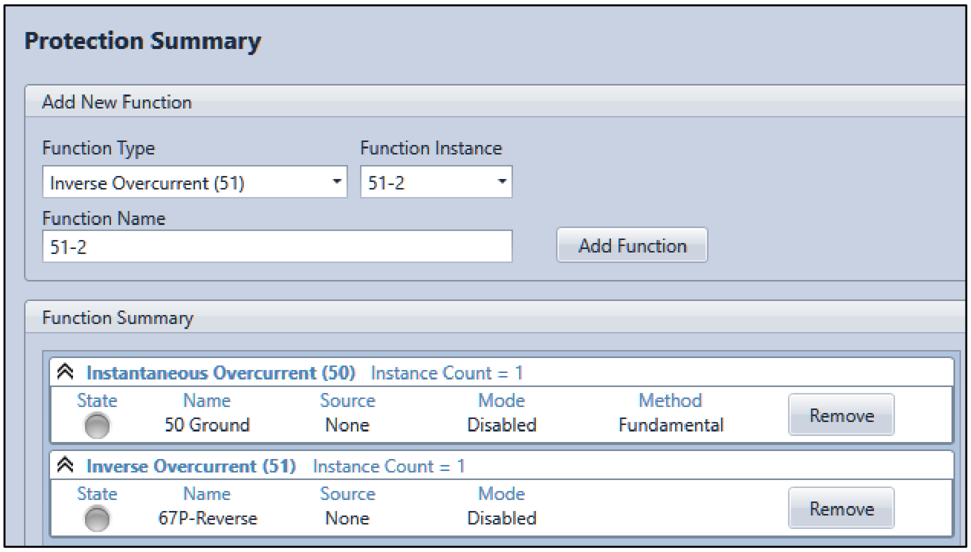


Figure 2-18. Protection Summary Screen

Step 12: Click the Gray state button next to the 50 Ground instance. Set Mode to IG, Source to Feeder (calls out the Circuit Instance "Feeder" created in Step 6), Pickup to 5.62 Secondary A, and Time Delay to 30000 ms (30 s). See Figure 2-19.

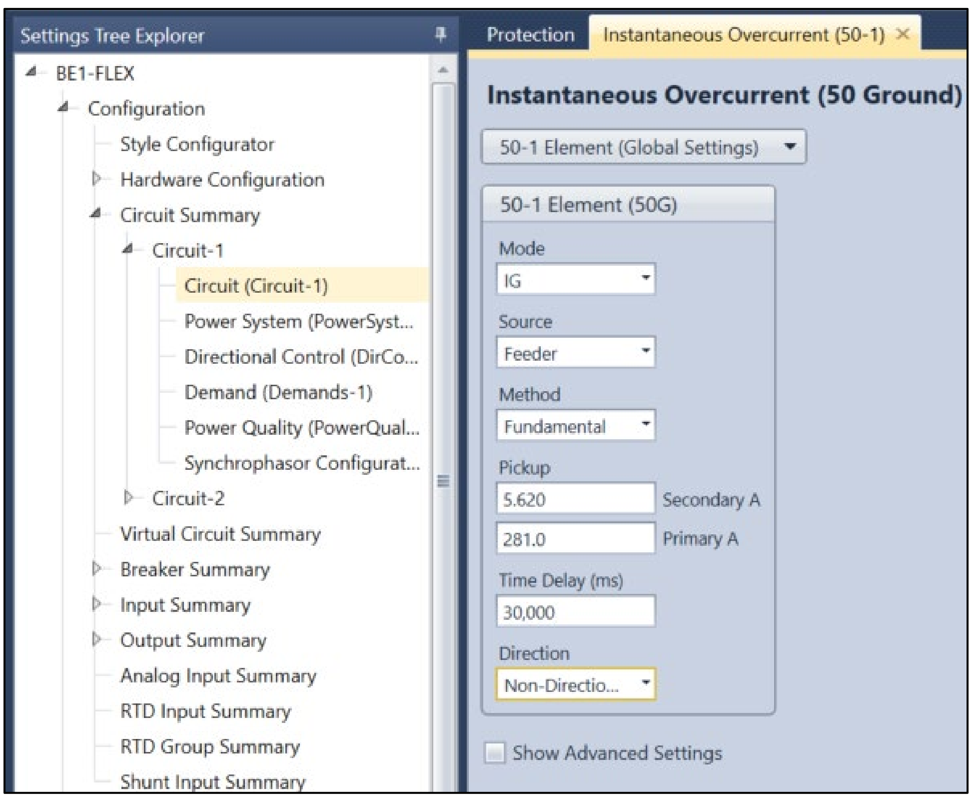


Figure 2-19. Instantaneous Overcurrent (50 Ground) Screen

Step 13: Click Protection from Settings menu to return to Protection Summary. Repeat step 11 for the 67P-Reverse element. Set Mode to 3 Phase, Source to Feeder, Pickup to 9 Secondary A, Curve to V2, Time Dial to 3.7, and Direction to Reverse. See Figure 2-20.

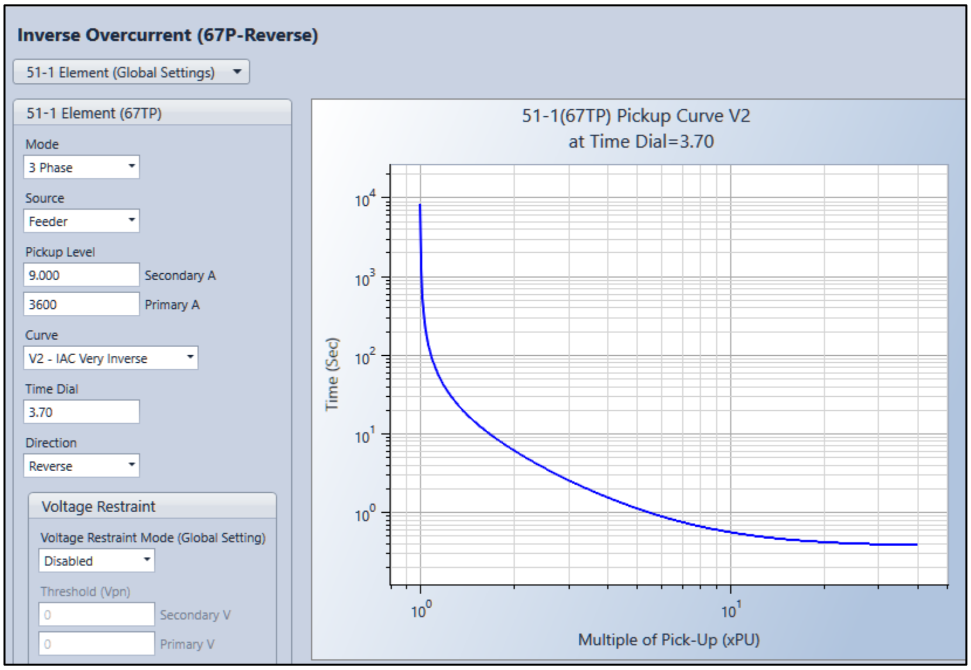


Figure 2-20. Inverse Overcurrent (67P-Reverse) Screen

Step 14: Select Protection from the Settings menu to verify both 50 and 51 elements have Green states. See Figure 2-21.

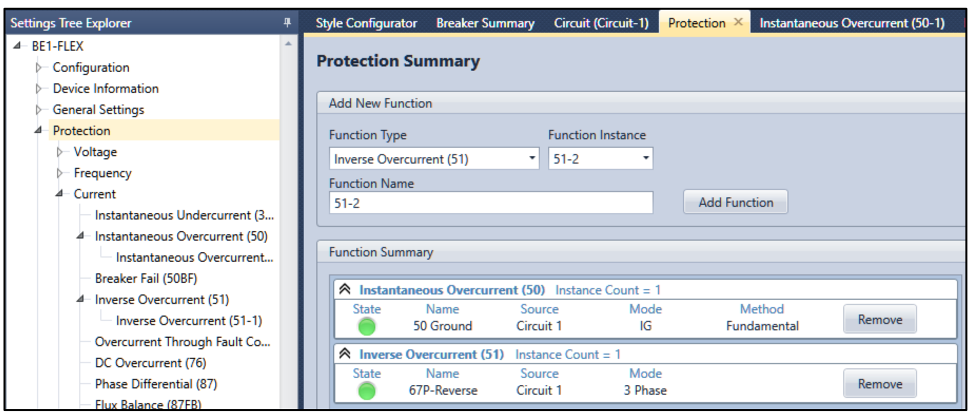


Figure 2-21. Protection Summary Screen

Step 15: In the Settings Explorer, click BESTlogic*Plus* Programmable Logic to open the logic diagram. Logic Page 1 in the workspace will be shown. Right click in the workspace and add or rename tabs as desired. Extra tabs are not used in this example.

A BESTspace™ workspace can be opened, saved, or set as default by clicking the View drop-down button. See Figure 2-6.

a. Select the Elements tab from the library in the center of the screen. Drag the 50-1 and 51-1 functions into the workspace. The Elements screen is shown in Figure 2-22.

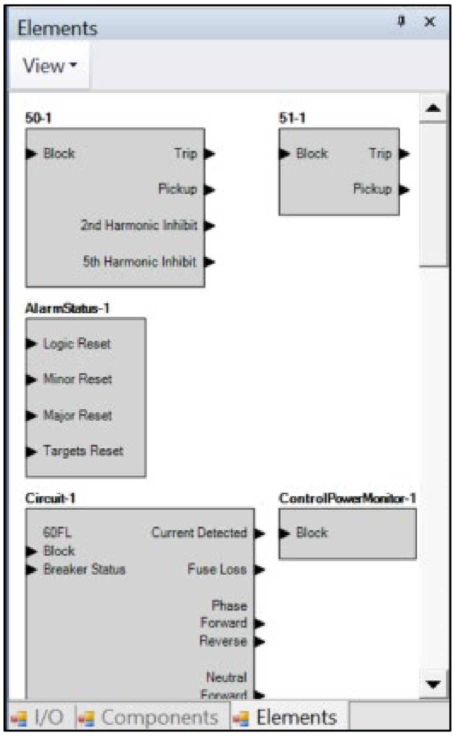


Figure 2-22. Elements Screen

b. Select the Components tab from the library. Drag an OR and NOR gate into the workspace. Hover over components for a description.

c. Select the I/O tab from the library. Drag Output Objects OUT-1 and OUT-2 into the workspace. Drag Alarms - Alarm Status - Major Alarm and Minor Alarm into workspace.

d. Wire (click and drag a line from an output to an input) as shown in Figure 2-23.

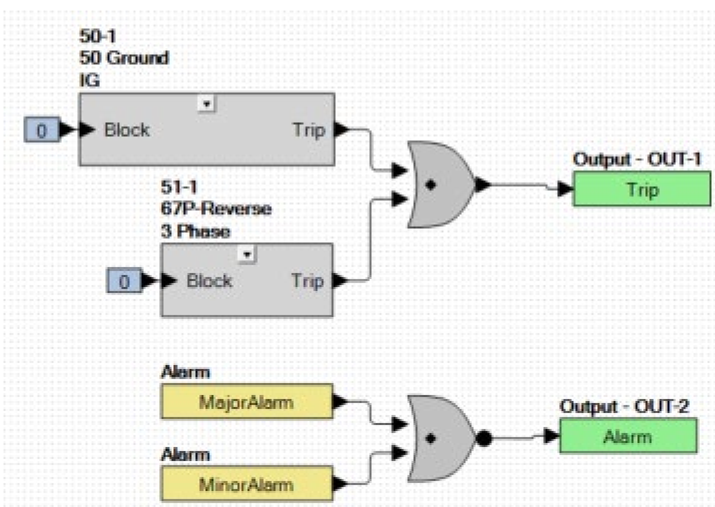


Figure 2-23. Logic Example

e. See the *BESTlogicPlus* chapter for more details on extra logic creation features including Notes and Off-Page Objects.

Step 16: Click the Save button to save the logic to BESTCOMS*Plus* memory for later inclusion in the settings file. The BESTlogic*Plus* toolbar is shown in Figure 2-24.

Figure 2-24. BESTlogic*Plus* Toolbar

Targets and fault recording are automatically enabled for Protective Elements. The Fault Recording option can be edited under each element and Target settings under Advanced - Targets. The Alarm output created will be operational for Relay Trouble conditions. For additional Major and Minor alarm conditions, navigate to Settings – Advanced – Alarms to set any additional conditions as desired.

Step 17: Select Save from the File pull-down menu to save your new settings file.

Step 18: To make your new settings active in the BE1-FLEX, select Upload to Device and select Settings and Logic from the Communication pull-down menu. Enter the username and password if required.

3 • Mounting

BE1-FLEX Protection, Automation, and Control Systems are supplied in a non-drawout, S1 size case (K option) that fits in a standard S1 case opening. Adapter plates are sold separately. A BE1-FLEX can be mounted at any convenient angle although the touchscreen HMI does not rotate.

Note
Case mounting studs are carbon steel #10-32. The torque applied to the provided nuts should be 20 to 25 inch-pounds (2.26 to 2.82 N•m).

Case Dimensions

Case front dimensions are shown in Figure 3-1 and case side dimensions are shown in Figure 3-2. Dimensions are shown in inches [millimeters].

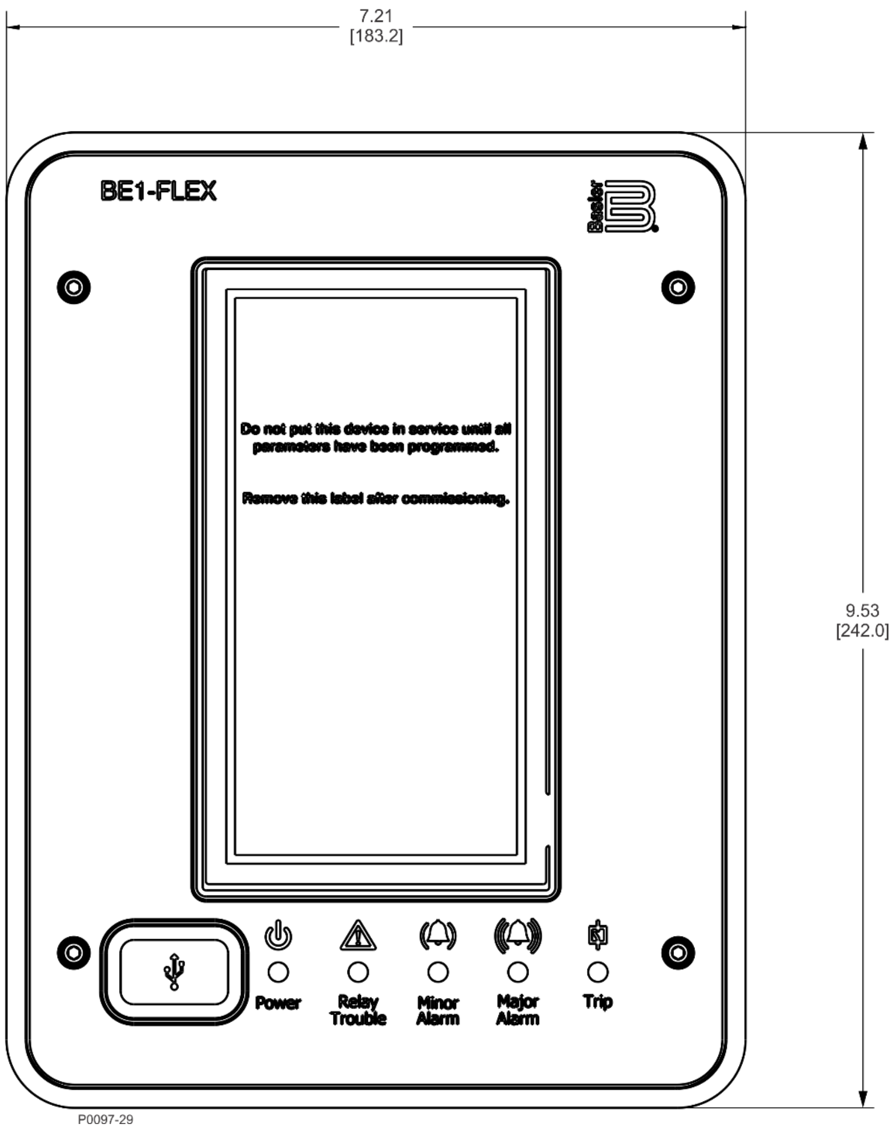


Figure 3-1. Case Front Dimensions

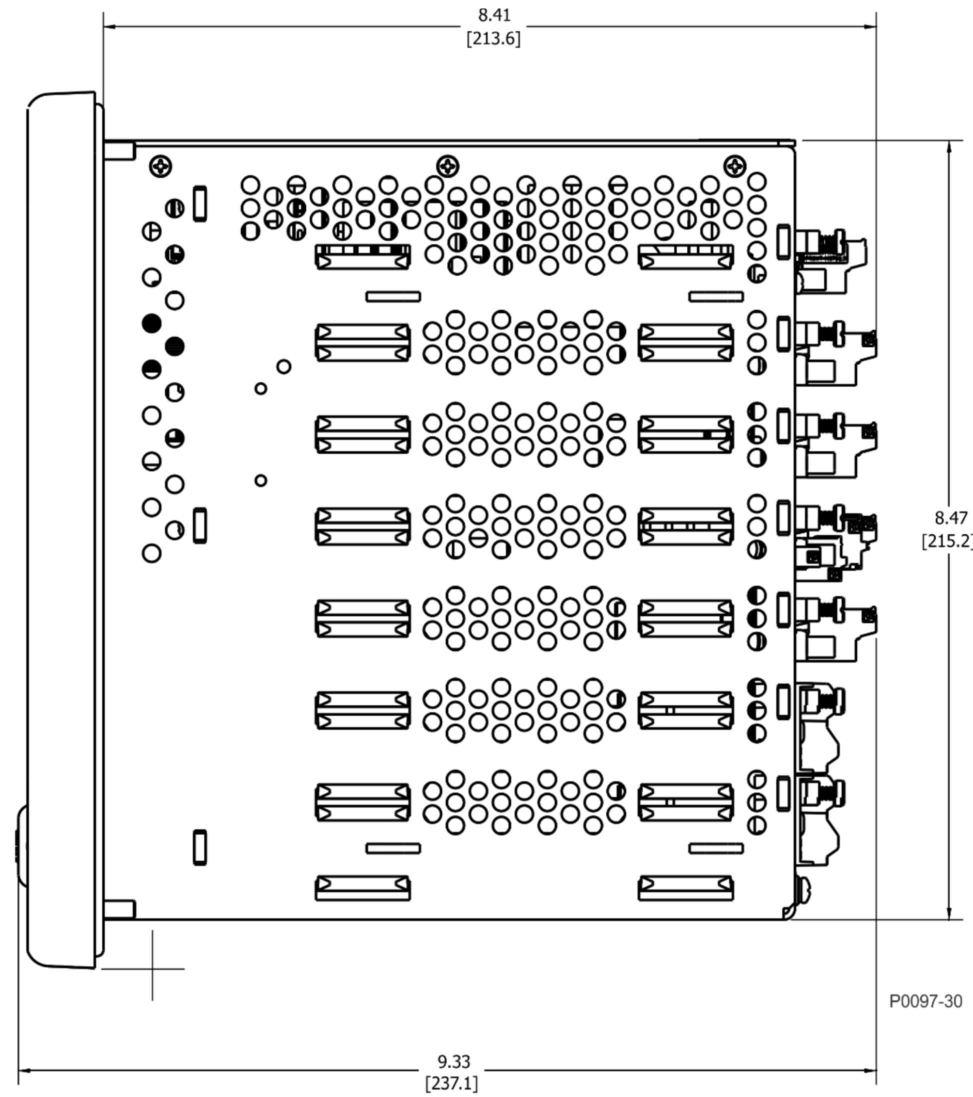


Figure 3-2. Case Side Dimensions

Panel Cutting and Drilling Dimensions

Panel cutting and drilling dimensions are shown in Figure 3-3. Dimensions are shown in inches (millimeters).

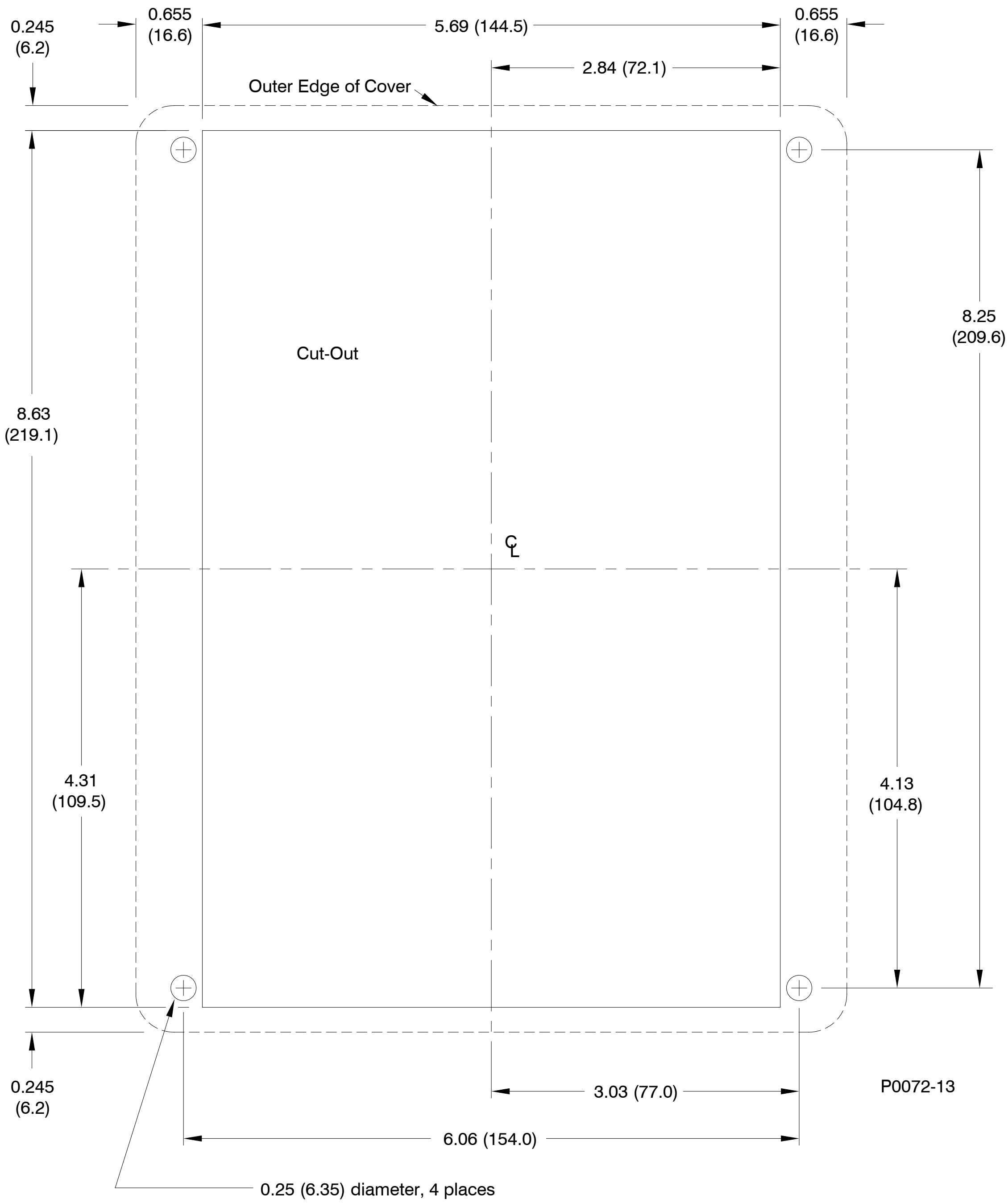


Figure 3-3. Panel Cutting and Drilling Dimensions

GE S2 and ABB FT-21 Adapter Plate

An adapter plate to mount a K case in a GE S2 or ABB FT-21 cutout is shown in Figure 3-4. Dimensions are shown in inches [millimeters]. Order Basler part number 9108551021.

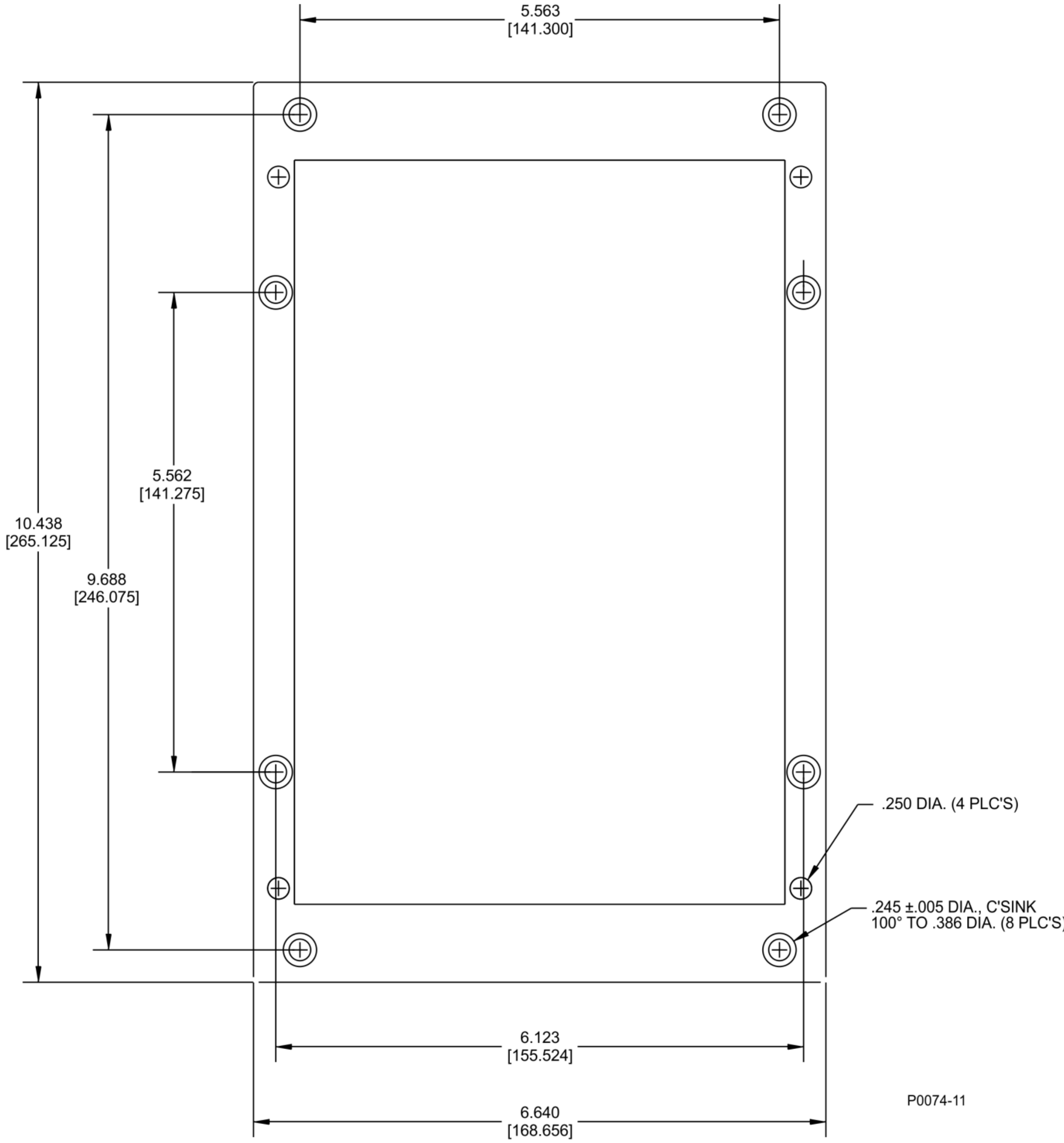


Figure 3-4. GE S2 and ABB FT-21 Adapter Plate (Basler P/N: 9108551021)

ABB FT-31/FT-32 Adapter Plate

An adapter plate to mount a K case in a ABB FT-31/FT-32 cutout is shown in Figure 3-5. Dimensions are shown in inches [millimeters]. Order Basler part number 9108551022.

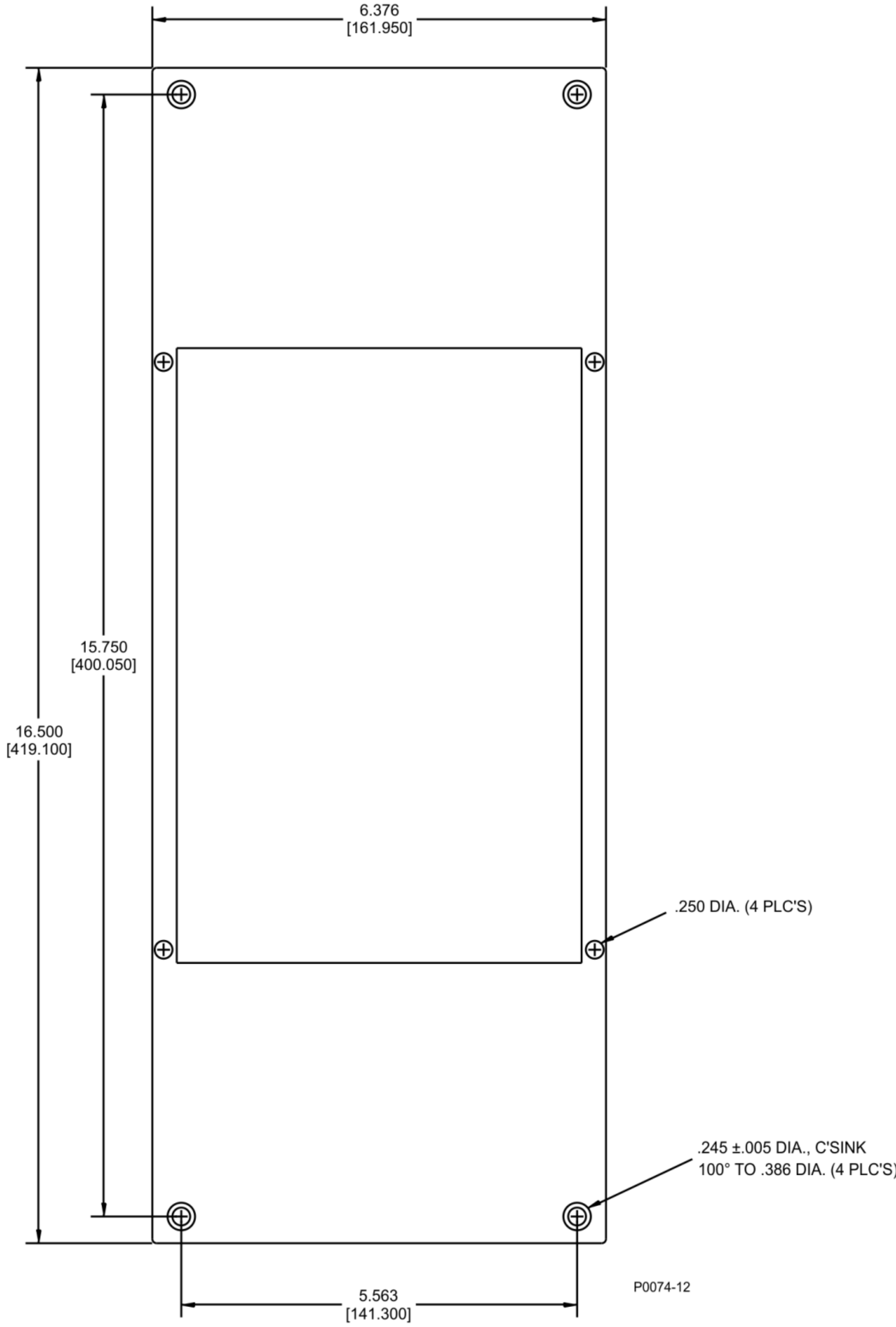


Figure 3-5. ABB FT-31/FT-32 Adapter Plate (Basler P/N: 9108551022)

GE M1/M2 Adapter

An adapter plate to mount a K case in a GE M1/M2 cutout or Basler M1 cutout is shown in Figure 3-6. Dimensions are shown in inches [millimeters]. Order Basler part number 9108551029.

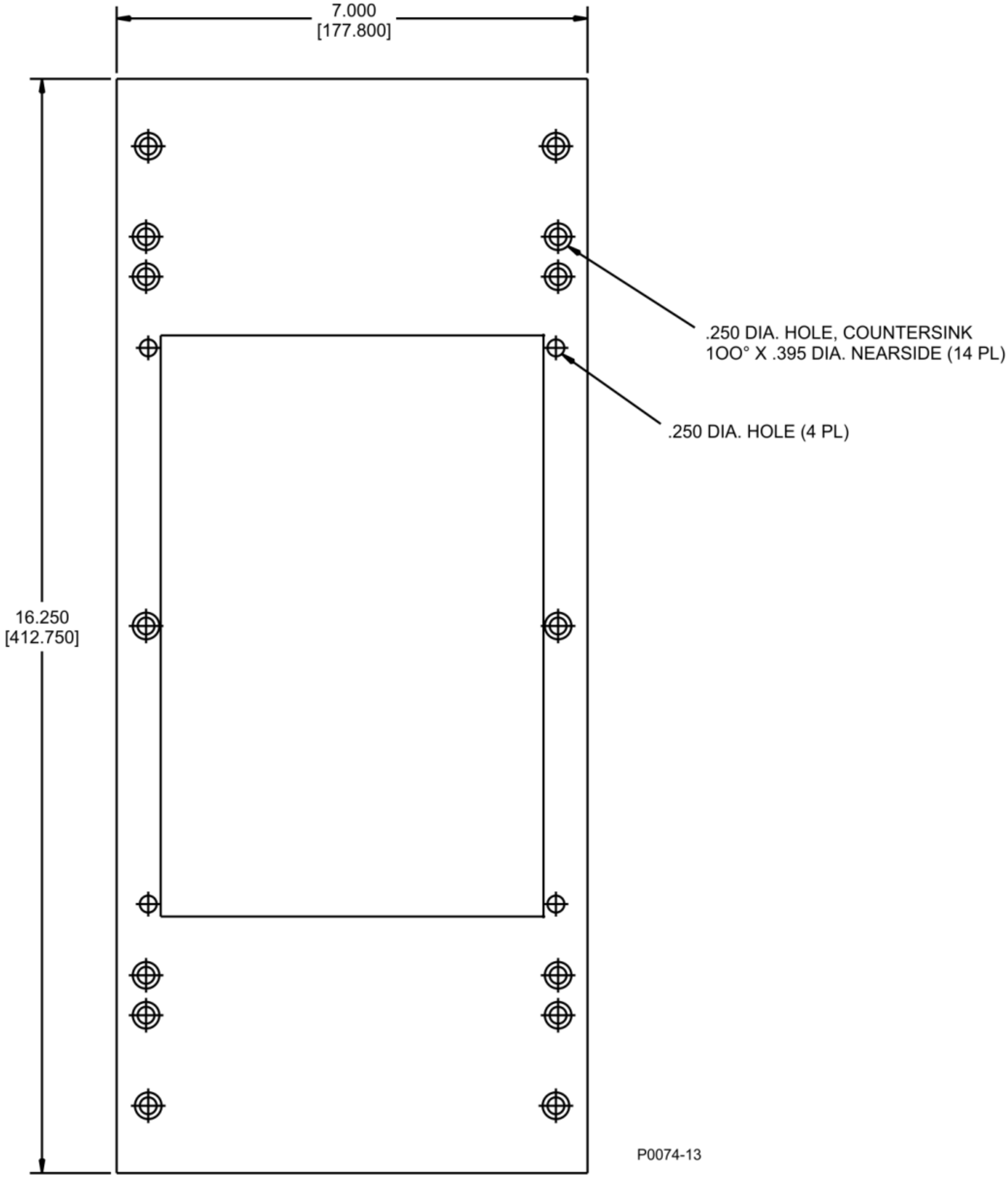


Figure 3-6. GE M1/M2 Adapter Plate (Basler P/N: 9108551029)

Multilin 345/745 Retrofit Mounting Plate

A K case retrofit mounting plate for the Multilin 345/745 consists of two parts. See Figure 3-7 and Figure 3-8. Dimensions are shown in inches [millimeters]. Order Basler part number 9424226101.

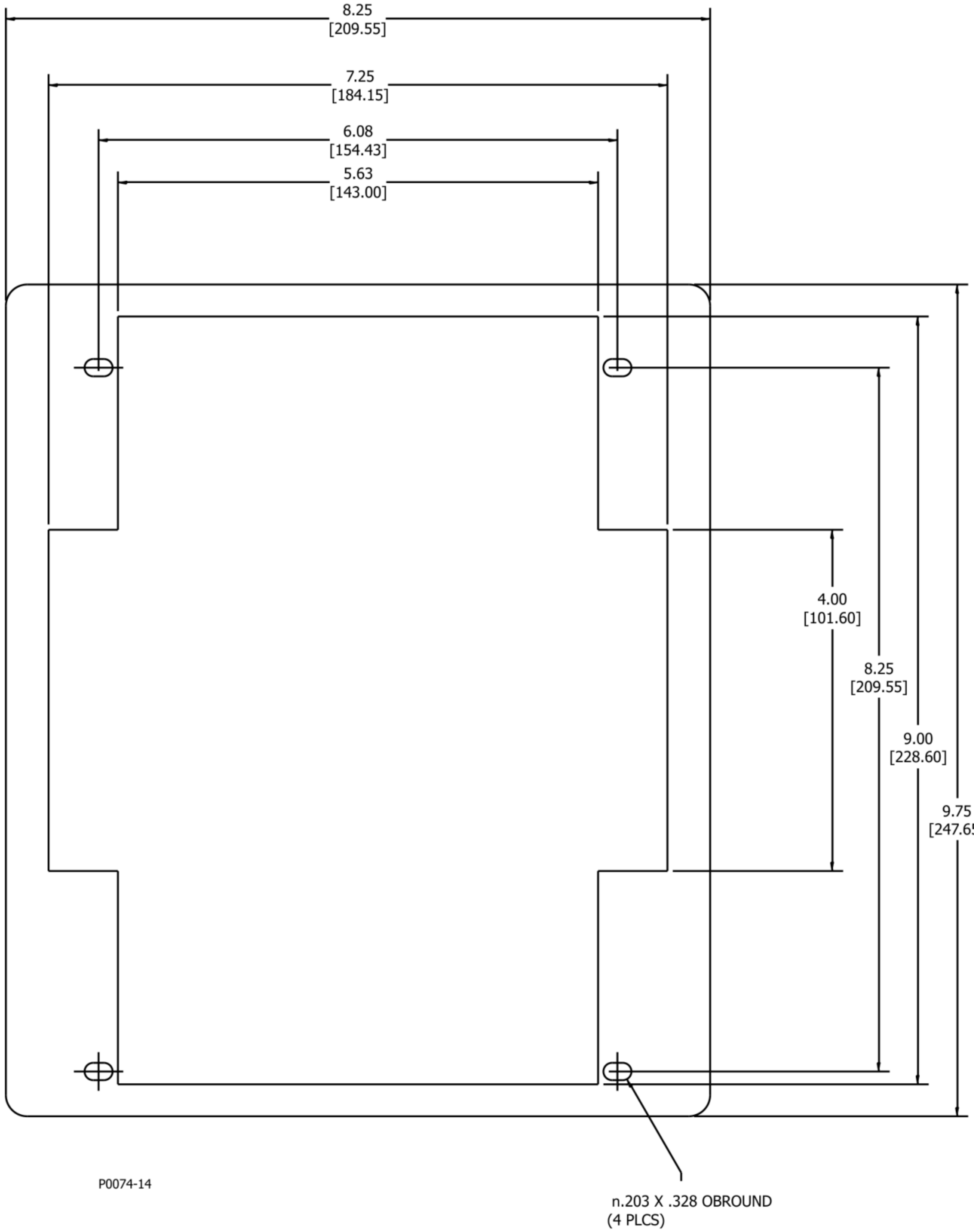


Figure 3-7. Multilin 345/745 Mounting Plate (Basler P/N: 9424200073) – Part 1 of 2

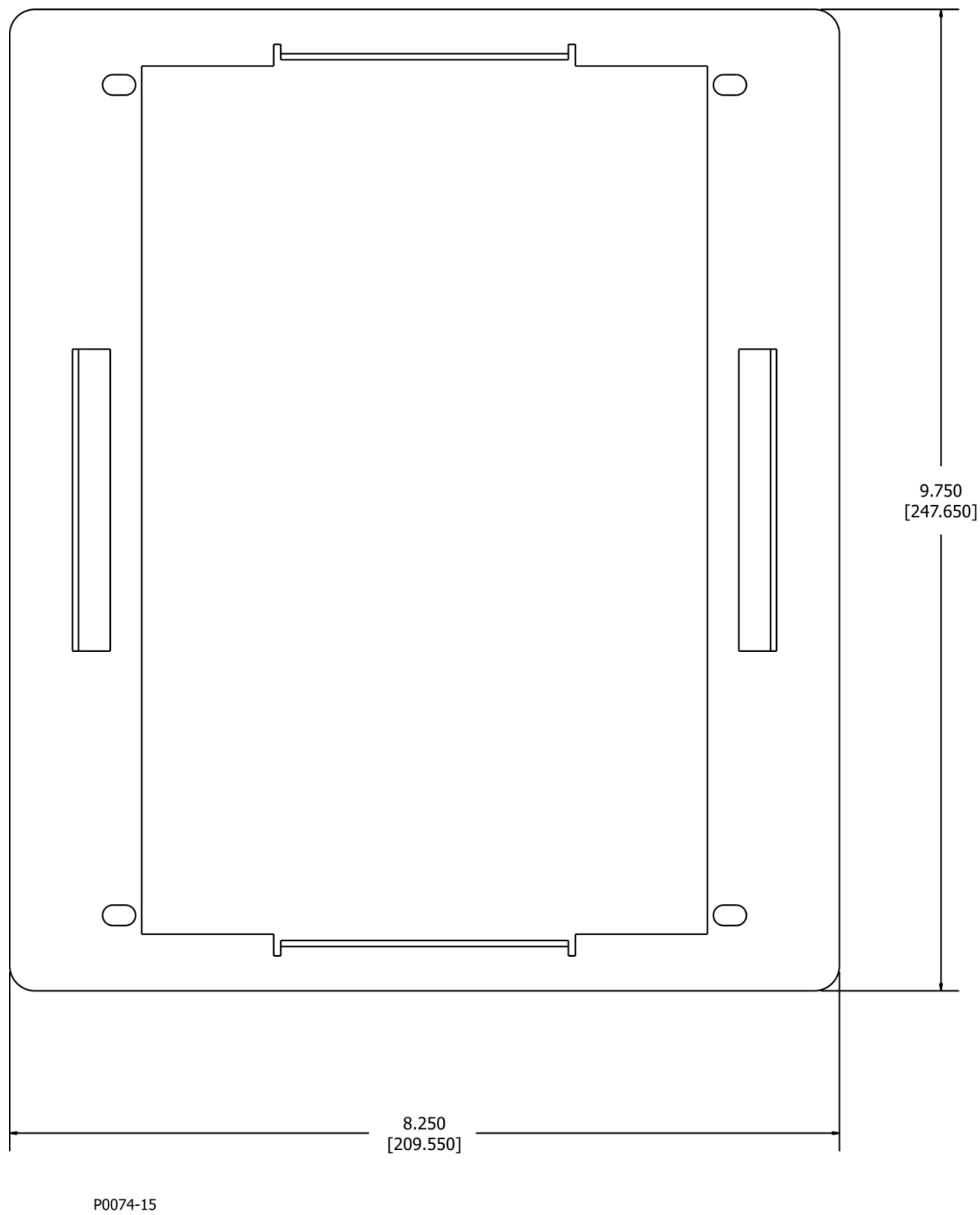
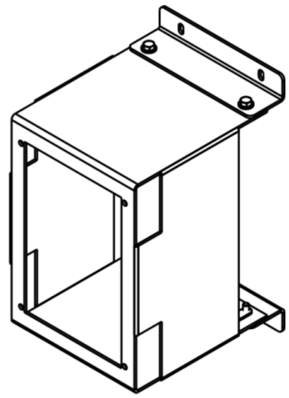


Figure 3-8. Multilin 345/745 Mounting Plate (Basler P/N: 9424200073) – Part 2 of 2

Pivoting Projection-Mounting Kit

A pivoting projection-mounting kit for a K case is shown in Figure 3-9. Dimensions are shown in inches [millimeters]. When installed, this kit provides rear access to connections by allowing the BE1-FLEX to swing left or right. Order Basler part number 9424226101.



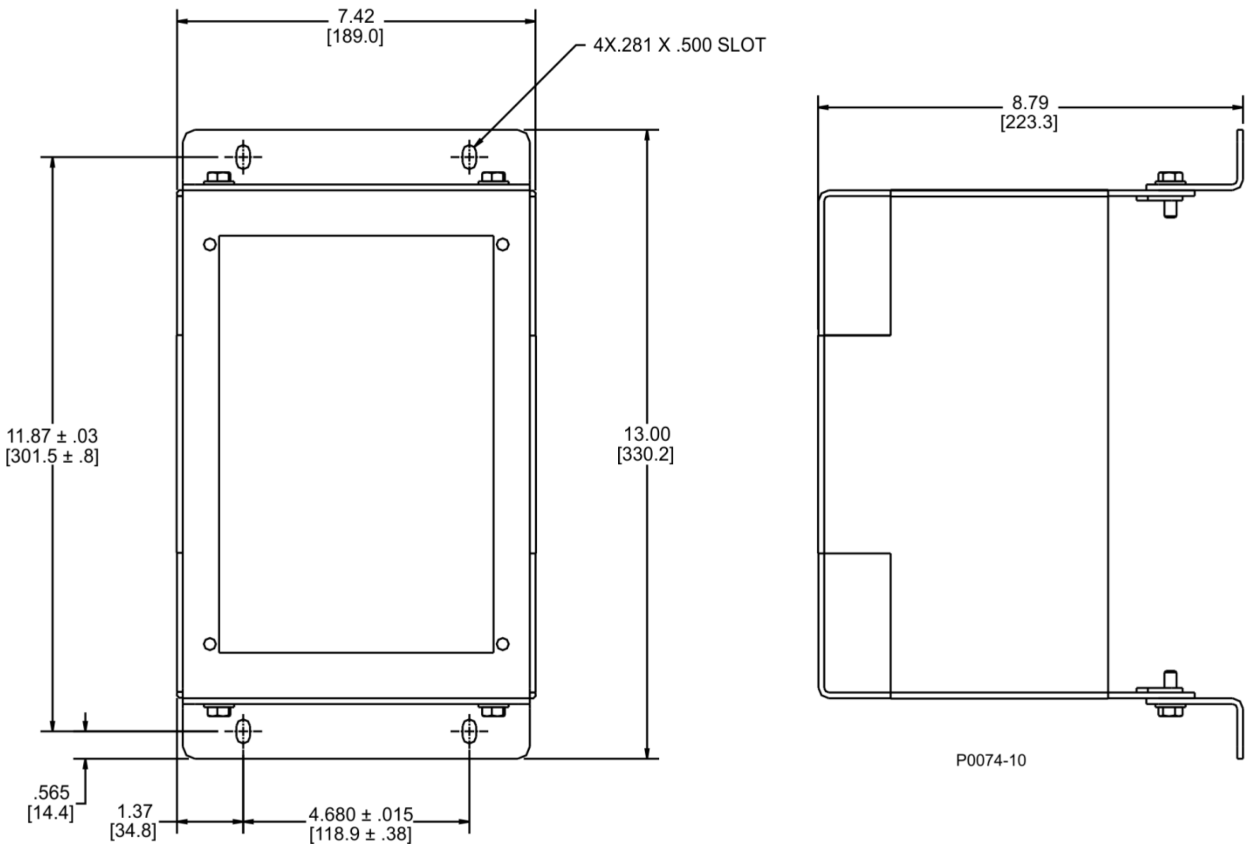


Figure 3-9. Pivoting Projection-Mounting Kit (Basler P/N: 9424226101)

19-Inch Rack Adapter Plate

A 19-inch rack adapter plate with four FT test switches is shown in Figure 3-10. Dimensions are shown in inches [millimeters]. Order Basler part number 9424227002.

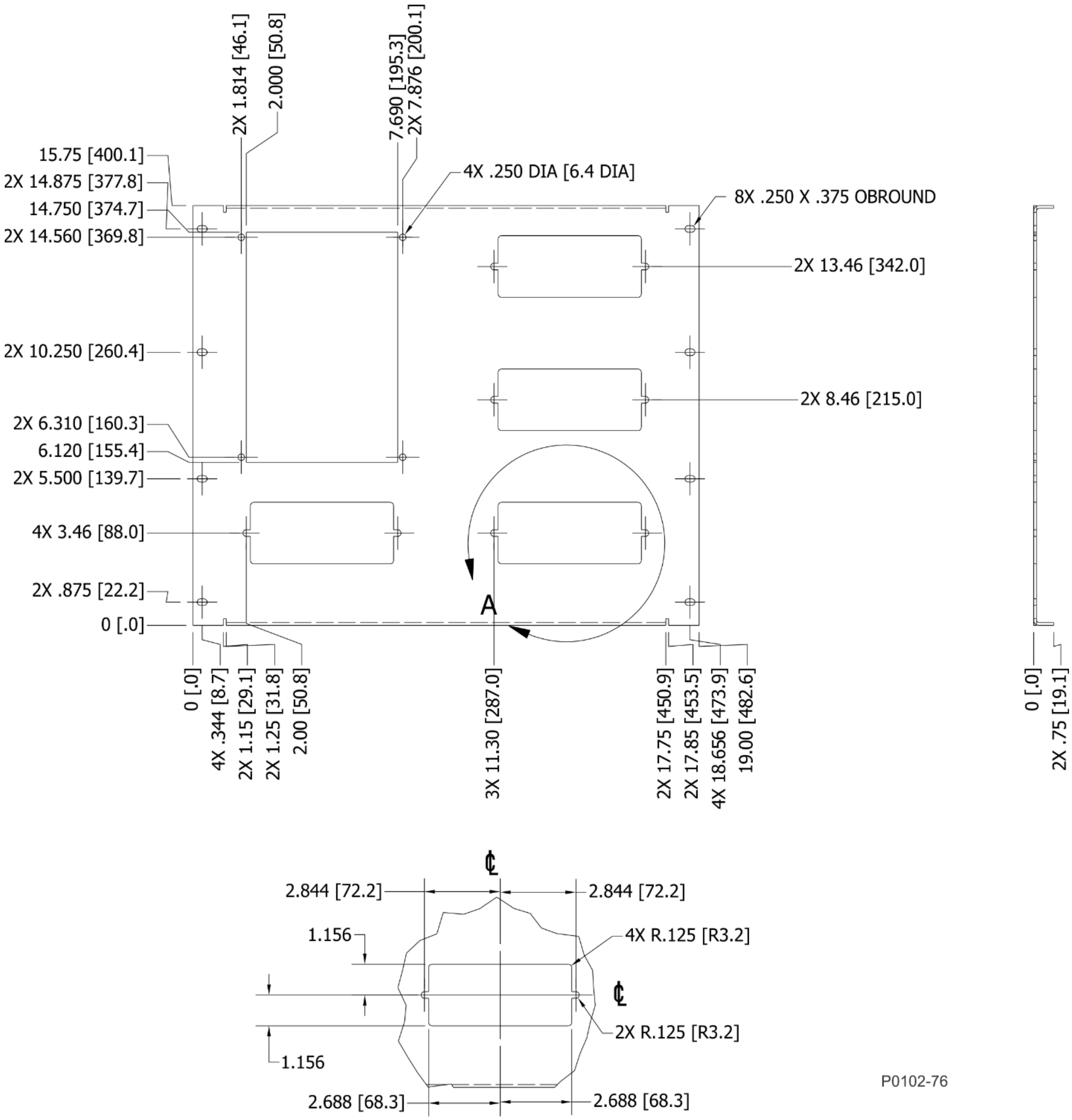


Figure 3-10. 19-Inch Rack Adapter Plate with Four FT Test Switches (Basler P/N: 9424227002)

4 • Hardware Configuration

The BE1-FLEX is a single hardware platform, loadable with application-style templates and a variety of circuit boards. The BE1-FLEX can be configured by uploading templates found at www.basler.com. Feeder, intertie, generator, transformer, motor, and bus protection applications are some of the templates available. Users can add to, customize, and save templates, or begin from a blank slate. Custom and application-type template choices are dependent on supported hardware and protection package selection.

The BE1-FLEX can be configured with a variety of circuit boards. The user can define how many of each element they want to use via a settings file, as supported by the Protection Package style option. Users can utilize any number of any element as desired. Each element type consumes a predefined percentage of capacity. The total capacity being utilized for a given settings file is displayed in BESTCOMS*Plus*. Communications and other processor-heavy functions are included in the capacity calculation as well. Percentage capacity will include contribution from any component in the settings as configured, even if disabled by mode, source selection, or otherwise functionally disabled. The percentage of function capacity shown in BESTCOMS*Plus* ensures a settings combination does not compromise processing speeds and ultimately, BE1-FLEX performance.

Circuit boards can be added and removed to configure the product in any manner the user deems necessary to accommodate the application. This can be done at the Basler factory or in the field. Users can remove the BE1-FLEX rear cover to add or remove boards as desired. Blank covers are available as accessories to fill the space previously occupied by removed boards. The case will accommodate a wide variety of board combinations. Slot numbering for the boards starts with the power supply in slot 1 and increases sequentially. The power supply can be installed only in slot 1. Communications boards can be installed only in slot 2. Analog boards can be installed in slots 4, 5, 6, or 7. I/O and auxiliary boards can be installed in any slot except for the power supply slot (SLOT 1). Figure 4-1 shows the slot positions.

Each non-analog board shows the numerical pinout number above the terminals. Analog board pin labeling is below the terminal. Because any specific board could be in a variety of slot positions, it is recommended to label the terminal with the slot position and pinout number on drawings and other reference material. The board type can also be referenced for added clarity. For example, if an N5 board is installed into slot 5, the 13th terminal would be listed as 5-13 or 5-N5-13.

Analog board terminals are screw (compression) type and support ring tongue lugs and up to two 10 AWG wires per terminal. The torque applied to the analog board screws should be 8 to 11 inch-pounds (0.90 to 1.24 N•m). Analog board screws should be 6-32x1/4 size, and ground screws should be 6-32x3/8 size. Unless otherwise noted, all other boards utilize spring or compression type removable plug connectors, which support up to a single 12 AWG bare wire or two 16 AWG wires with twin ferrule. The ferrule length for both power supply and I/O terminals is 8 to 10 millimeters, requiring a strip length of 10 millimeters for a secure connection. Compression type utilize an embedded screw to hold wiring into place. Spring types include an internal spring to create the pressure required to hold wiring. Compression terminals are shown in Figure 4-1. Spring types include a wire removal button instead of a screw. Torque applied to non-analog board compression type connectors should be 4.4 to 5.3 inch-pounds (0.5 to 0.6 N•m). Use 75°C (167°F) Cu wires for all boards.

If an individual board has failed or it is desired to change, refer to *Individual Board Reconfiguration and Replacement*. If an individual board is suspected to be misoperating (alarms, communications, etc.), refer to the *Alarms* chapter for Diagnostic Log information.

Note
It is recommended in all applications, where contact outputs drive relay coils, that a reverse-biased flyback diode be implemented in parallel with the relay coil for EMI suppression.

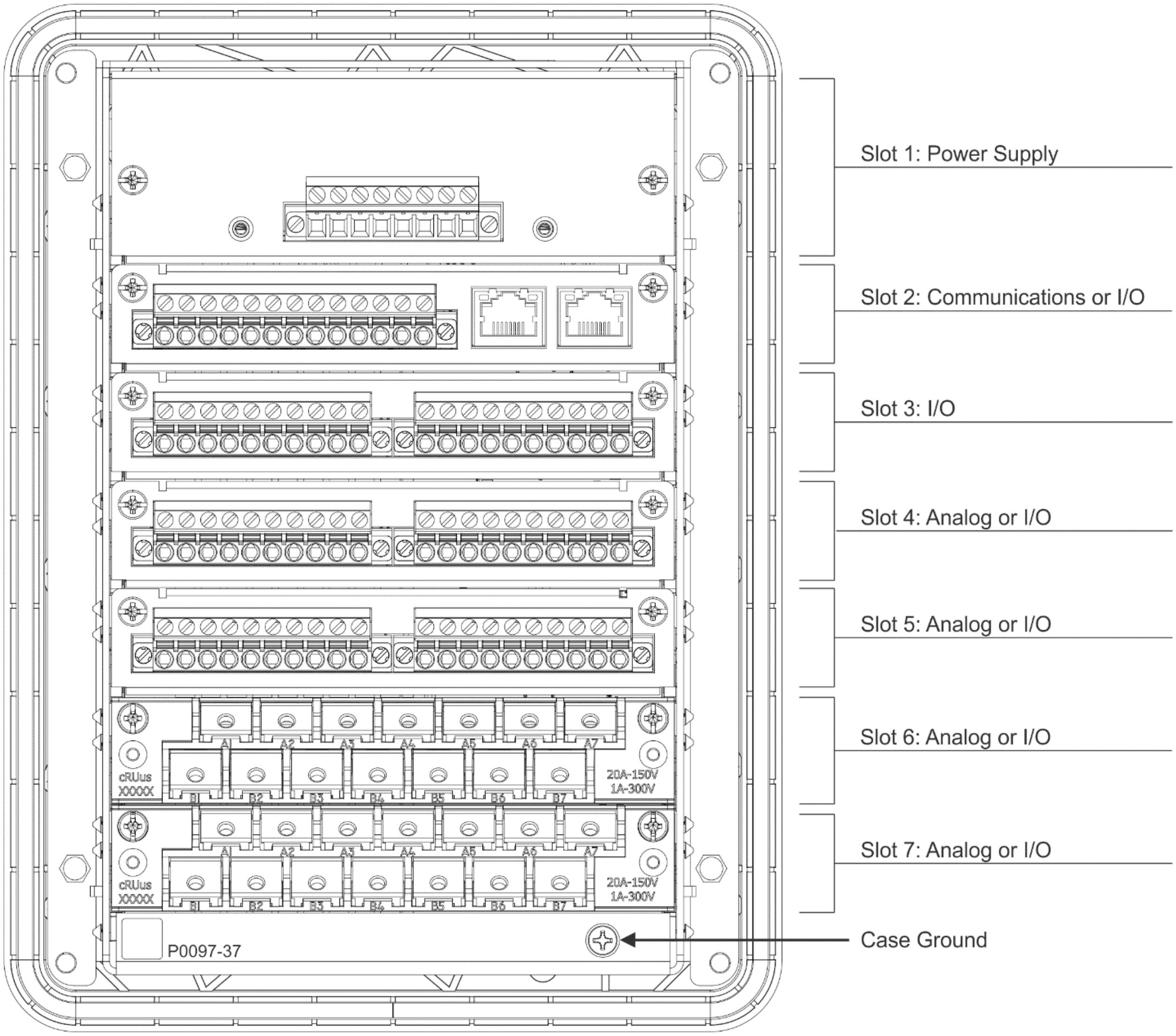


Figure 4-1. Slot Positions

Power Supply Boards

Available power supply configurations are listed in Table 4-1. Connections are shown in Figures 4-2 through 4-4.

Table 4-1. Power Supply Board Configurations

Option	Description	Connections
1	48/125 Vdc, 120 Vac	Figure 4-2
2	250 Vdc, 240 Vac	Figure 4-3
3	24 Vdc	Figure 4-4

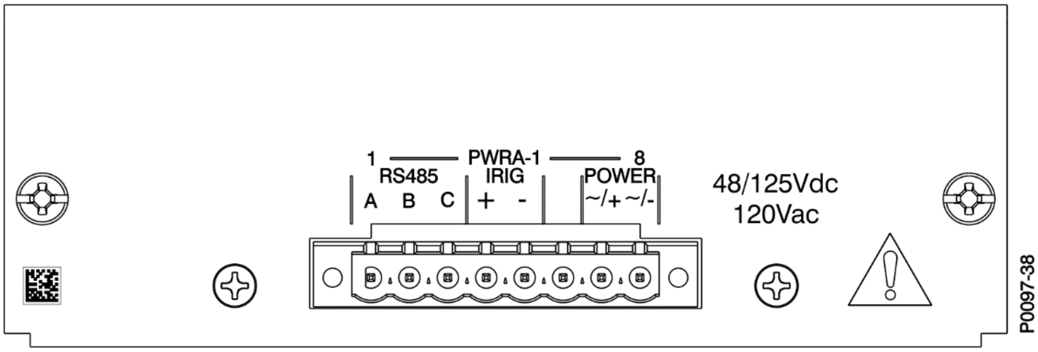


Figure 4-2. Power Supply Board Connections, Option 1

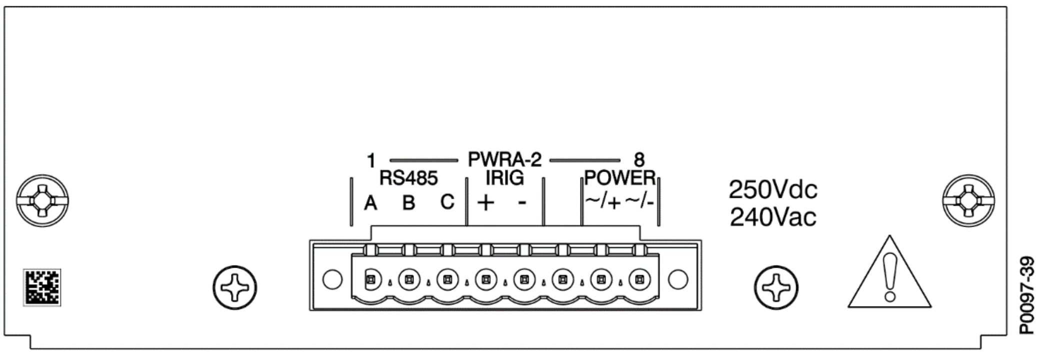


Figure 4-3. Power Supply Board Connections, Option 2

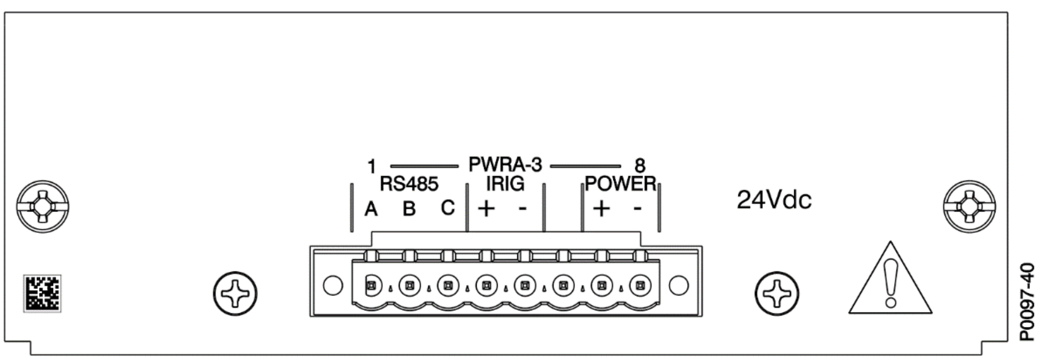


Figure 4-4. Power Supply Board Connections, Option 3

Communications Boards

Available communications configurations are listed in Table 4-2. Connections are shown in Figures 4-5 through 4-10.

Table 4-2. Communications Board Configurations

Option	Description	Connections
E5	Ethernet – (1) Copper (with 3 input, 2 output form A , 1 output form C)	Figure 4-5
P7	Ethernet – (1) Fiber	Figure 4-6
W2	Ethernet – (2) Independent Copper (with 3 input, 2 output form A, 1 output form C)	Figure 4-7
G3	Ethernet – (1) Copper, (1) Redundant Copper, and (1) Independent Copper	Figure 4-8
H8	Ethernet – (1) Fiber, (1) Redundant Fiber, and (1) Independent Fiber	Figure 4-9
H7	Ethernet – (1) Fiber, (1) Redundant Fiber, and (1) Independent Copper	Figure 4-10

Fiber Ethernet is 100Base-FX, LC Connector; Copper Ethernet is 10/100/1000 Base-T, RJ-45 connector.

10Base-T only applies to copper Ethernet port 1. All copper ports support 100/1000 Base-T communications.

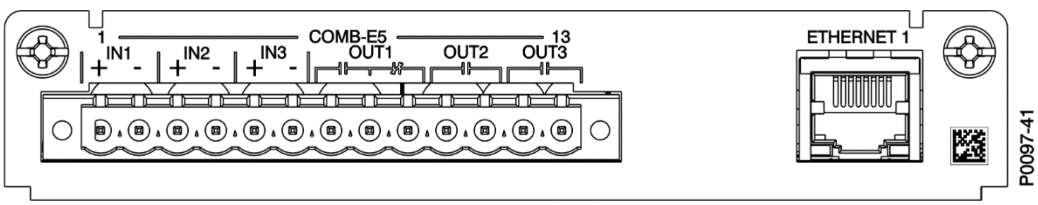


Figure 4-5. Communications Board Connections, Option E5

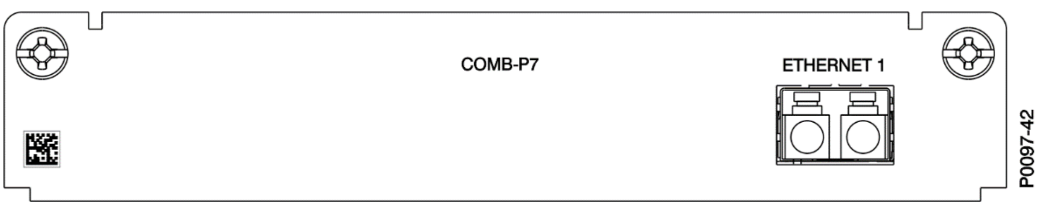


Figure 4-6. Communications Board Connections, Option P7

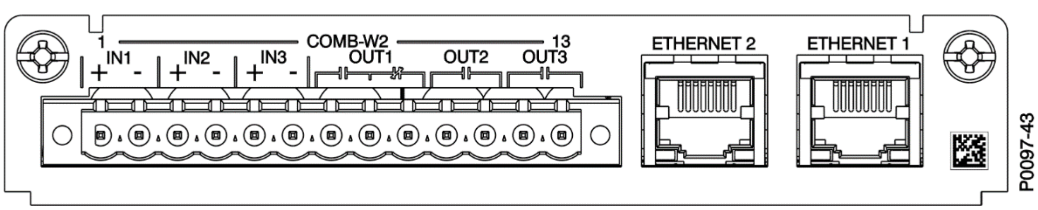


Figure 4-7. Communications Board Connections, Option W2

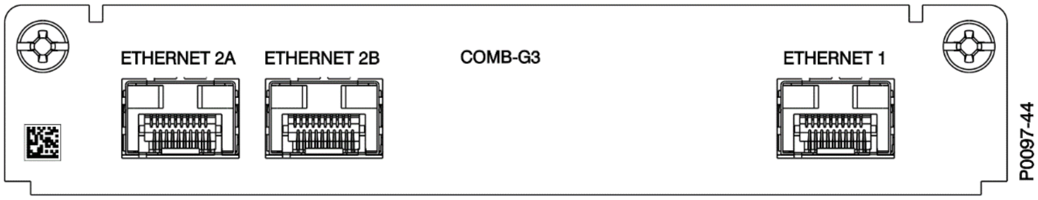


Figure 4-8. Communications Board Connections, Option G3

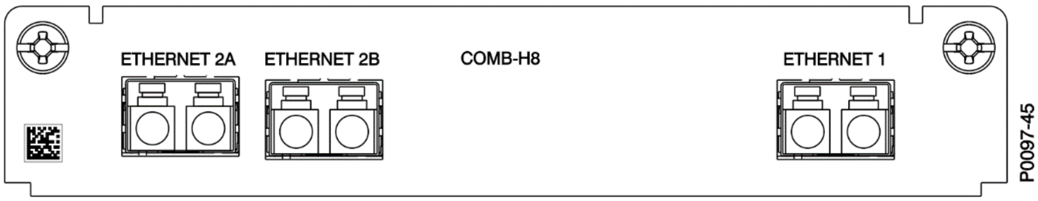


Figure 4-9. Communications Board Connections, Option H8

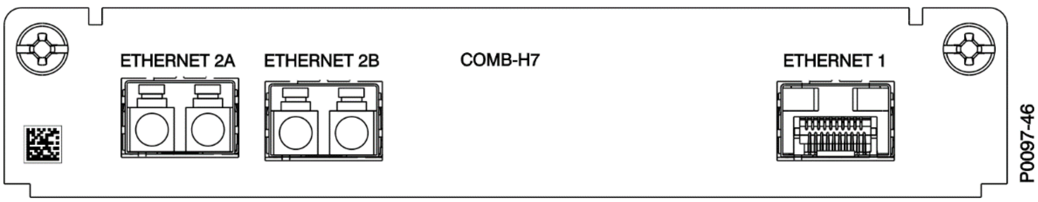


Figure 4-10. Communications Board Connections, Option H7

Analog Sensing Boards

Available analog sensing configurations are listed in Table 4-3. Connections are shown in Figures 4-11 through 4-17.

All current inputs, except SEF, have the same operating range and can be mapped to any Circuit Phase or Ground setting. SEF inputs have a lower operating range and populate to I7 on seven-CT Boards and I4 on four-CT Boards. Typically, I1-3 is mapped to IA, IB, and IC, and I4 is mapped to IG.

Table 4-3. Analog Sensing Board Configurations

Option	Description	Connections
L6	4 channel current (1 or 5 A phase and ground)	Figure 4-11
A9	4 channel current (1 or 5 A phase and SEF ground)	Figure 4-12
X6	7 channel current (1 or 5 A phase and ground)	Figure 4-13
L2	7 channel current (1 or 5 A phase and SEF ground)	Figure 4-14
X9	4 channel voltage (300 Vac max, 3 phase, 4 wire plus auxiliary)	Figure 4-15
T3	4 channel voltage (300 Vac max), 4 channel current (1 or 5 A phase and ground)	Figure 4-16
M0	4 channel voltage (300 Vac max), 4 channel current (1 or 5 A phase and SEF ground)	Figure 4-17

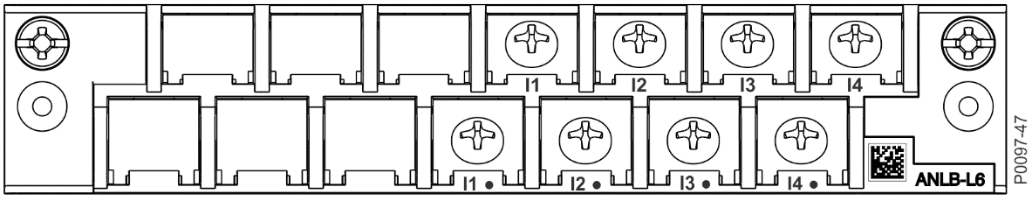


Figure 4-11. Analog Sensing Board Connections, Option L6

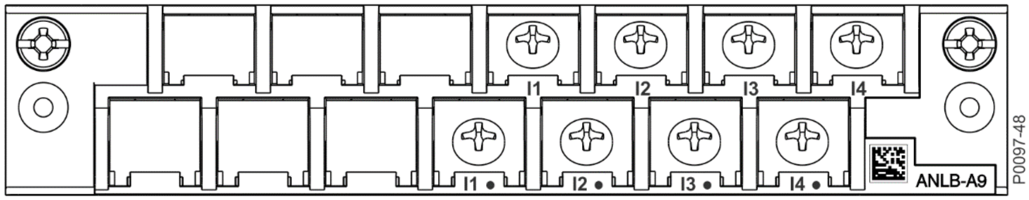


Figure 4-12. Analog Sensing Board Connections, I4 = SEF Channel, Option A9

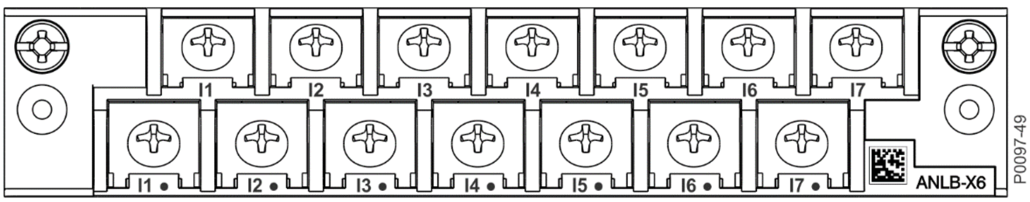


Figure 4-13. Analog Sensing Board Connections, Option X6

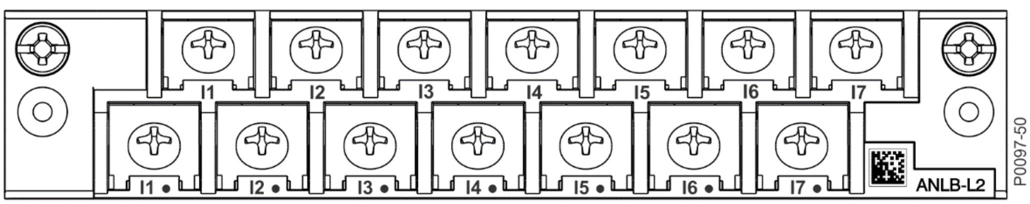


Figure 4-14. Analog Sensing Board Connections, I7 = SEF Channel, Option L2

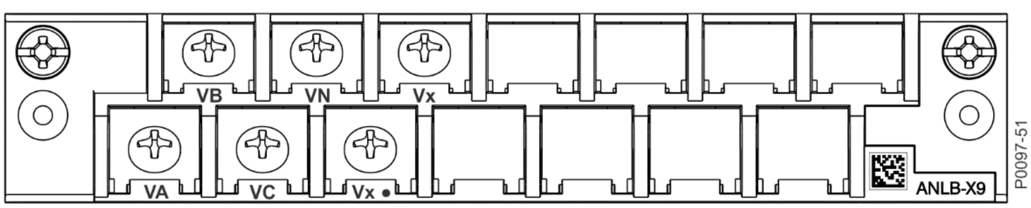


Figure 4-15. Analog Sensing Board Connections, Option X9

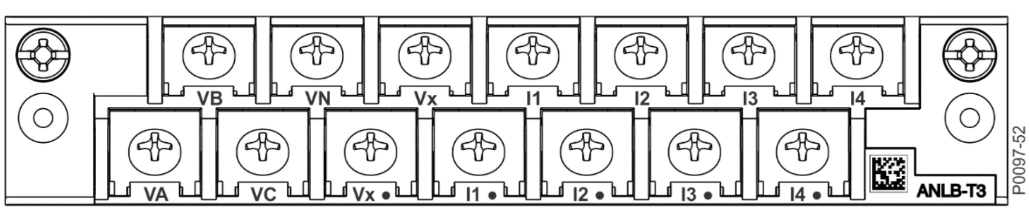


Figure 4-16. Analog Sensing Board Connections, Option T3

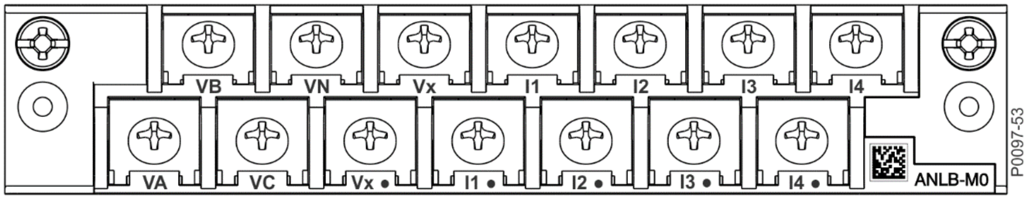


Figure 4-17. Analog Sensing Board Connections, I4 = SEF Channel, Option M0

I/O and Auxiliary Boards

Available I/O and auxiliary configurations are listed in Table 4-4. U4 and A2 options are non-removable, fixed terminals. Inputs and outputs are dry contacts. Analog inputs can accept 0 to 10 V or 4 to 20 mA signals. mV inputs measure signals from 50 mV or 100 mV nominal devices. RTDs measure from 10-ohm Copper, 100-ohm Platinum, 100-ohm Nickel, and 120-ohm Nickel sensors. Connections are shown in Figures 4-18 through 4-22.

Table 4-4. I/O and Auxiliary Board Configurations

Option	Description	Connections
W9	5 inputs, 2 outputs form A, 2 outputs form C	Figure 4-18
N5	12 inputs, six sets of 2 with shared commons	Figure 4-19
U4	7 analog inputs, single mVdc input (50 or 100 mV)	Figure 4-20
C5	8 outputs (5 form A, 3 form C)	Figure 4-21
A2	7 RTDs, single mVdc input (50 or 100 mV)	Figure 4-22

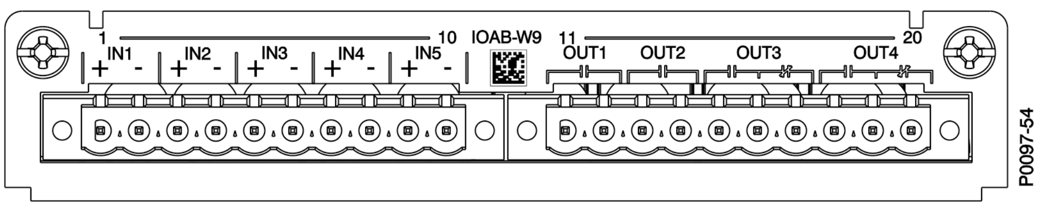


Figure 4-18. I/O and Auxiliary Board Connections, Option W9

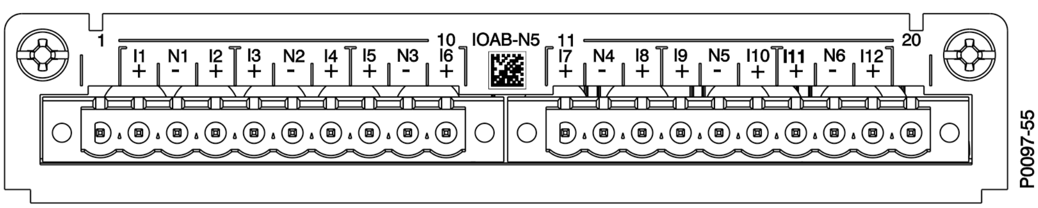


Figure 4-19. I/O and Auxiliary Board Connections, Option N5

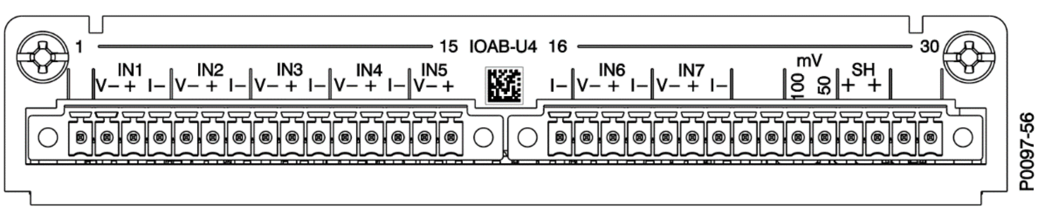


Figure 4-20. I/O and Auxiliary Board Connections, Option U4

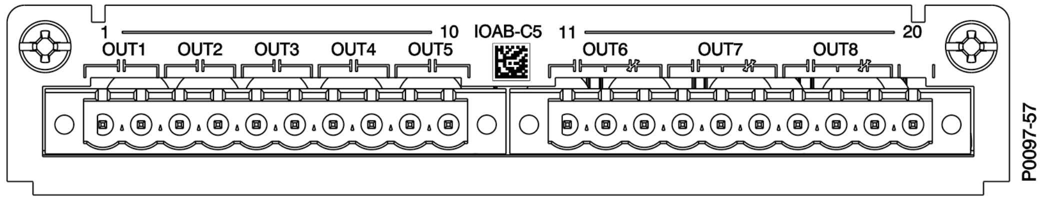


Figure 4-21. I/O and Auxiliary Board Connections, Option C5

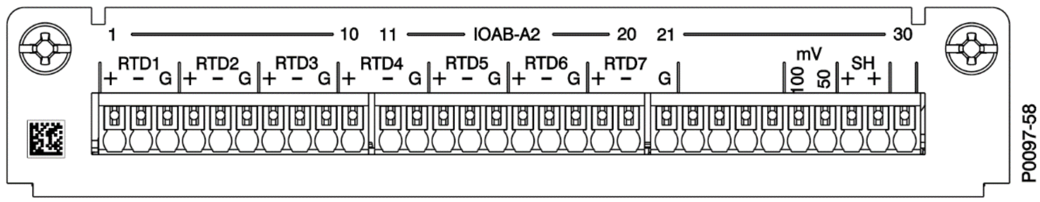


Figure 4-22. I/O and Auxiliary Board Connections, Option A2

Board Reconfiguration and Replacement

The BE1-FLEX is designed to accommodate board changes while installed. Replacing a board or HMI of the same type is automatically detected on relay power up and operational without any settings changes or updates. For firmware only updates, see the Firmware Update and Style Upgrade process in the *Device Information* chapter.

To physically replace boards, follow the below procedure:

Note
Handle boards with HBM Class 0A Electrostatic Discharge (ESD) control precautions.

Step 1. Disconnect control power and remove terminals as required per application configuration.

Step 2. Extract board unscrewing one screw on each side of the board; four corners for the HMI.

Step 3. Pull board straight back, HMI straight forward. Pulling sideways or vertically could damage board guides and internal connectors.

Step 4. Insert new board or HMI. Pressing on corners to seat flush.

Step 5. Screw into place at the same positions as step 2.

The below details the steps to modify the hardware configuration. This process applies to removal of the board, change the board type, and adding boards. Active settings files require the configured style to match the hardware configuration. Mismatch of settings to hardware configuration will result in a Relay Trouble alarm and all outputs disabled. The below steps define how to match the settings to the configured hardware.

Note
Adding or changing hardware may require a firmware update. Please contact Basler Technical Support for the latest firmware.

Step 1. In the settings explorer, select BE1-FLEX, Configuration, Style Configurator to recognize the newly configured style. The style displayed will match the configured hardware automatically.

Step 2. Edit the Terminal Kit selection, and then change it back to the original setting. This will activate the Update Instance button. Click Update Instance.

Step 3. An Auto Populate Items window will appear. Select Save to save the newly configured style to the remainder of the settings. Select or deselect auto population as desired. Click Ok.

Step 4. View the Settings Validation window (Figure 4-23) on the bottom of the BESTCOMS*Plus* window. Click Revalidate. This will display all validation errors in the settings file, including errors caused by the new board configuration.

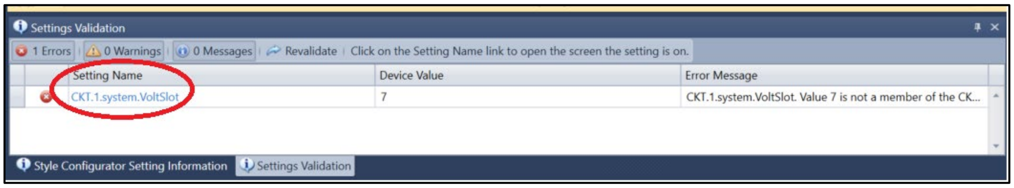


Figure 4-23. Settings Validation Screen

Step 5. Click Setting Name of each item to jump to the associated programming screen. Enter a valid setting based upon the newly configured hardware.

Step 6. Save and Upload Settings and Logic to Device from the Communication pull-down menu.

5 • Typical Connections

Connections are made on the rear of the BE1-FLEX and configured through Configuration, Circuit Summary in BESTCOMS*Plus*®. For an illustration of BE1-FLEX terminals, refer to the *Hardware Configuration* chapter.

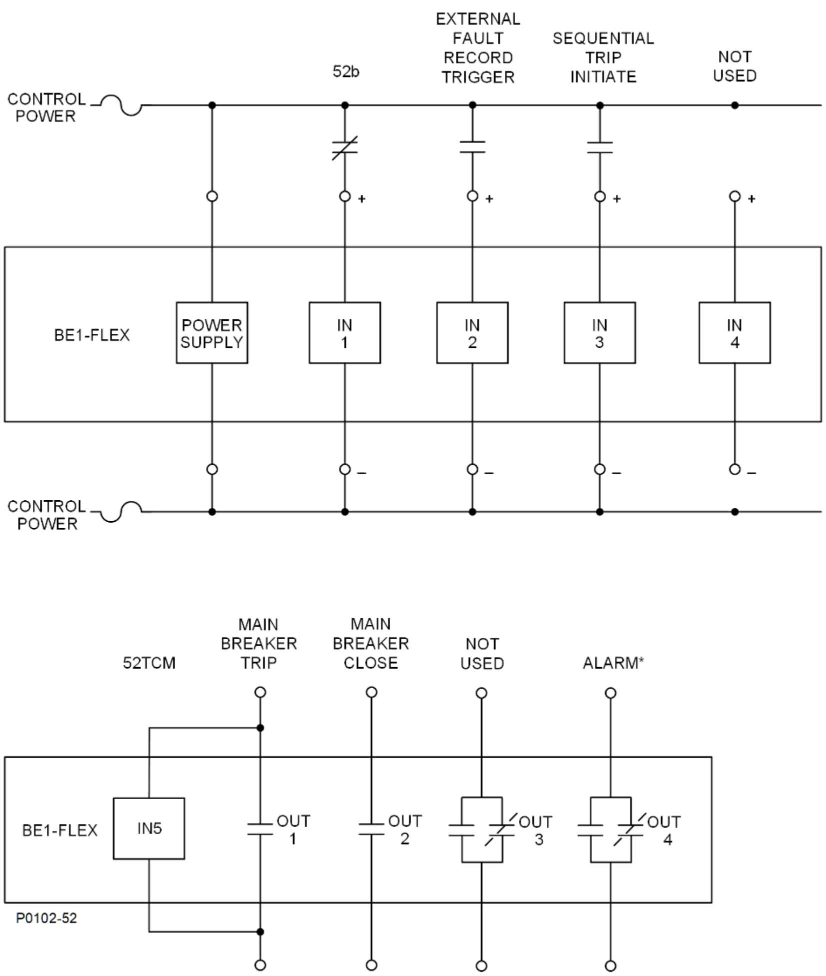
Notes

Connections to the BE1-FLEX current inputs and ground terminal should be made with a minimum wire size of 12 AWG (4 mm²).

The relay should be hard-wired to earth ground with the wire attached to the rear ground terminal of the relay case as shown in Figure 4-1 in the *Hardware Configuration* chapter. When the relay is configured in a system with other protective devices, a separate ground bus lead is recommended for each relay.

I/O Connections

Typical external ac or dc connections for the BE1-FLEX are shown in Figure 5-1.



*Refer to the *Power System Configuration* chapter for information on how to create alarm contact logic.

Figure 5-1. Typical External Connections

AC Connections

Typical external ac connection schemes are shown in the following illustrations:

- Feeder or intertie: Figure 5-2
- Generator differential: Figure 5-3
- Overall differential: Figure 5-4
- Flux-balance differential: Figure 5-5
- Transformer: Figure 5-6

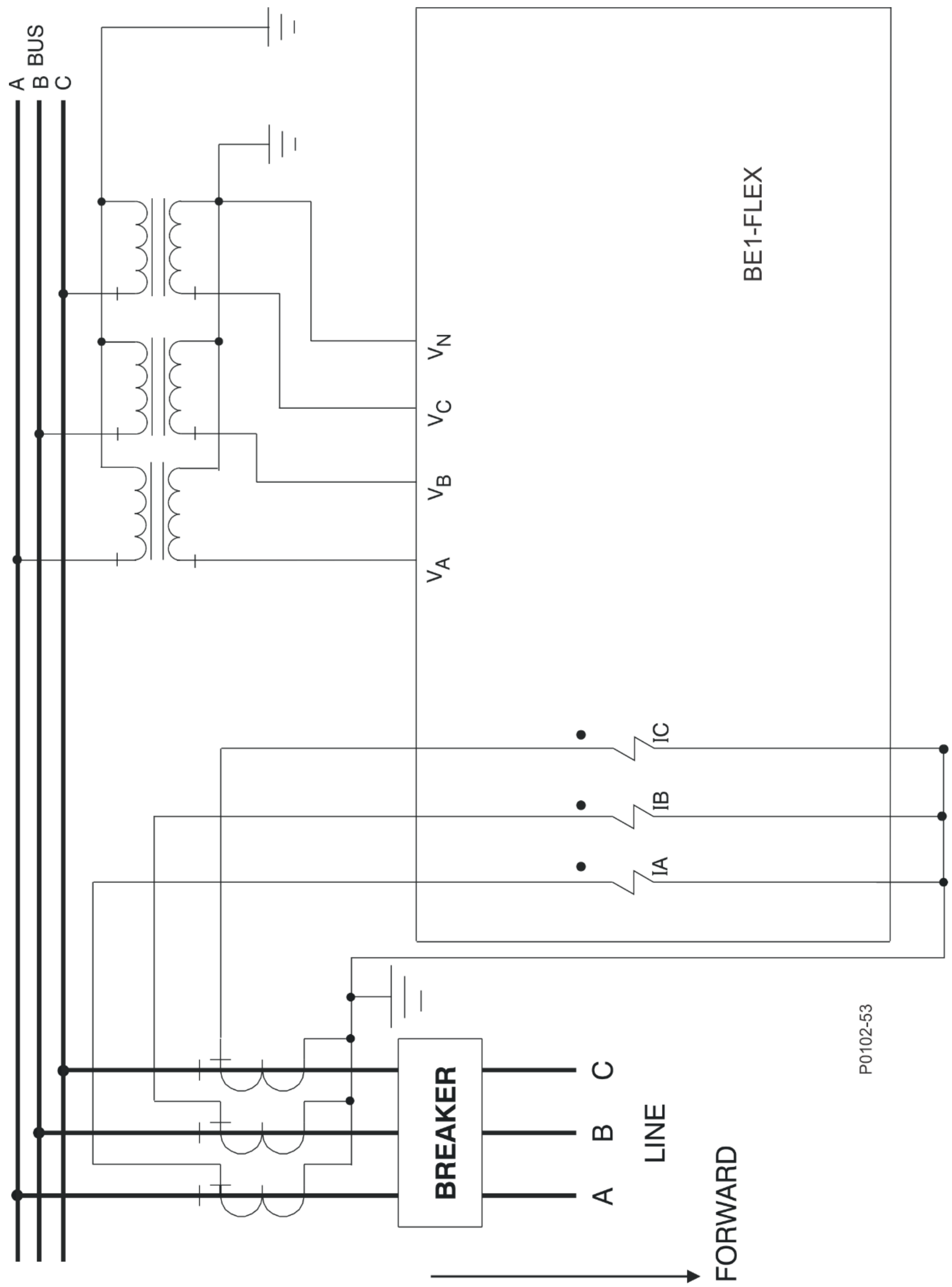
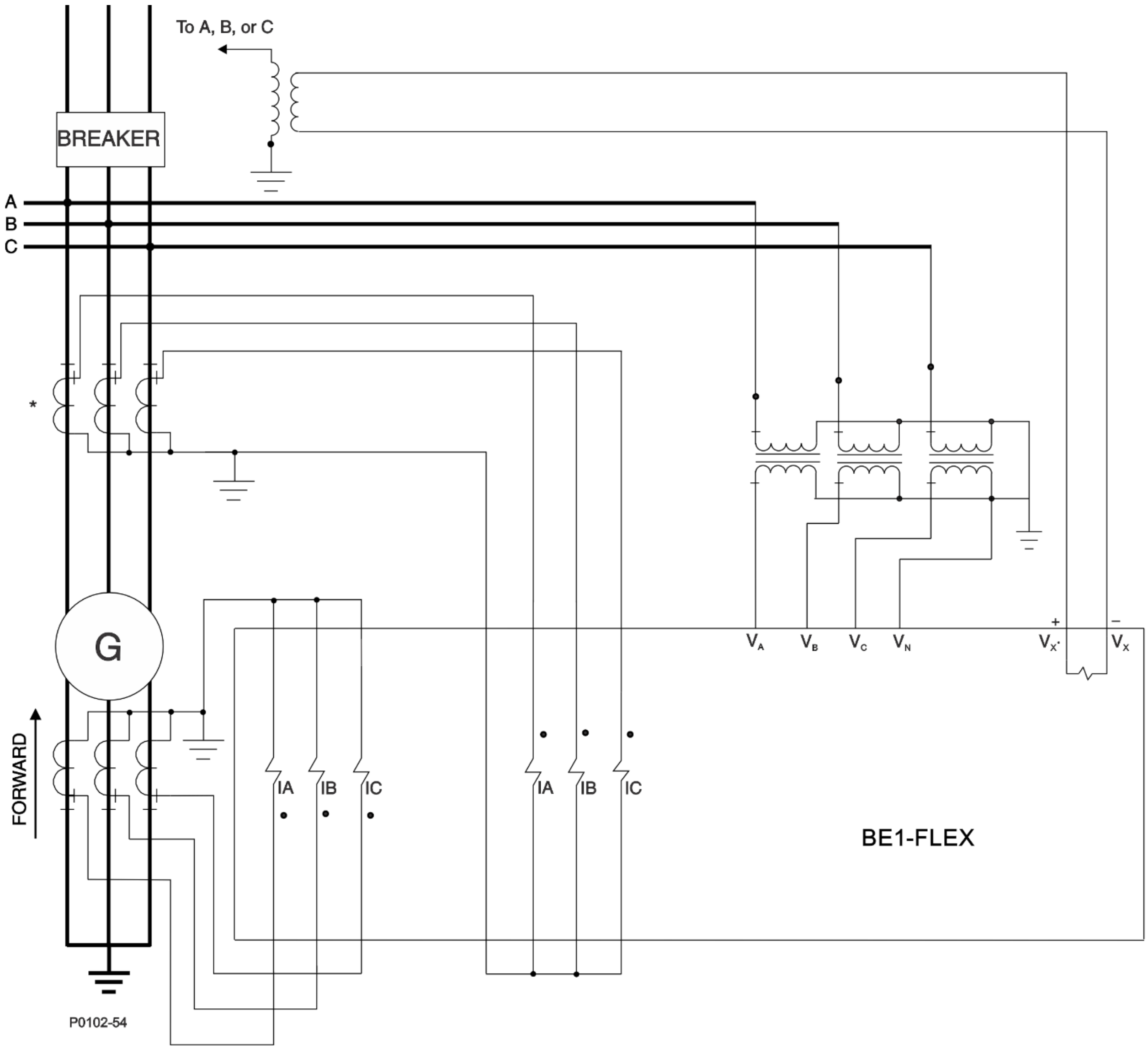


Figure 5-2. Typical AC Connections for Feeder or Intertie



* Second set of CTs only used for differential protection.

Figure 5-3. Typical AC Connections for Generator Differential

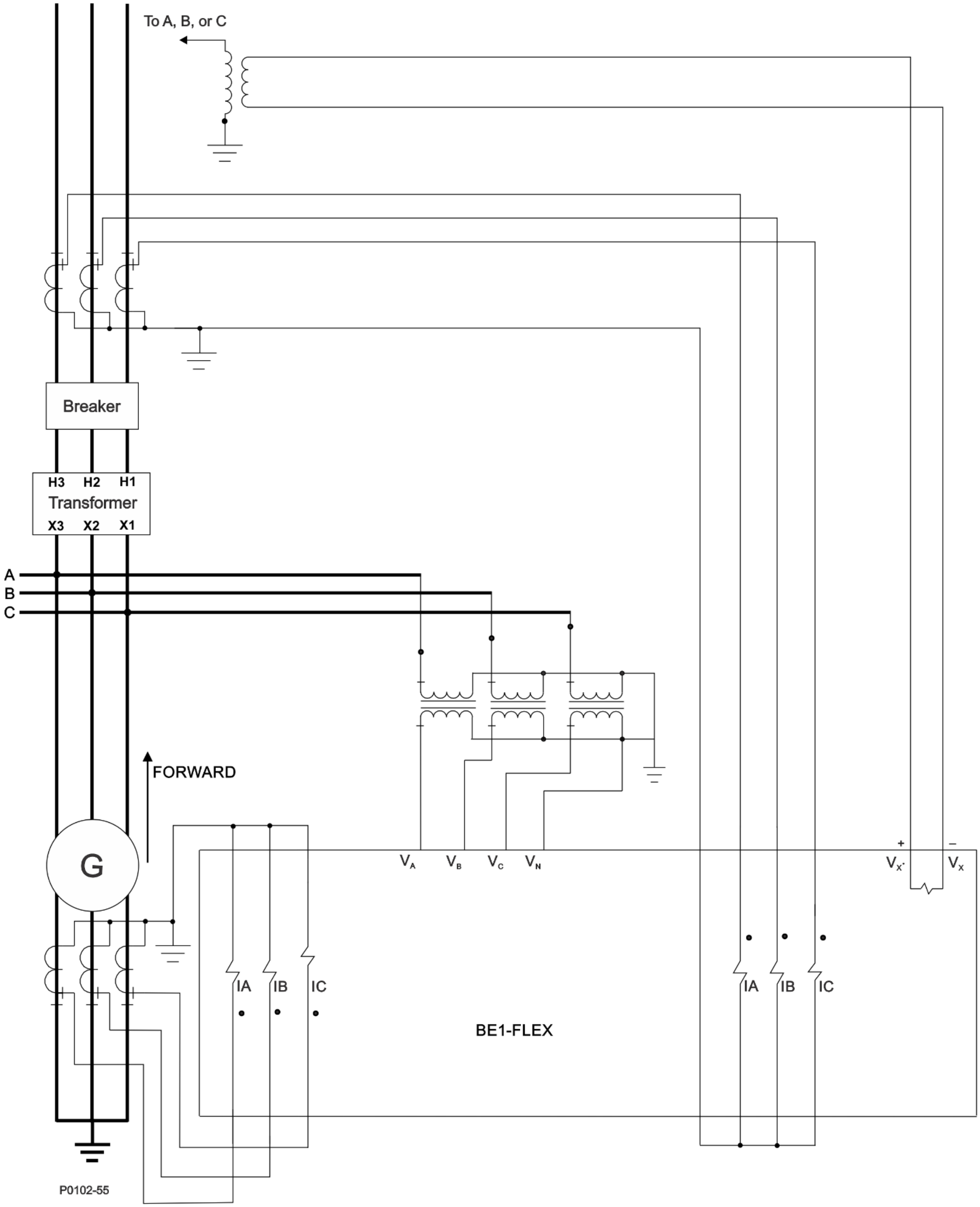


Figure 5-4. Typical AC Connections for Overall Differential

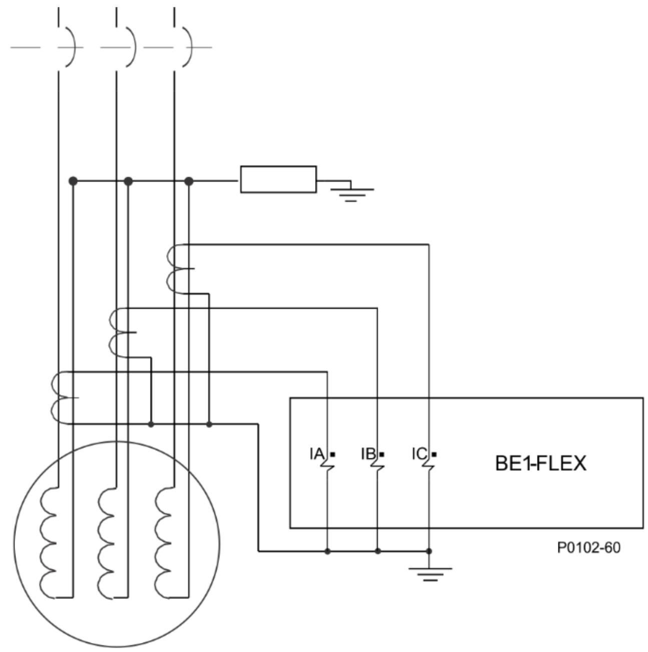


Figure 5-5. Typical AC Connections for Flux-Balance Differential

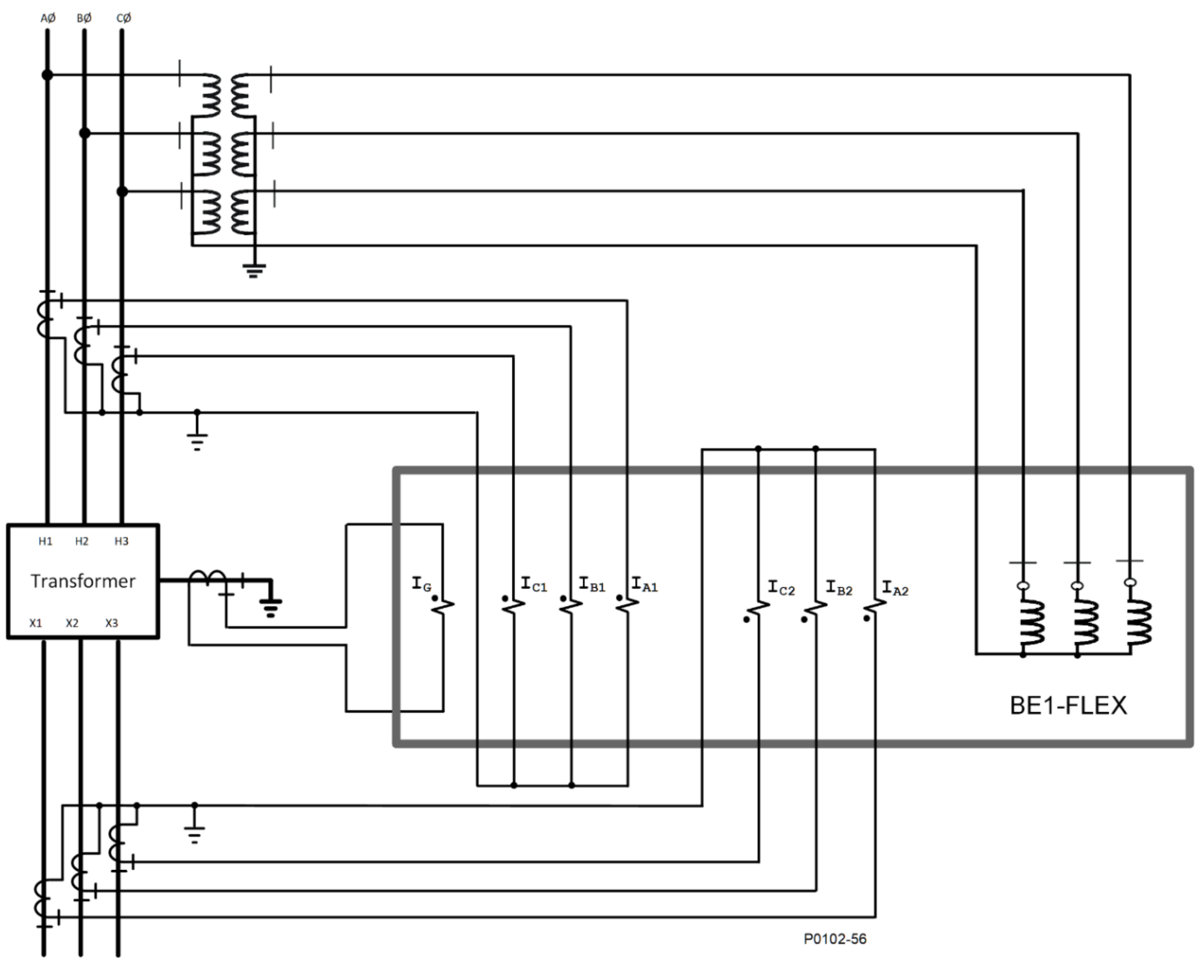


Figure 5-6. Typical AC Connections for Transformer

Voltage and Current Sensing Connections

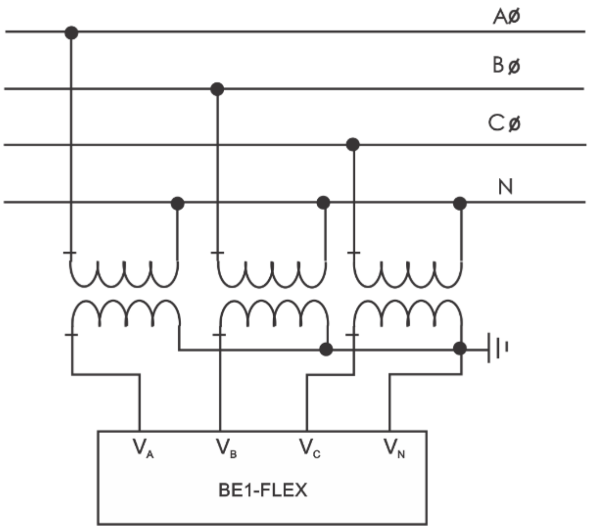
Three-phase voltage sensing, alternate VT inputs are shown in Figure 5-7.

The BE1-FLEX calculates circuit frequency from specific hardware channels. To ensure optimal sampling, include a hardware channel with frequency detection circuitry in every configured circuit. For common frequency across multiple circuit applications such as bus differential, the BE1-FLEX moves through circuits in a zone configuration until it finds a reliable frequency.

Hardware channels with internal frequency detection are:

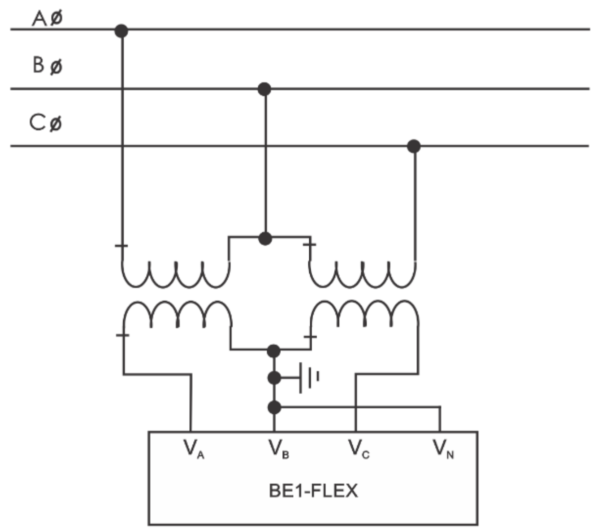
- T3 and M0 boards: VA, VC, VX, I1
- X6 and L2 boards: I1, I2, I4, I7
- L6, A9 and X9 boards: All channels

Note
When VT connection is set to single phase to neutral or phase-to-phase, the BE1-FLEX will calculate and show phantom voltage and power, real time metering, and power quality values. The phantom values are rotated 120 degrees and equal magnitude to the measured phase.



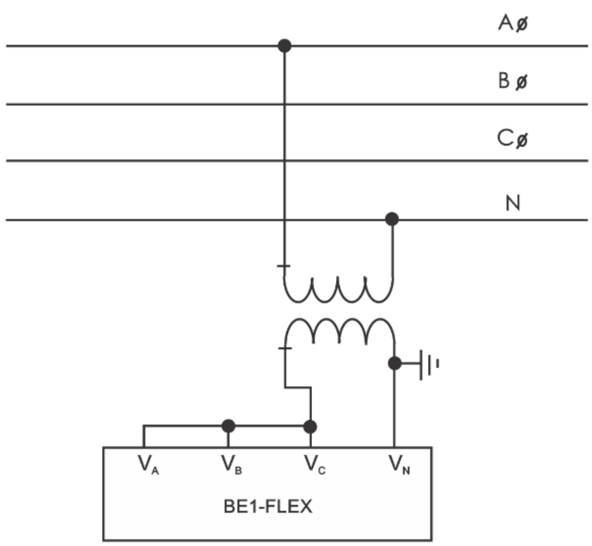
A) Three Phase VTs; 4-Wire Connection

Provides three-element metering. Elements 27P and 59P can be P-N or P-P. Provides negative- and zero-sequence polarizing for ground faults (67N).



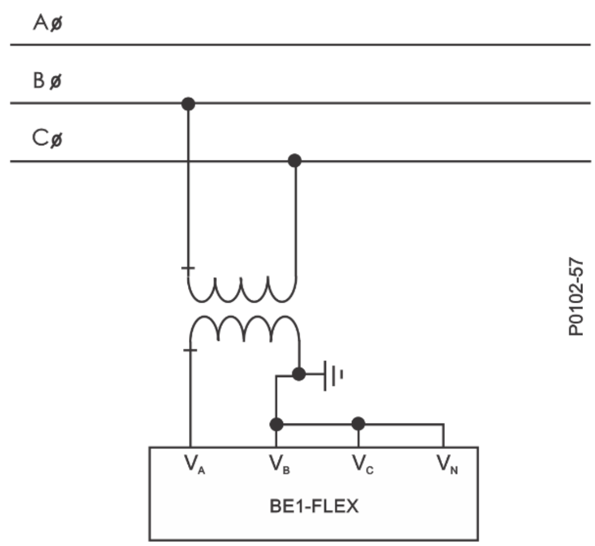
B) Three Phase VTs; 3-Wire Connection

Provides two-element metering. Elements 27P and 59P are P-P. Provides negative-sequence polarizing for ground faults (67N). Note relay B-to-N connection.



C) One Phase VT; P-N Connection

VT primary can be connected to any phase A-N, B-N, or C-N. One-element metering. Elements 47 (V2) and 59N (3V0) are disabled. Elements 27P and 59P are P-N.



D) One Phase VT; P-P Connection

VT primary can be connected to any phase A-B, B-C, or C-A. One-element metering (30° shift). Elements 47 (V2) and 59N (3V0) are disabled. Elements 27P and 59P are P-P. Single phase P-P connections must wire to Phase A voltage. The VT connection in the settings is used to set the primary of the VT to the wired phases.

Figure 5-7. Voltage Sensing, Alternate VTP Inputs

Single-phase current sensing connections are shown in Figure 5-8.

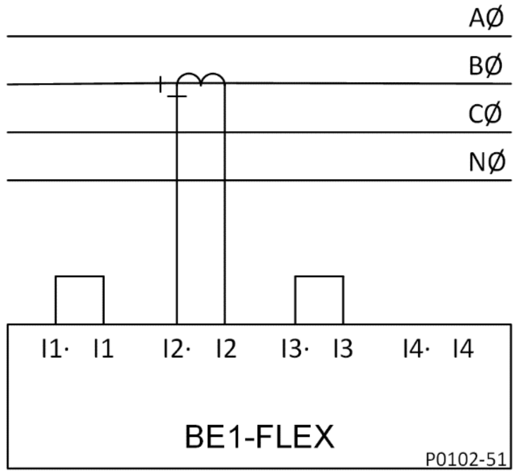


Figure 5-8. Single-Phase Current Sensing Connections

Note
Some elements may not function properly in certain modes when using single-phase current sensing.

Analog Input Connections

Voltage input connections are shown in Figure 5-9 and current input connections are shown in Figure 5-10. When using the current input, AIN V– and AIN I– must be tied together.

Analog Input – Voltage Input Connections

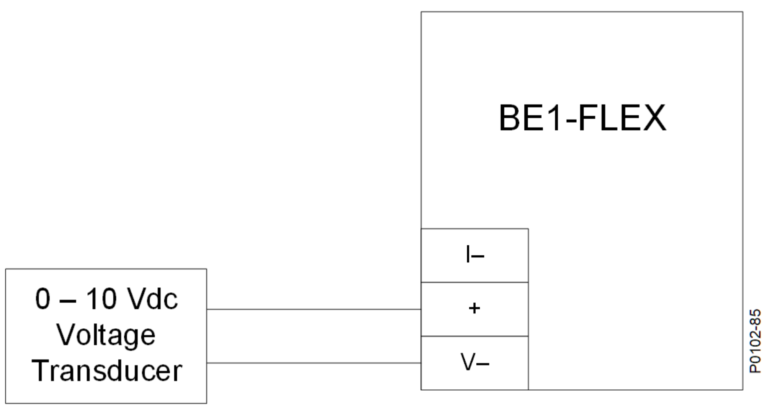


Figure 5-9. Analog Input – Voltage Input Connections

Analog Input – Current Input Connections

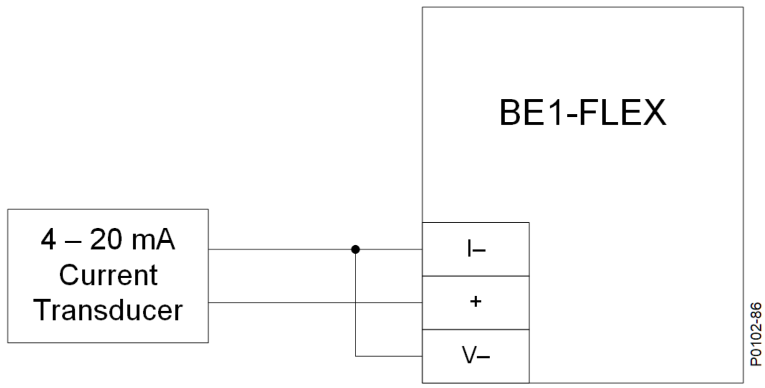


Figure 5-10. Analog Input – Current Input Connections

RTD Input Connections

Two-wire RTD input connections are shown in Figure 5-11. Figure 5-12 shows three-wire RTD input connections.

RTD Input –Two-Wire RTD Input Connections

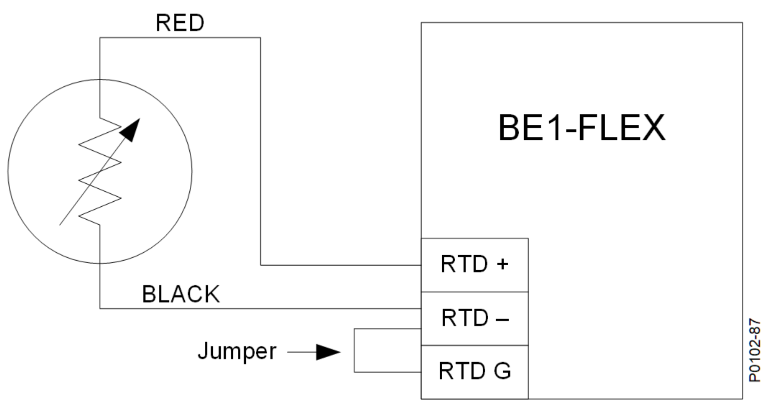


Figure 5-11. RTD Input – Two-Wire RTD Input Connections

RTD Input – Three-Wire RTD Input Connections

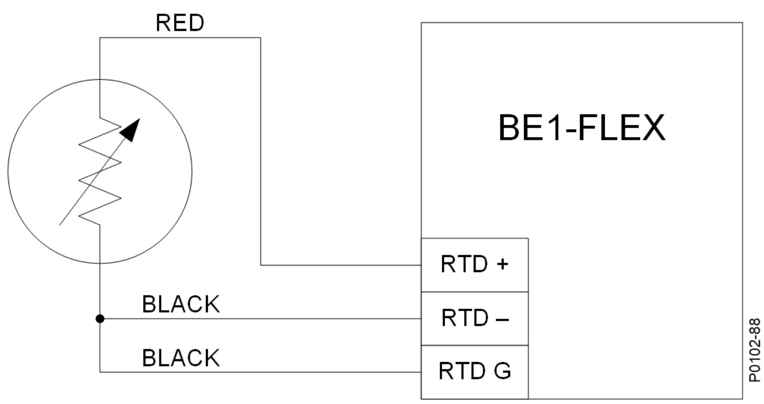
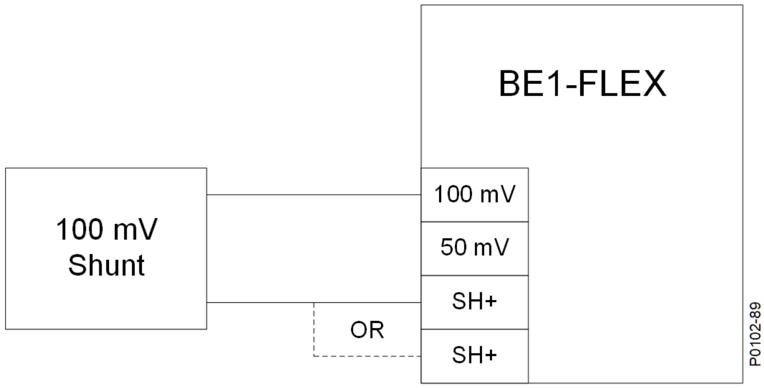


Figure 5-12. RTD Input – Three-Wire RTD Input Connections

Shunt Input Connections

Shunt input connections are shown in Figure 5-11.



Note: If using a 50 mV shunt, connect wire to the 50 mV input.

Figure 5-13. Shunt Input Connections

6 • Application Templates

Setting up a digital relay has never been easier than with BESTCOMS*Plus* and the 'add any feature' capabilities of the BE1-FLEX. A national study on electrical reliability has shown that the majority of numeric relay misoperations are caused by incorrect settings and design errors. BESTCOMS*Plus* combats the issue by filtering based upon required and advanced settings, showing only used functions and providing summary and graphical screens through the configuration - minimizing errors and time spent creating settings files. Although BESTCOMS*Plus* files can be created and customized, the purpose of this guide is to assist you in using Basler Electric preconfigured application templates.

Purpose

Application Template and Application Component descriptions are described at the top of the first logic tab for each template. Additional functions are included throughout the logic settings. The logic is available in PDF format from the template download in addition to the logic settings pages themselves. System one-lines are included with the download for most templates.

Application Templates provide protection settings templates for the full system. At a minimum, pickup values must be set to enable functions. Additional changes can be made to templates as needed and described below.

Application Components are a subset of a full application template and only show a specific purpose or function. Components can be utilized alone, but are commonly utilized as part of a larger multifunction solution. Application Components are only available in PDF format for recreation into larger protection, automation, and control schemes. Functions, inputs, outputs, and other instances will normally need to be edited to match available hardware when part of a larger design.

The Generator - Basic High Impedance Grounded logic scheme is shown in Figure 6-1 and the one-line is shown in Figure 6-2 as an example. All templates can be downloaded from www.basler.com.

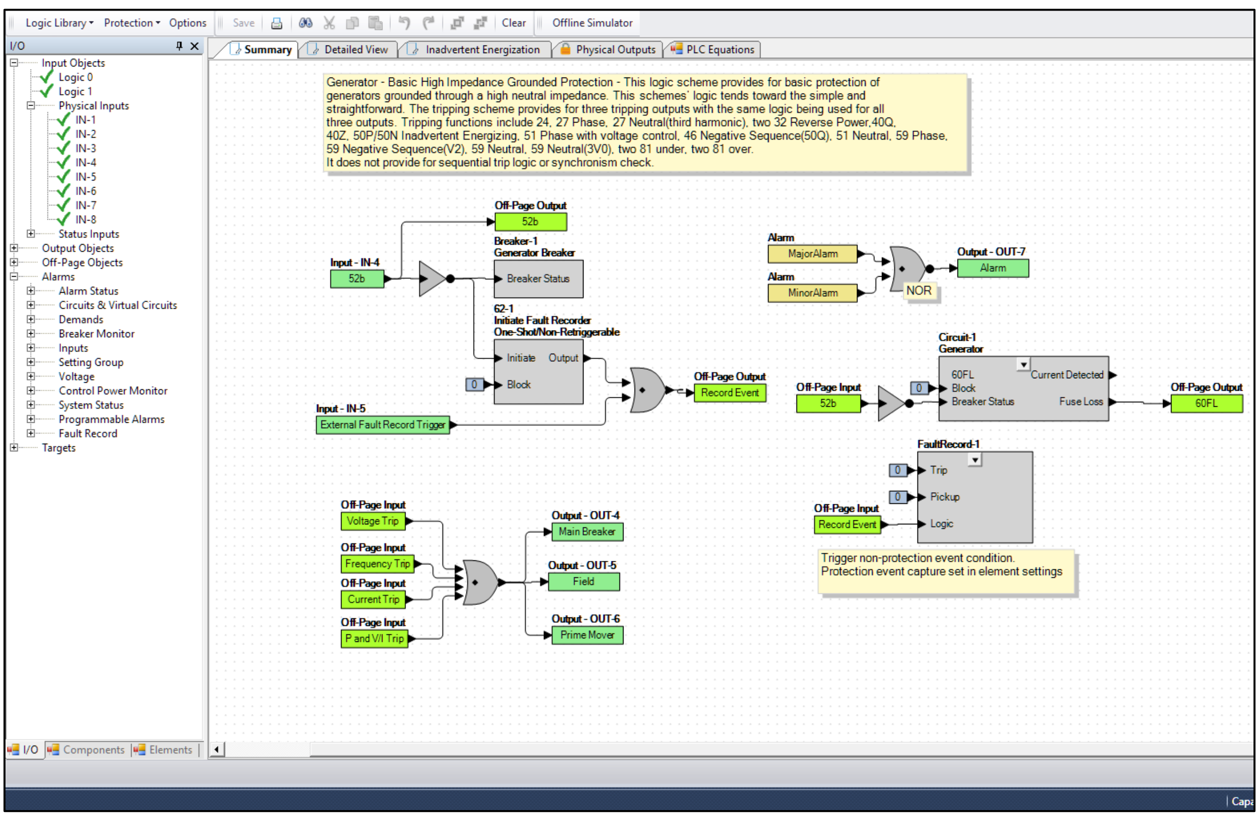


Figure 6-1. Generator - Basic High Impedance Grounded Logic

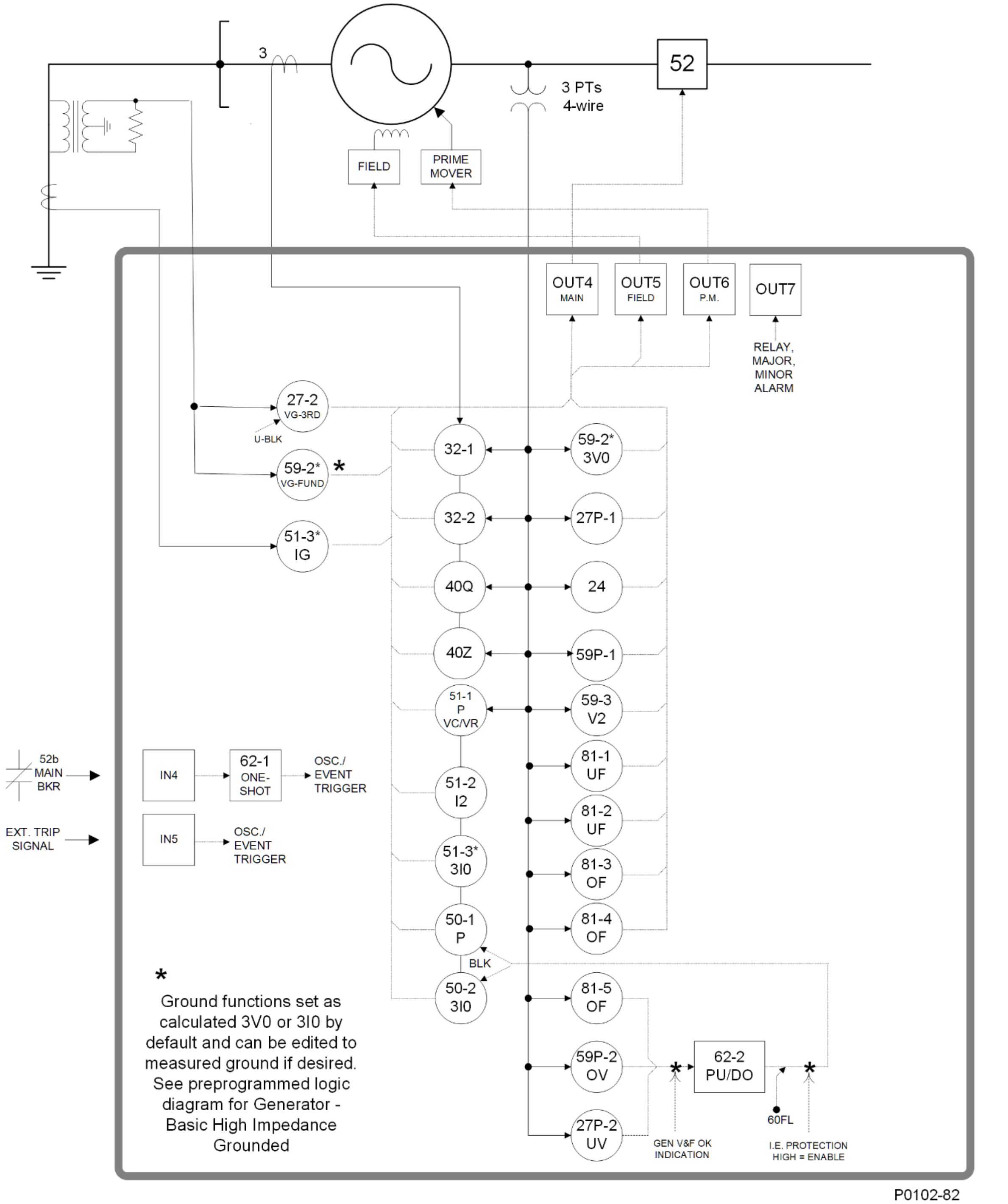


Figure 6-2. Generator - Basic High Impedance Grounded One-Line

Opening an Application Template

BESTCOMS*Plus* refers to the software suite used to program BE1-FLEX devices. If not already installed on your computer, it is easy to download the latest version at www.basler.com.

Step 1. Launch BESTCOMS*Plus* and click on the File pull-down menu at the top left-hand corner of the window.

Step 2. Select Open and select the Application Template file. BESTCOMS*Plus* will then open the Application Template.

Utilizing Application Components

Application Components assume a general system settings file has already been created and saved.

Step 1. Launch BESTCOMS*Plus* and click on the File pull-down menu at the top left-hand corner of the window.

Step 2. Select Open and select the original settings file as shown in Figure 6-3.

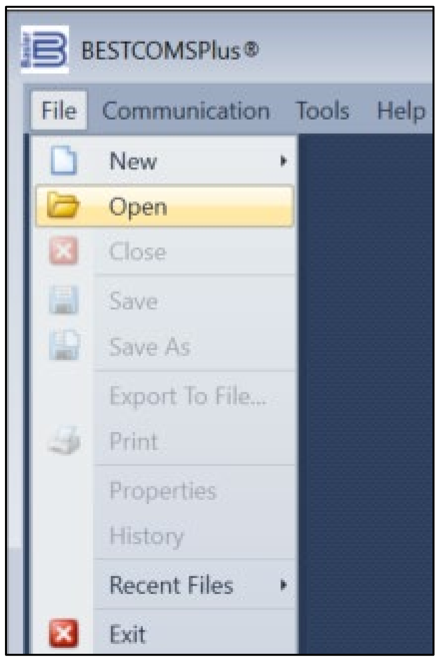


Figure 6-3. Opening a File in BESTCOMS*Plus*

Step 3. Open/view the Application Component Logic document.

Follow the Application Template steps below as a guide and add instances of each item as needed for the application component. For example, Inadvertent Energization will add a Frequency (81), Undervoltage (27), Overvoltage (59), and Logic Timer (62). Add logic as shown and save/upload.

Style Configurator

View the style configuration applicable for the application template. Changes can be made to match available hardware. If any changes are made, click Update Instances to make the newly created features available. Using the auto-generating instances can cause instance mapping to change and should only be used with templates when acknowledging the changes that are being made. The Style Configurator screen is shown in Figure 6-4.

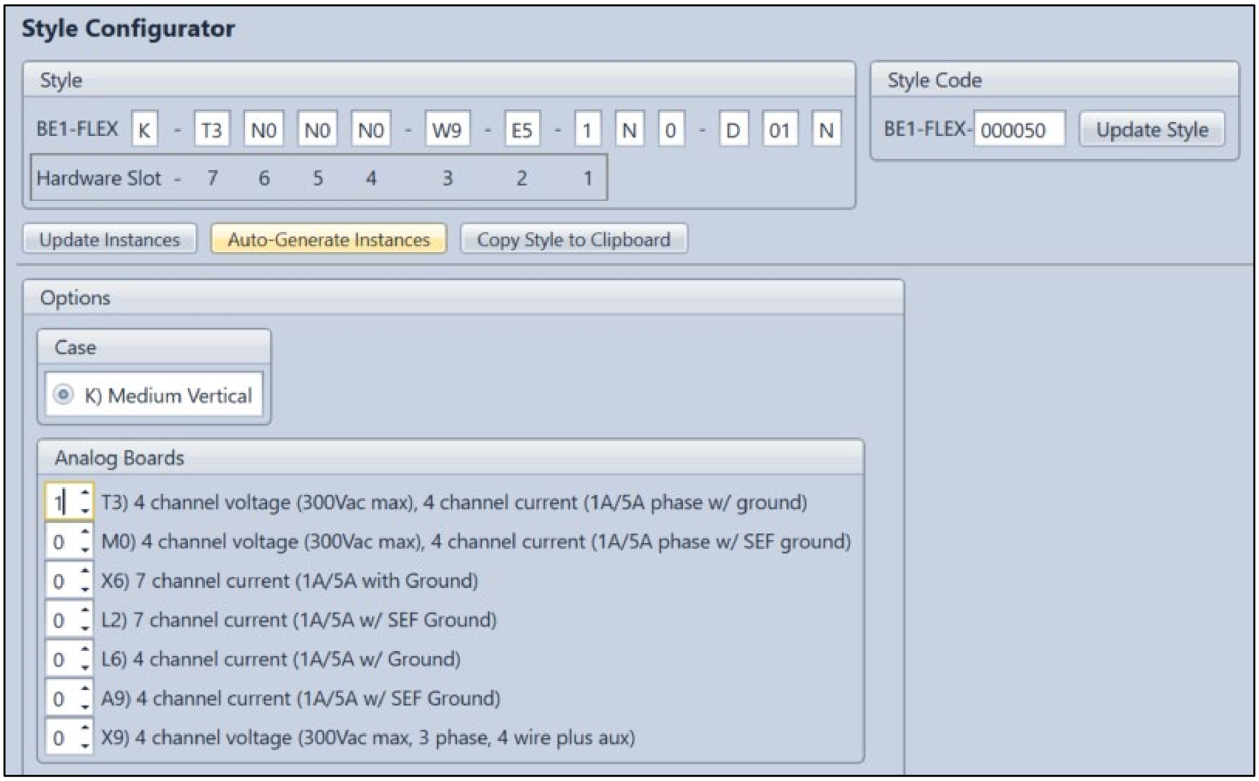


Figure 6-4. Style Configurator Screen

Hardware Configuration

Contact sensing inputs are versatile and accept any wetting voltage based upon Hardware Info settings. The default setting is 120/125 Vac/Vdc. If other wetting voltage is being used, change the Sensing Level setting per board from the Hardware Configuration, Hardware Info (per slot) screens. See Figure 6-5.

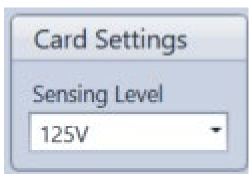


Figure 6-5. Input-Sensing Voltage

Circuit, Breaker, Input and Output Summary

Summary views in the Configuration menu display mapping of hardware to device configuration. Templates have already been automatically configured based upon the configured style of the template. The Circuit Configuration screen is shown in Figure 6-6.

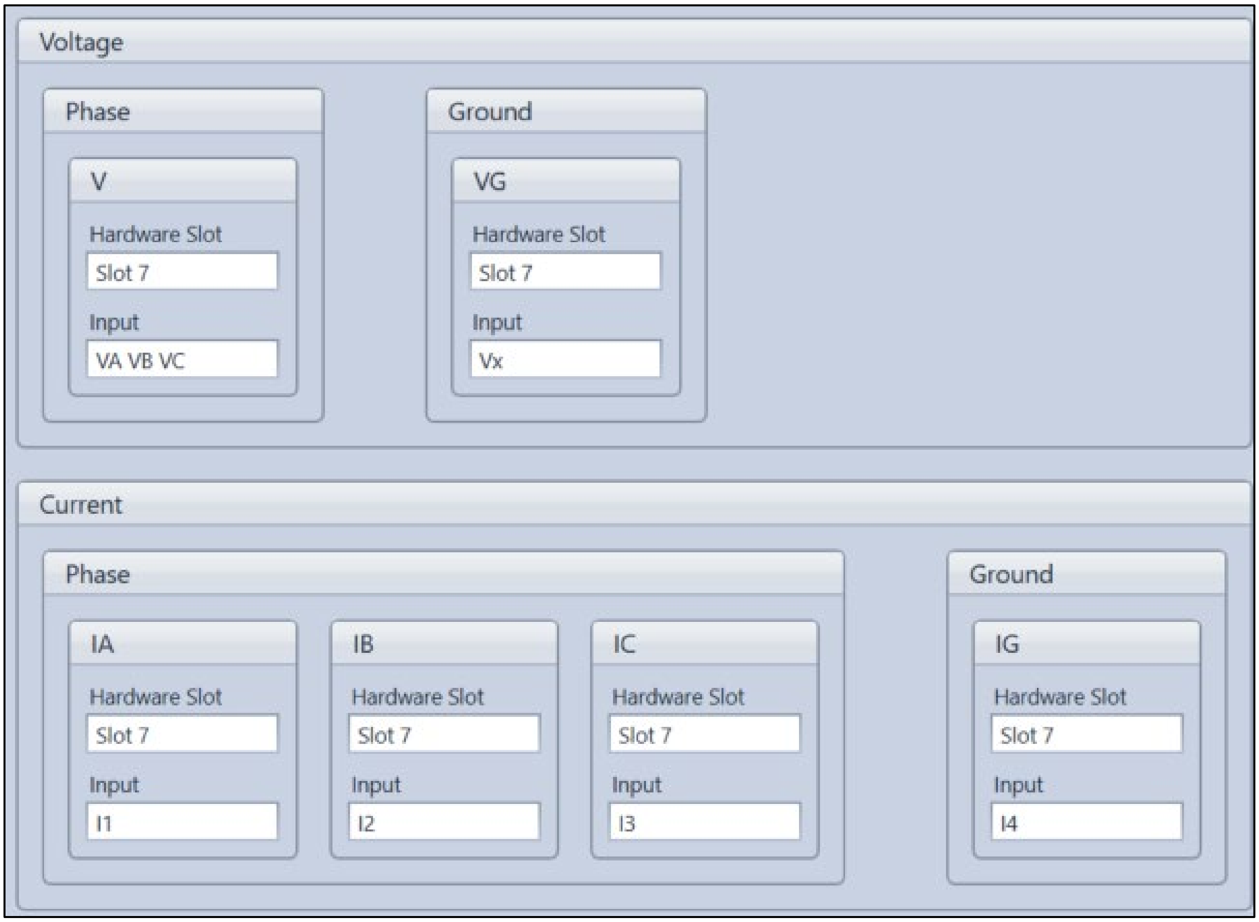


Figure 6-6. Circuit Configuration Screen

Power System Configuration

The Configuration, Circuit Summary, Circuit 1, Power System screen (Figure 6-7) displays information on your system that the relay uses to perform internal calculations. Starting under Nominal Settings, enter the system frequency, nominal secondary voltage in terms of Phase to Neutral (Vpn) quantities, and nominal secondary current (this is the secondary rating of your CT). The ground voltage input should be set up similarly as it is used for detection of zero and negative-sequence overvoltage. The phase rotation of the system is crucial. A reverse setting will cause the relay to calculate erroneous negative-sequence current and possibly misoperate.

CT and VT Setup Ratios contain settings used to calculate primary voltage and current from the sensed secondary values. These settings are important for accurate primary metering and pickup values set in terms of primary quantities. Enter the turns ratio for the phase and ground CTs. For example, if your CT is 1200:5, the setting would be 1200/5=240. If there is no ground CT in your system, this setting can be left unchanged.

Follow the same process for the phase VT setup making sure to specify the type of transformer connection (4W-Y, 3W, PN, or PP). The Ground VT ratio and connection type settings should be specified similarly. When using a 4W-Y connection, the relay can operate on PN or PP sensed voltage for the 27 and 59 element. Select the units you wish to use under the 27/59 and 27R Mode settings.

Repeat for additional circuits as needed.

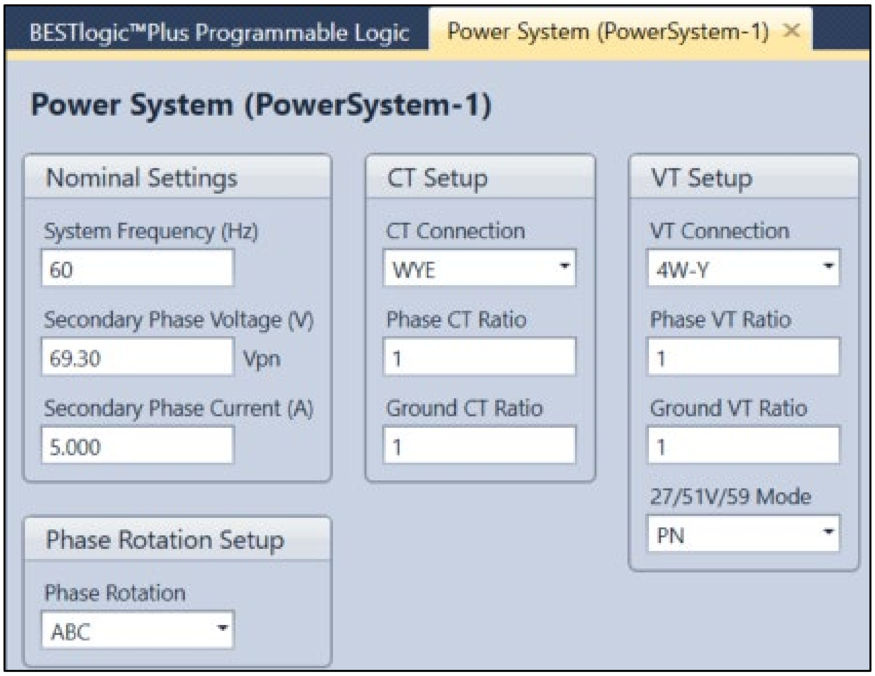


Figure 6-7. Power System Settings Screen

Contact Input(s) and Output(s)

If desired, edit the Contact Input and Outputs settings from the Input Summary and Output Summary screens. These screens allow you to customize the physical alarms and contact I/O with labels and energized state labels.

Each input has a contact recognition and debounce setting. The default contact recognition and debounce settings enable their use on ac signals as well as dc signals.

The hold attribute serves several purposes for contact outputs. The main use for the BE1-FLEX is to prevent the relay contact from dropping out until the current has been interrupted by the 52a contacts in series with the trip coil. If the tripping contact opens before the dc current is interrupted, the contact might be damaged.

Labeling of the output contacts is not required but it is useful for categorizing outputs as the settings file is created and for later analyzing relay operations.

The Output Summary screen is shown in Figure 6-8.

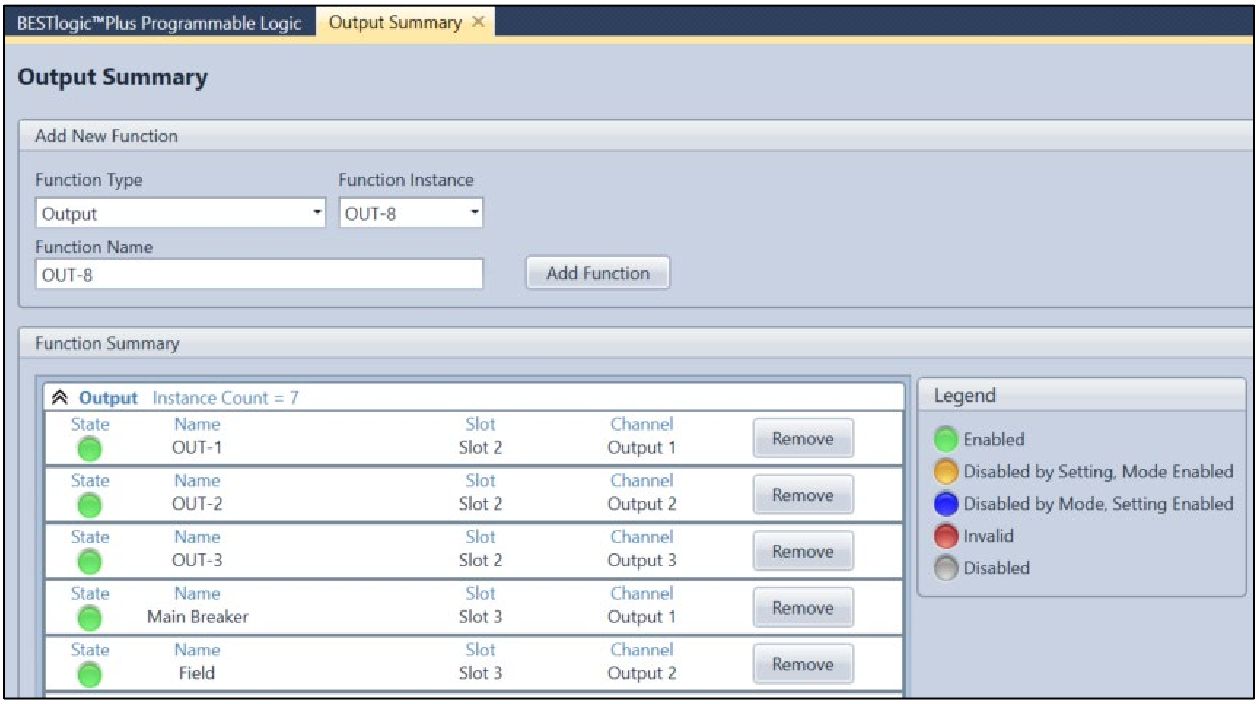


Figure 6-8. Output Summary Screen

Accessing Device Info

Select the Device Info from the Device Information folder. The Device Info screen contains information about the embedded software in the connected BE1-FLEX relay when communicating. If you are not connected to a relay, this should be mostly blank. It will populate information automatically when settings are downloaded from a relay. Device, station, and user IDs also can be specified here.

Protection

All enabled protective functions in the template can be viewed by clicking Protection from the settings menu. Clicking the State bubble from the list will jump to each function.

By default, all protection elements are disabled by pickup setting equal to zero. For each function desired, enable it by entering in your pickups, time dial, reset dial, and so on.

See the protection chapters in this manual and the Application Guides from www.basler.com for further details on each element's function.

Click on Protection once all functions are set as intended. Verify that each desired is function enabled by a green status indicator.

The Protection Summary screen is shown in Figure 6-9.

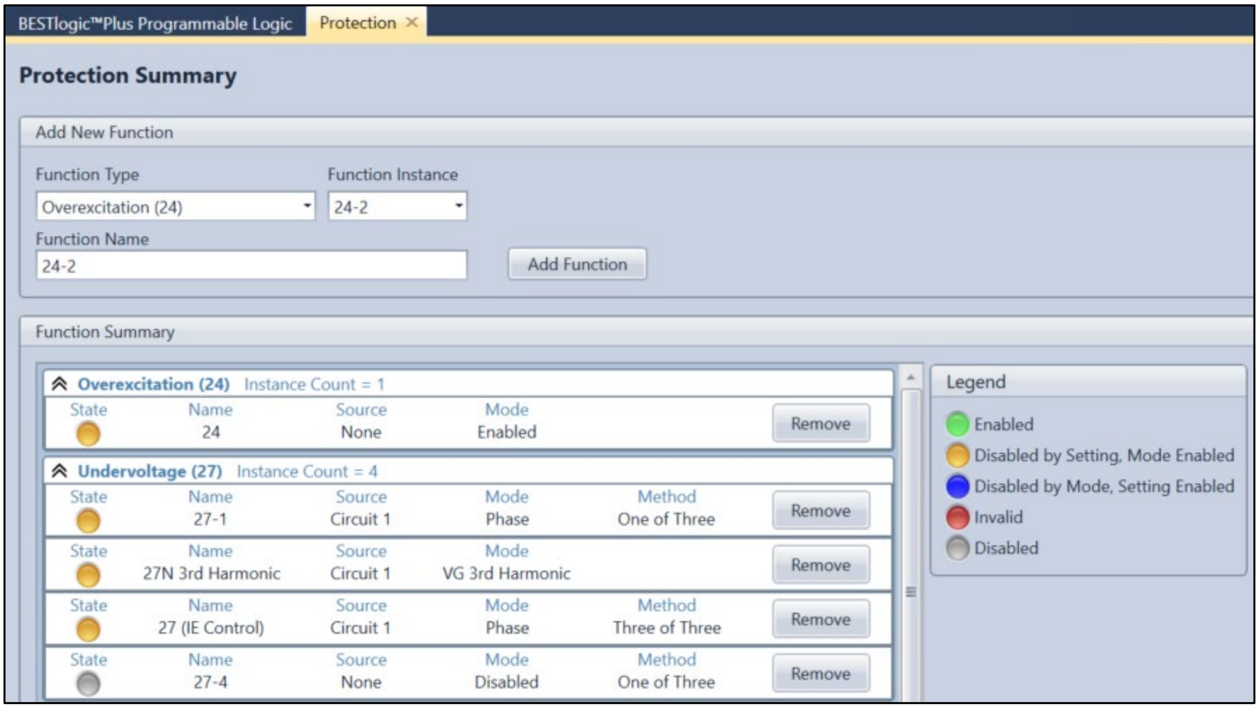


Figure 6-9. Protection Summary Screen

Control

Similar to Protection, not all functions in the template are valid by default settings. Click Control from the settings menu to view each control function in the template. Clicking the State bubble from the list will jump to each function.

Note
Some control functions will appear green from the Summary screen with default settings, as they are valid settings. However, they may be invalid for the application.

See the control chapters in this manual and the Application Guides from www.basler.com for further details on each element's function.

Click on Control once all functions are set as intended. Verify that each desired function is enabled by a green status indicator.

The Control Summary screen is shown in Figure 6-10.

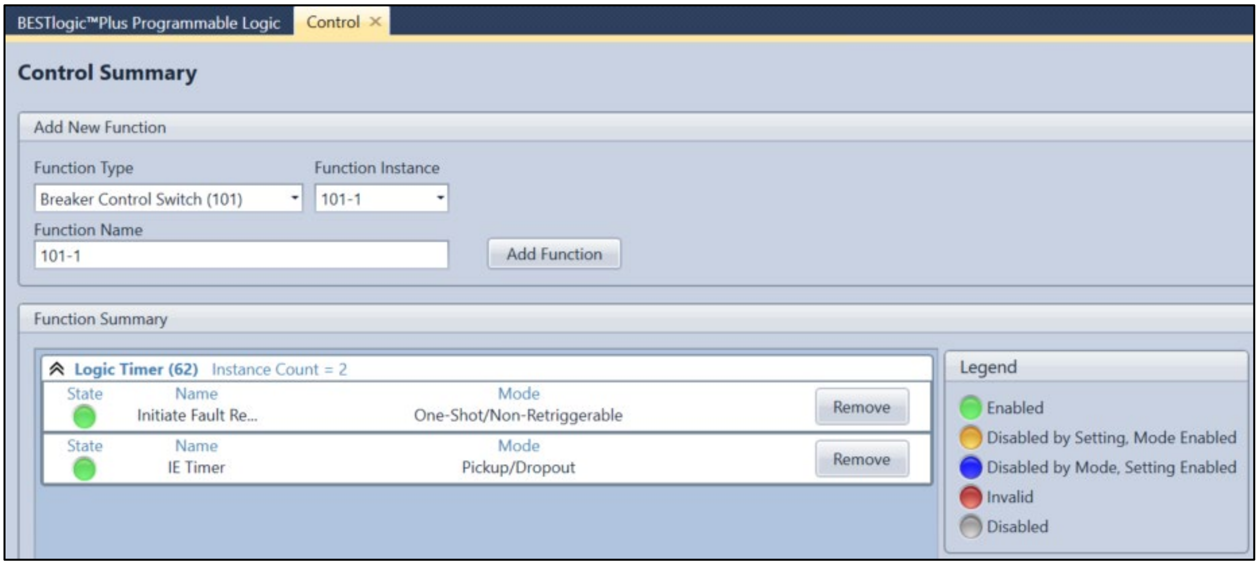


Figure 6-10. Control Summary Screen

BESTlogic™Plus

BESTlogic*Plus* is a powerful logic editor used to customize relay operation and internally route trip signals and other virtual I/O into physical I/O. Notable features in the logic editor include being able to conditionally enable or disable protective elements and trigger oscillographic records.

The BESTlogic*Plus* working environment is nested within BESTCOMS*Plus* and follows the same tabbed interface. Each tab is a new page to organize and build logic. To the left of the logic pages is a toolbox containing all status inputs, physical I/O, logic gates, and elements. Items in the toolbox can be dragged and dropped onto any logic page. Logical I/O is conveyed between pages using custom-labeled off-page inputs and outputs. Refer to the *BESTlogicPlus* chapter for more information.

The BESTlogic*Plus* Programmable Logic screen is shown in Figure 6-11.

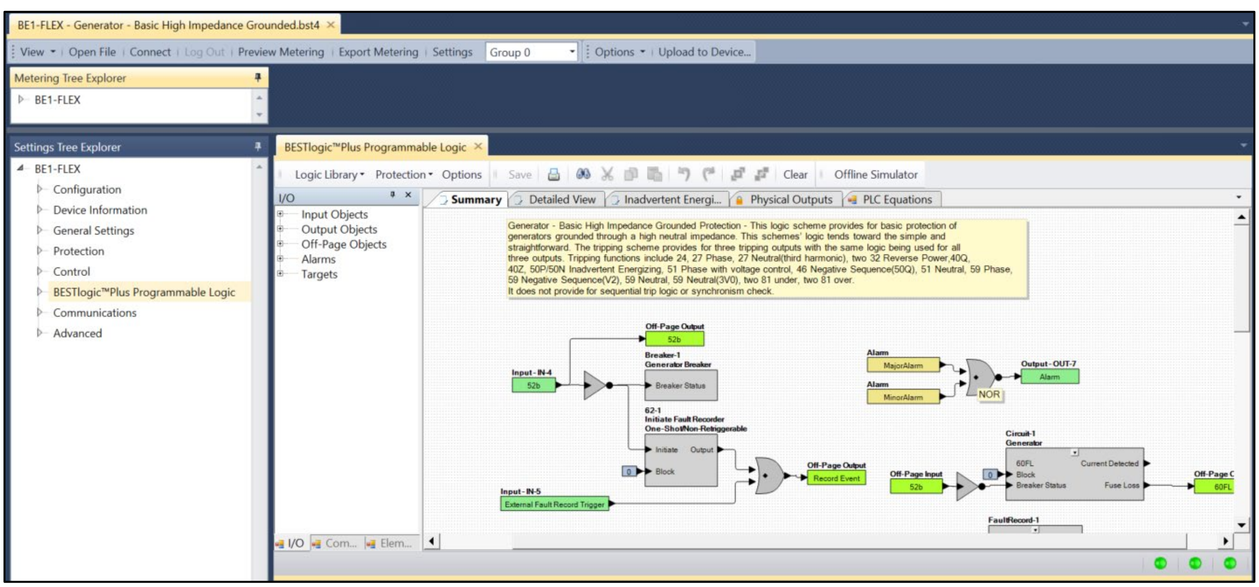


Figure 6-11. BESTlogic*Plus* Programmable Logic Screen

Save and Upload

Application Template logic is now complete. No changes are necessary to use it if the device has not been reconfigured. Reviewing it is recommended as it provides useful detail on the operation and purpose of the logic.

To use the logic scheme, click the Save button shown in Figure 6-12 so that it is saved to the settings file. Before saving, a healthy logic scheme will have three indicators at the bottom right-hand corner of the window. A yellow and two greens indicate that there are no errors in the scheme and it can be saved. Saving the logic will result in three green indicators.

To save the edited template, save the entire settings file by clicking on the File pull-down menu at the top left-hand corner of the BESTCOMS*Plus* and select Save or Save As. See Figure 6-12.

Connect to a device from the Icon bar and Upload settings from the Communication pull-down menu if desired. See Figure 6-13.

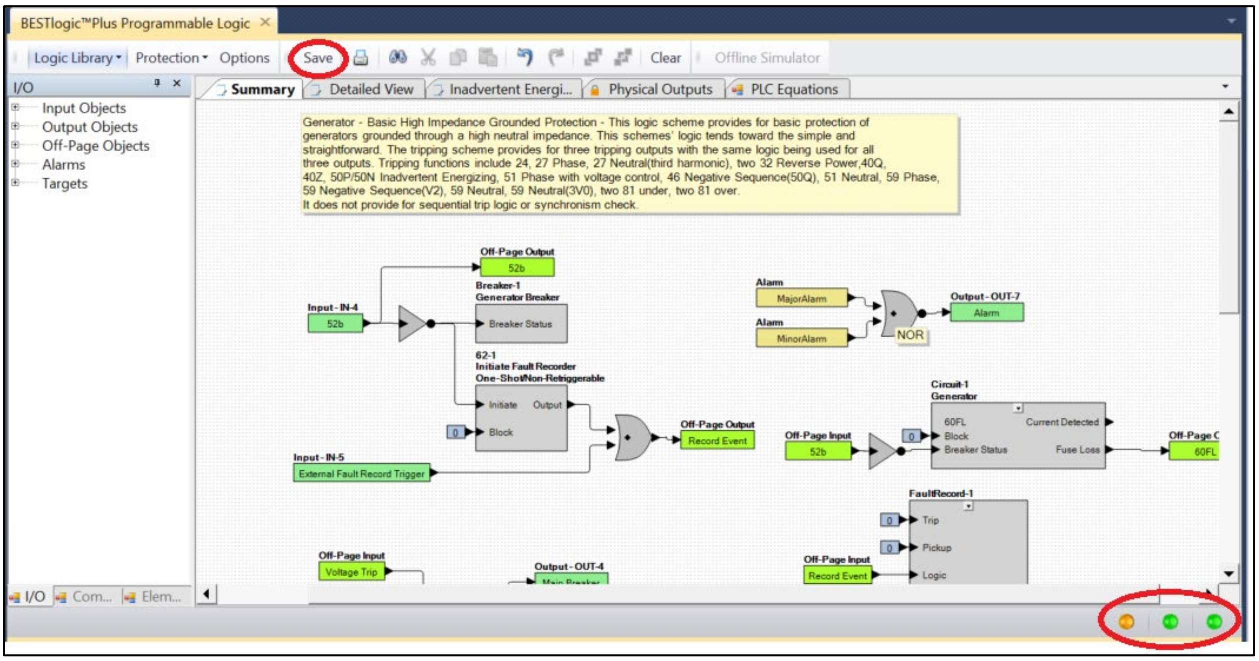


Figure 6-12. Saving a Settings File with a Functional Logic Scheme

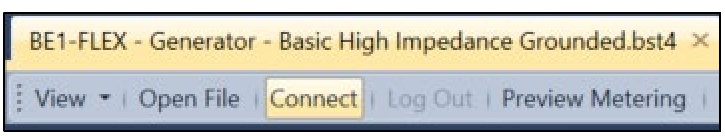


Figure 6-13. Connect Button on Icon Bar

For More Information

To get more information on BESTCOMS*Plus* and the BE1- FLEX product line, including additional application notes and the product bulletin, visit www.basler.com or contact Technical Support at 618-654-2341.

7 • Human Machine Interface (HMI)

BE1-FLEX controls and indicators are located on the front panel and include LED (light emitting diode) indicator lamps and a touchscreen display.

The BE1-FLEX Interface is intentionally the same for both the traditional front panel HMI as well as remotely via web browser (BESTnet™*Plus*) pages to create a consistent and intuitive user experience. Webpages are hosted internally by the BE1-FLEX and accessed from a web browser at the device IP address in the Device Information settings. Both BESTnet*Plus* and local Touchscreen user access is controlled by Security settings. BESTnet*Plus* can additionally be fully disabled if desired. See the *Security* chapter for access control information.

Illustration and Descriptions

The HMI (Human-Machine Interface) of a BE1-FLEX is illustrated in Figure 7-1 and described in Table 7-1. The locators and descriptions of Table 7-1 correspond to the locators shown in Figure 7-1.

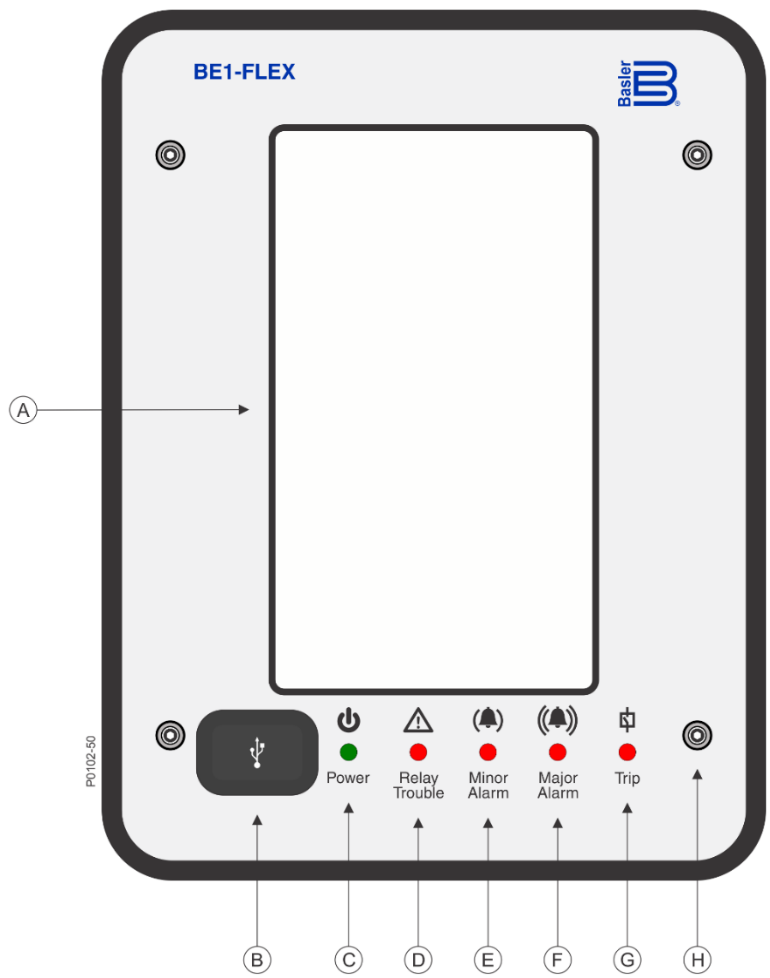


Figure 7-1. Front Panel

Table 7-1. Front Panel Descriptions

Locator	Description
A	Touchscreen Display – The touchscreen displays system parameters and BE1-FLEX settings and status. The screen's touch control enables changes to BE1-FLEX settings, resetting of targets, and direct access to controls and switches (with the appropriate password access).
B	USB Communication Port – The USB-C connector is intended for local communication between the BE1-FLEX and a PC operating BESTCOMS*Plus*® software. This communication port complies with the USB 2.0 specification and enables commissioning, interrogation, and downloading of BE1-FLEX settings and configuration files. Included USB plug required to maintain IP54 environmental rating.
C	Power Indicator – This green indicator lights when operating power is applied to the BE1-FLEX.
D	Relay Trouble Indicator – This red indicator lights when the BE1-FLEX self-diagnostics detect an internal fault that compromises the relay's core functions. A relay trouble condition will return all outputs to their normal condition state.
E, F	Alarm Indicators – The red Minor Alarm and Major Alarm indicators can be independently programmed to annunciate one or more alarm conditions or user-defined logic states. Alarm conditions can also be configured to operate any of the BE1-FLEX contact outputs. Refer to the *Alarms* chapter for alarm indicator programming details.
G	Trip Indicator – This red indicator flashes when the fault recorder pickup bit is true (includes fault recorder setting per element and within logic) and lights continuously when any target is active. The Trip indicator latches (seals in) until targets are reset.
H	Front Panel Mounting Screws – Four screws are used to remove and then secure the front panel to upgrade or replace the HMI assembly. The front panel is removed and installed using a 7/64-inch hex driver. Maximum screw torque is 10 in-lb. (1.12 N•m).

Touchscreen Operations

The large BE1-FLEX Home screen (Figure 7-2) is customizable to provide most information without menu navigation. One lines, control buttons, indicators, and three quick-access tabs can be set up as desired from a *.hmic settings file.

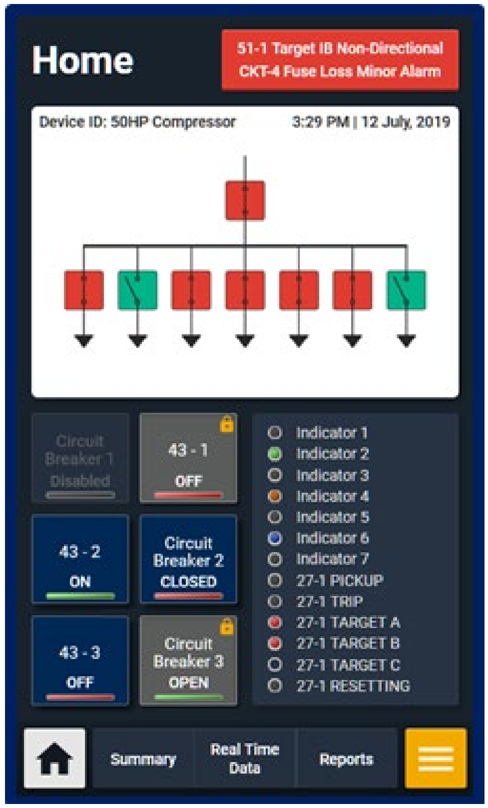


Figure 7-2. Home Screen

In addition to Alarm and Trip LED's, the BE1-FLEX will display active targets and alarms in the upper right corner of the touchscreen. Touching the targets and alarm banner will pull up the Targets & Alarms summary screen shown in Figure 7-3. This screen is designed to provide access to all necessary fault and alarm memory information from a single location. BESTnet*Plus* also includes a Download Files button to export desired files to a PC, Mac®, or supported mobile device.

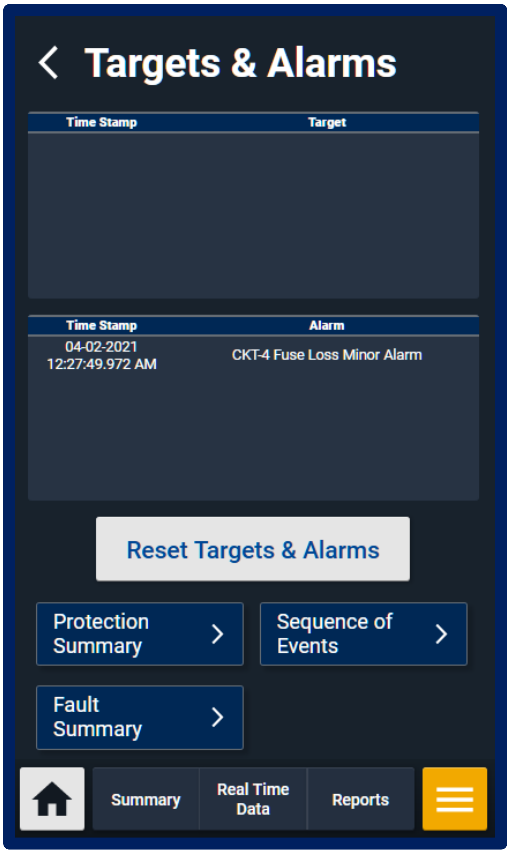


Figure 7-3. Targets & Alarms Summary Screen

A menu tree with Metering, Reports, Protection, Control, Settings, and Device Information branches can be accessed through the front-panel touchscreen and web interface. A greater level of detail in a menu branch is accessed using the touchscreen.

The following paragraphs describe how the touchscreen is used to set and control BE1-FLEX functions.

User Login

If password security has been initiated for a function, the front-panel display will prompt you to enter a username and password before viewing data or performing the requested operation. To gain access, you must enter the appropriate username and password.

If the user logged in does not have sufficient access, the User Login prompt will again appear when the access or operation is requested. If an incorrect username or password has been entered, the User Login screen will remain and an entry will be logged into the Security log.

Once you gain access, it remains in effect until the access timeout length setting expires.

The logged in user is displayed at the top of the menu when expanded. Users can manually log out or switch users by selecting Menu > User Account from the bottom of the screen.

One-Line Diagram

The HMI Home screen is customizable via *.hmic file import. All one-line components, including breakers and power lines, can be active to change color, shape, size, and a wide variety of other modes based upon nearly any digital point state. The BE1-FLEX ships with a blank space one-line displaying only the Device Name and Device Time and Date. BESTCOMS*Plus* comes with a variety of common application one-lines for easy configuration. Common *.hmic files are automatically installed with BESTCOMS*Plus* and can be selected from the BE1-FLEX HMI settings page. The default installation location is C:\Program Files\Basler Electric\BESTCOMSPlus\HMICLibrary\BE1-FLEX\en.

Note

The one-line may not display if a function called out in the HMIC file is not in the settings file. For example, if the one-line includes breaker status, the associated Breaker instance needs to be enabled in the settings file for the one-line to display. This is to prevent the one-line from showing an unknown status.

Control Buttons

A user-configurable number of Breaker Control (101) and Virtual Switches (43) can be shown and controlled from the HMI via general settings. Unless customized otherwise, up to six switches are shown on the home screen. All enabled 101s and 43s can be controlled and viewed from the Menu > Control screen.

Control buttons for the virtual switches (43's) display user configured state descriptions and user configured On and Off colors (Grey, Red, Blue, Green, Yellow, or Orange).

For security purposes, a single-click location will never operate a control button. Select-and-operate are always in a different location on the screen. Requiring user login provides additional protection against inadvertent operation.

Indicators

Indicators, otherwise known as annunciators, are fully customizable to any logic condition in the BE1-FLEX. Virtually any number of indicators can be configured with customizable descriptions and On and Off colors (Grey, Red, Blue, Green, Yellow, or Orange).

A user-configurable number of Indicators can be shown from the Home screen as configured in the *.hmic settings. Unless customized otherwise, up to eight indicators are shown on the home screen. All enabled indicators can be viewed from the Menu > Metering > Status > Indicator screen.

Indicators are controlled based upon BESTlogic™*Plus* and configured under the BESTlogic*Plus* folder. See Figure 7-4.

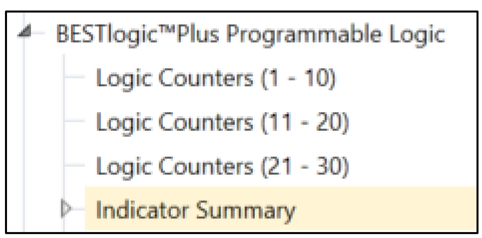


Figure 7-4. BESTlogic*Plus* Folder Layout

Quick Tab Setup

Three user-customizable quick tabs, similar to hyperlinks, allow access to other common screens in the HMI navigation directly from the Home screen as configured in the *.hmic settings. Default tabs link to the Protection Summary, Real Time Metering (phasor and numerical view) and Reports screens. Quick tabs minimize menu navigation operator knowledge.

HMI Settings

Navigation Path: General Settings, HMI Settings

Front-panel display settings are described in the following paragraphs. The BESTCOMS*Plus* Front Panel HMI settings screen is illustrated in Figure 7-5.

Backlight

The backlighting of the front-panel LCD (liquid crystal display) can be adjusted to suit the desired brightness for the environmental conditions.

Sleep Time

A power saving feature, referred to as Sleep mode, turn off the front-panel LCD backlight when the front-panel is not touched for more than the user-settable time delay. Normal display operation is resumed when any location on front-panel is pressed. Forced multi-location touch requirements prevent inadvertent control operation caused by a wake up touch. Adding security requirements further prevent accidental operation.

Language

The language can be set for English or Spanish. Language changes will affect the front-panel LCD, sequence of events, fault reports, oscillography reports, load profile, and web pages.

HMI Customization

The HMI can be customized by importing a Scalable Vector Graphic (*.svg) file which has been adapted into a BE1-FLEX HMI (*.hmic) file. SVG drawings can be created with a wide variety of commercially-available graphic design software programs. The file can also be exported and imported into another BE1-FLEX unit.

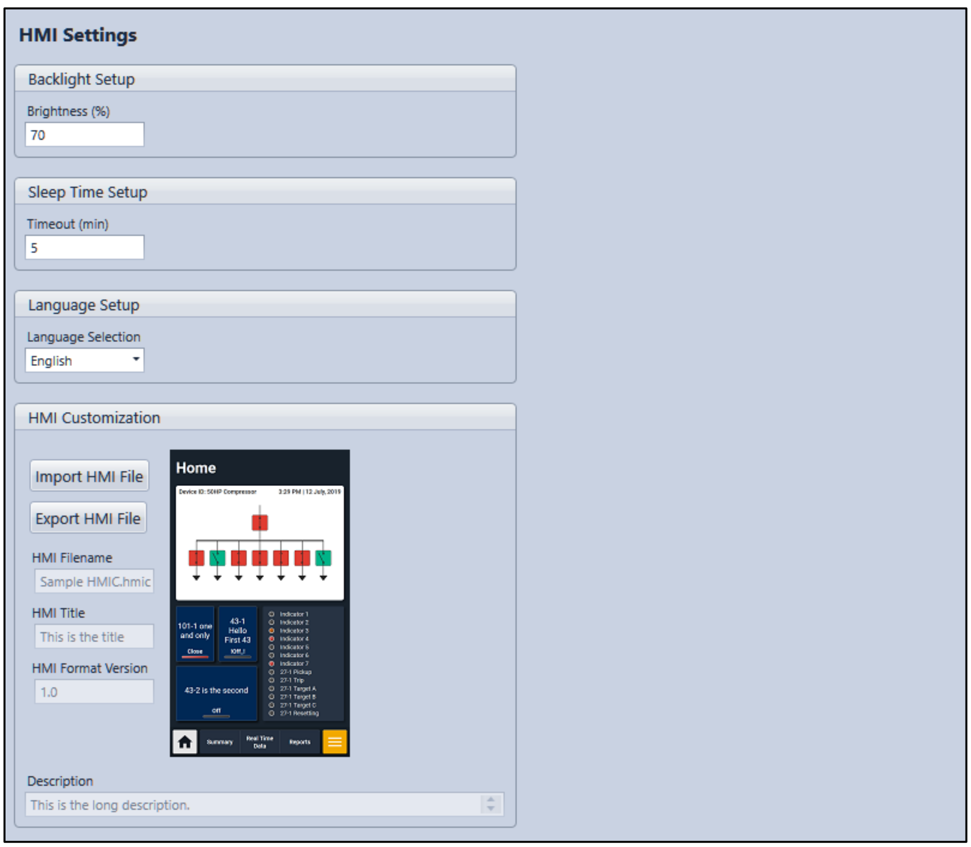


Figure 7-5. HMI Settings Screen

Advanced HMIC (Human-Machine Interface Configuration) Editor

The BE1-FLEX home screen can be customized using the HMIC Editor under the Advanced settings tree branch in BESTCOMS*Plus*. The one-line space in the top half of the home screen is customized by importing an SVG or HMIC file. The HMIC Editor then maps digital points in the BE1-FLEX to IDs within the SVG file to make components of the drawing hidden or visible based upon digital point status.

There are multiple methods available to create IDs within an SVG file. One common method is to use drawing layers to create IDs. The SVG image must be 560 pixels wide by 382 pixels high. Exporting a BESTCOMS*Plus* HMIC template from the BESTCOMS*Plus* installation folder (C:\Program Files\Basler Electric\BESTCOMSPlus\HMICLibrary\BE1-FLEX) to SVG format is typically recommended in order to create the correct drawing size and visualize how the drawings can be created.

All other home screen functionality, including Indicators, Control, Quick-Links, and Overlay can be configured within the HMIC Editor. A preview is available to visualize the customized HMIC settings. Advanced HMIC settings are shown in Figure 7-6 and described below. Contact your application engineer for additional custom HMI creation support as needed.

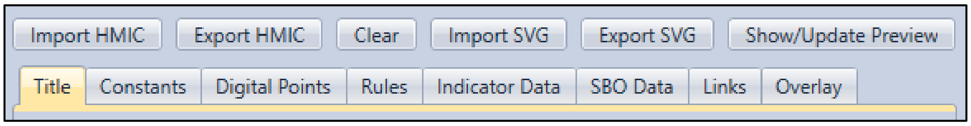


Figure 7-6. HMIC Editor Settings Screen

Import/Export HMIC Buttons

These buttons are used to import and export HMIC files. An HMIC file is a subset of the full BE1-FLEX settings file that defines the home screen. The SVG file is included in the HMIC file.

Clear Button

This button clears all HMIC data and loads the default file to the overall settings file.

Import/Export SVG Buttons

These buttons are used to import and export SVG files. The BE1-FLEX one-line space drawing originates as an SVG file. One-line animation is performed based upon the IDs available in the SVG file and ultimately the HMIC file.

Show/Update Preview Button

This button is used to preview the HMIC file. Click the Update Thumbnail button to refresh the preview after making any changes on the HMIC Editor screens. Update Thumbnail also refreshes the image on the Title tab. The Preview window is shown in Figure 7-7.

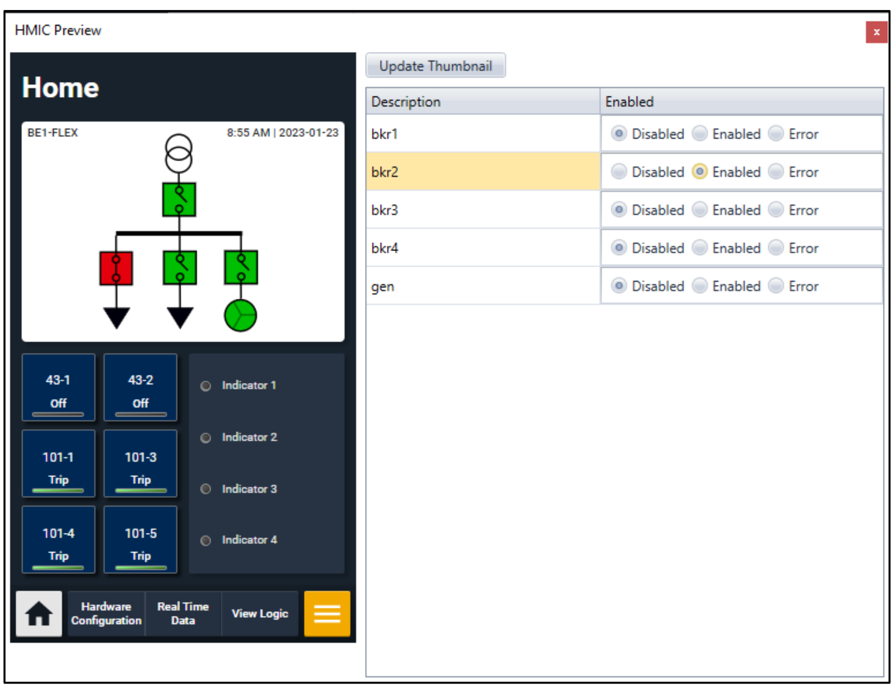


Figure 7-7. Preview Window

Title Tab

The HMIC file title and description are entered on this screen. The Title tab is show in Figure 7-8.

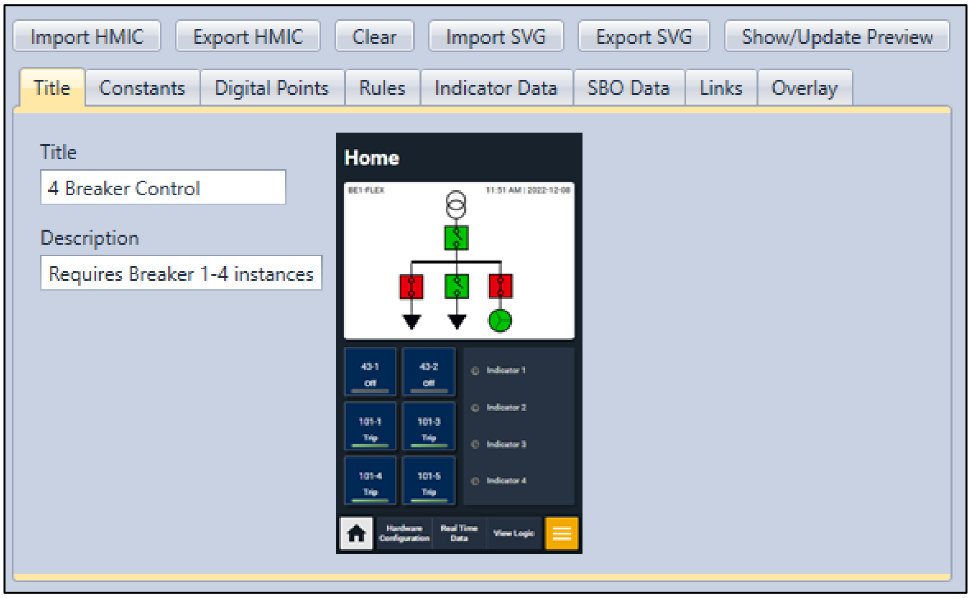


Figure 7-8. HMIC Editor, Title Tab

Constants Tab

Constants can be used to color IDs based upon digital point status. Colors are defined on this screen. Alternatively, component colors can be assigned within the SVG file itself without utilizing the constants. Click the Add Constant button to add constants. Constant names must be entered in alphanumeric format and begin with a lowercase letter. The Constants tab is shown in Figure 7-9.

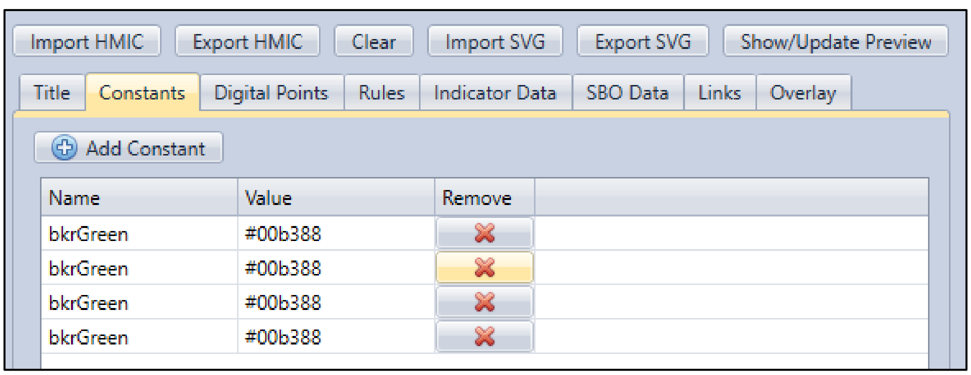


Figure 7-9. HMIC Editor, Constants Tab

Digital Points Tab

Digital points in the BE1-FLEX that control HMI one-line changes are defined on this screen. Click the Add Digital Points button to add digital points. The Name will be utilized later within the rules and the Description is only informational. Digital Point names must be entered in alphanumeric format and begin with a lowercase letter. The Digital Points tab is shown in Figure 7-10.

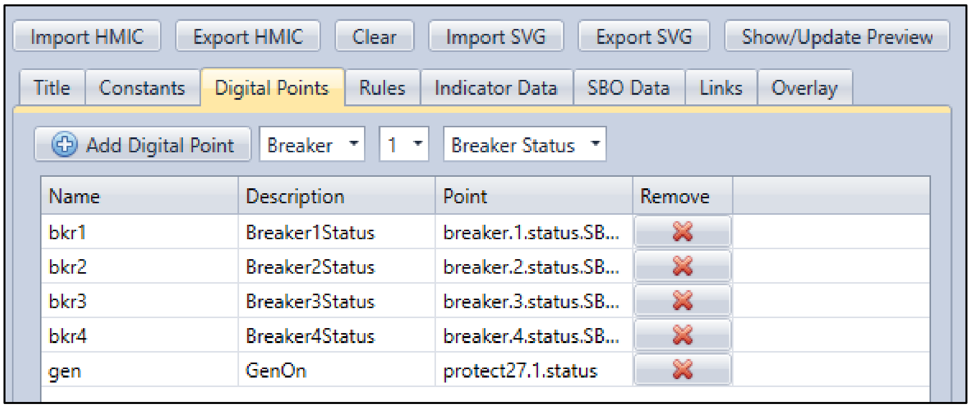


Figure 7-10. HMIC Editor, Digital Points Tab

Rules Tab

A rule defines what happens when a digital point is true, false, and does not exist. Click the Add Rule button to display the Rules tab (Figure 7-11) and add rules.

The Match ID defines what ID component of the SVG file is controlled. Value is commonly 'fill' or 'visibility'. Fill will color the ID to the constant-defined color. Visibility can be set to visible or hidden pending the desired status.

For coloring via constant, after an ID color is defined on the Constants tab, enter "fill:@ConstantName" in the Value field on the Rules tab to change that ID component to the defined color.

Click a visibility value to change whether an ID is shown or hidden based on status.

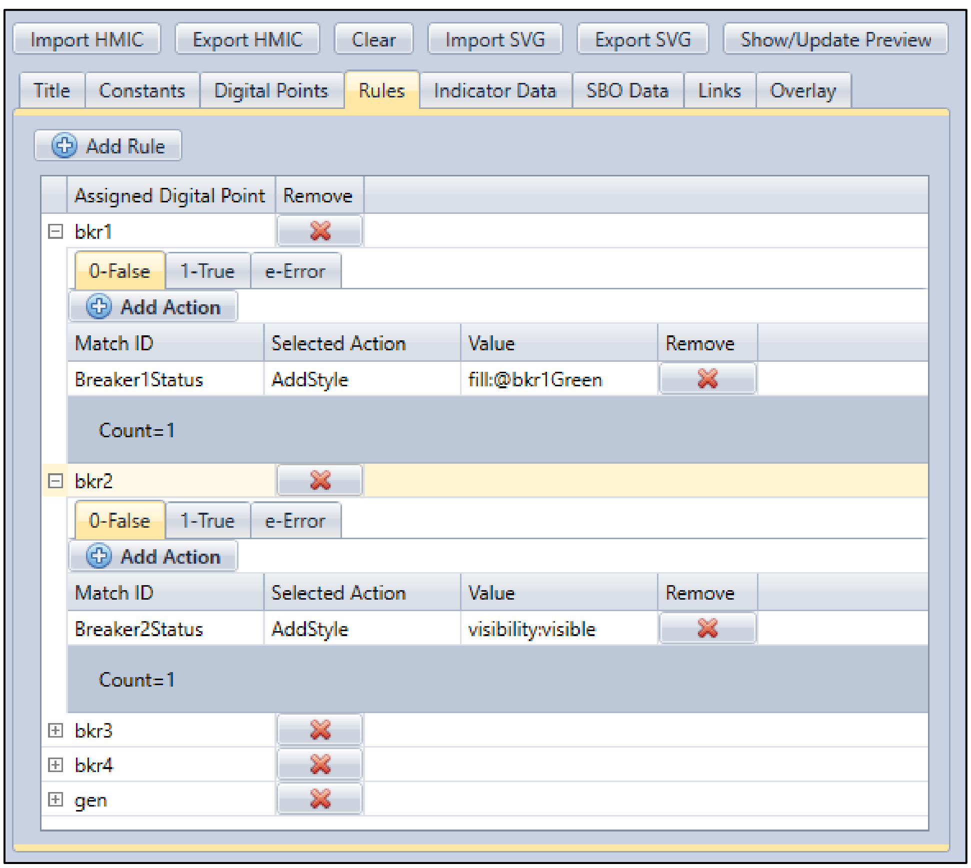


Figure 7-11. HMIC Editor, Rules Tab

Indicator Data Tab

This screen defines how many and which indicators appear in the lower right quadrant of the HMI. Indicators can be driven in logic or points can be polled directly in the HMIC file. Up to 15 indicators can be shown, but overflow can exist if indicator names are lengthy. An eight-indicator maximum allows for several lines of point description on the home screen. Click the Add Indicator button to add indicators. The Indicator Data tab is shown in Figure 7-12.

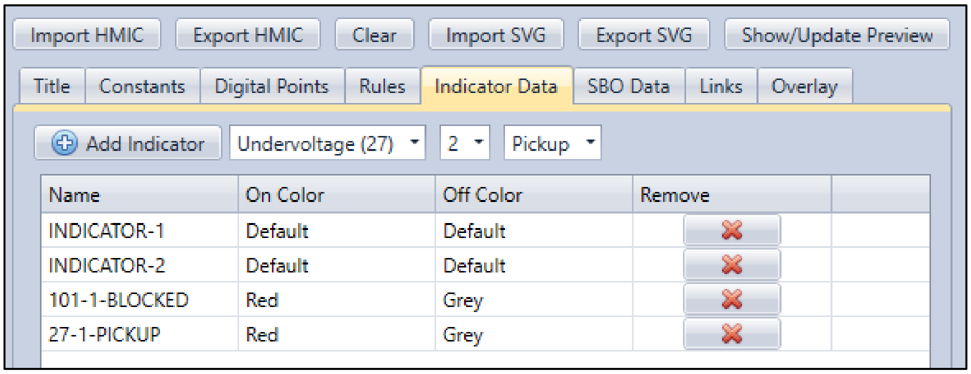


Figure 7-12. HMIC Editor, Indicator Data Tab

SBO Tab

The SBO (Select-Before-Operate) screen defines how many and which 43 and 101 switches are shown on the HMI. Up to six instances can be shown. Click the Add SBO button to add instances. The SBO Data tab is shown in Figure 7-13.

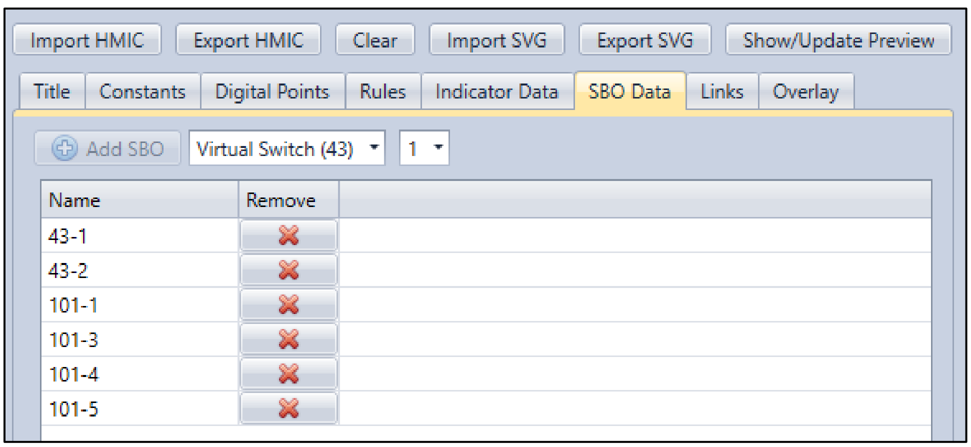


Figure 7-13. HMIC Editor, SBO Data Tab

Links Tab

The bottom middle three buttons on the HMI can be hyperlinked to any menu pages. Use the drop-down menu to select which menu pages to link and click the Add Link button. The Links tab is shown in Figure 7-14.

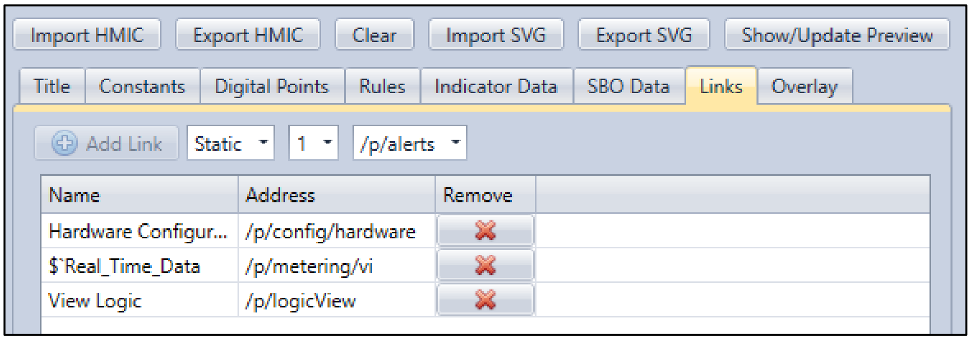


Figure 7-14. HMIC Editor, Links Tab

Overlay Tab

Common system level information can be added to the corners around the one-line drawing. The Style field accepts CSS (Cascading Style Sheets) to format and lay out the HMI. For example, to position the overlay item 10 pixels from the top and 10 pixels from the left, enter 'position:absolute;top:10px;left:10px' in the Style field.

When Text is selected as the overlay option, enter the text to display in the Text field. When InfoAppData is selected as the overlay option, click in the Device Info Value column and select the information to display. Click and drag a line to reorder.

Click the Add Overlay button to add overlays. The Overlay tab is shown in Figure 7-15.

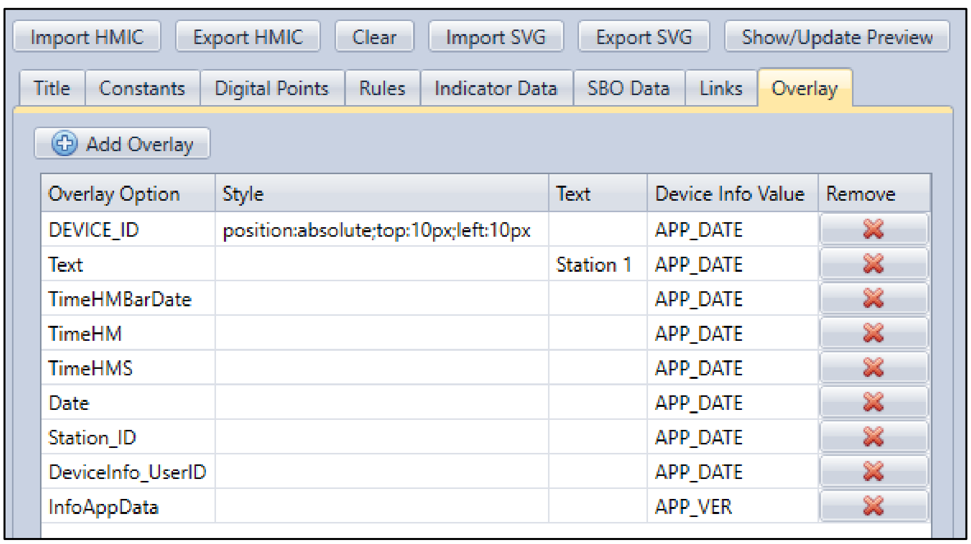


Figure 7-15. HMIC Editor, Overlay Tab

8 • BESTCOMS*Plus*® Software

BESTCOMS*Plus* is a Windows®-based, PC application that provides a user-friendly, graphical user interface (GUI) for use with Basler Electric communicating products. The name BESTCOMS*Plus* is an acronym that stands for Basler Electric Software Tool for Communications, Operations, Maintenance, and Settings.

BESTCOMS*Plus* provides the user with a point-and-click means to set and monitor the BE1-FLEX. The capabilities of BESTCOMS*Plus* make the configuration of one or several BE1-FLEX Protection, Automation, and Control Systems fast and efficient. A primary advantage of BESTCOMS*Plus* is that a settings scheme can be created, saved as a file, and then uploaded to the BE1-FLEX at the user's convenience.

BESTCOMS*Plus* uses plugins allowing the user to manage several different Basler Electric products. The BE1-FLEX plugin opens inside the BESTCOMS*Plus* main shell.

BESTlogic™*Plus* Programmable Logic is used to program BE1-FLEX logic for protection elements, inputs, outputs, alarms, etc. This is accomplished by the drag-and-drop method. The user can drag elements, components, inputs, and outputs onto the program grid and make connections between them to create the desired logic scheme.

BESTCOMS*Plus* also allows for downloading industry-standard COMTRADE files for analysis of stored oscillography data. Detailed analysis of the oscillography files can be accomplished using BESTdata software. BESTdata software is free and available at www.basler.com.

Figure 8-1 illustrates the typical user interface components of the BE1-FLEX plugin with BESTCOMS*Plus*.

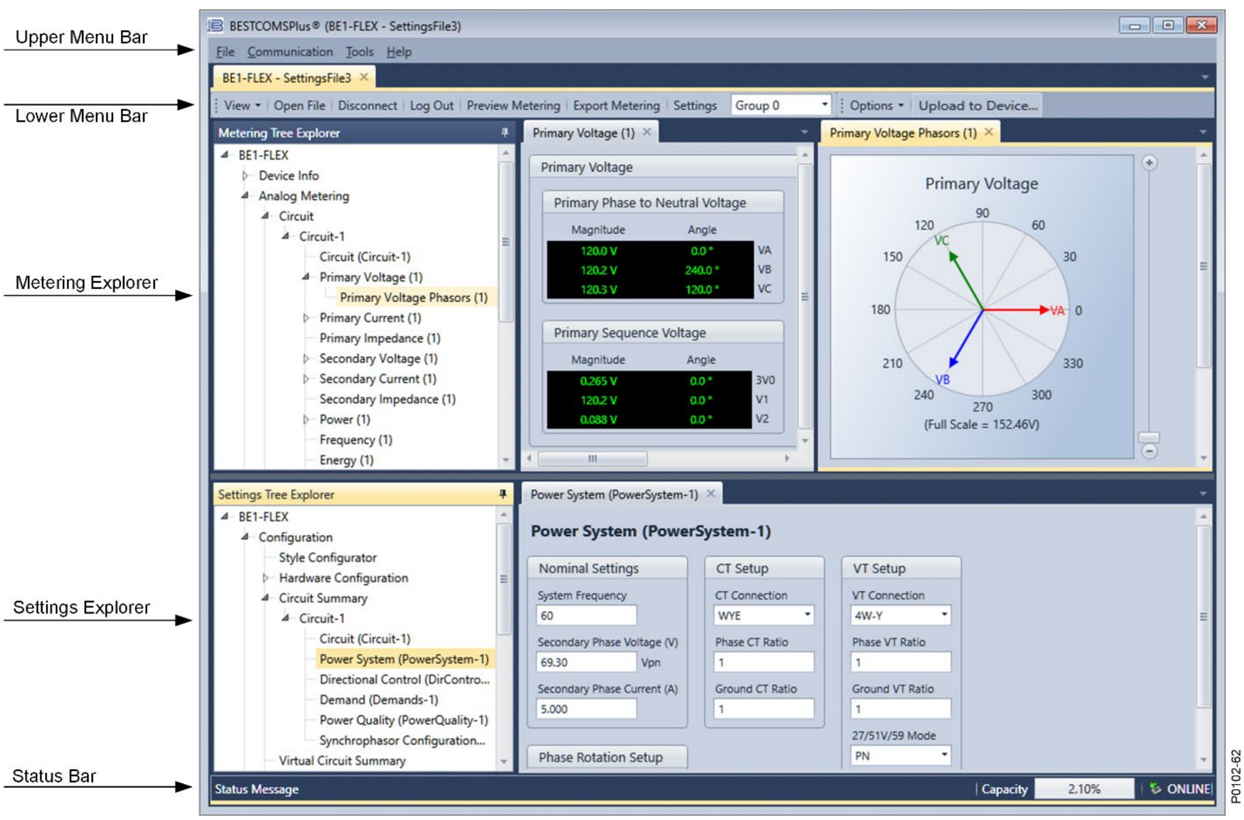


Figure 8-1. Typical User Interface Components

Installation

BESTCOMS*Plus* software is built on the Microsoft® .NET Framework. The setup utility that installs BESTCOMS*Plus* on your PC also installs the BE1-FLEX plugin and the required version of .NET Framework (if not already installed). BESTCOMS*Plus* operates with systems using Windows® 7 SP1, Windows 8.1, Windows 10 version 1607 (Anniversary Edition) or later, and Windows 11. System recommendations for the .NET Framework and BESTCOMS*Plus* are listed in Table 8-1.

Table 8-1. System Recommendations for BESTCOMS*Plus* and the .NET Framework

System Type	Component	Recommendation
32/64 bit	Processor	2.0 GHz
32/64 bit	RAM	1 GB (minimum), 2 GB (recommended)
32 bit	Hard Drive	200 MB (if .NET Framework is already installed on PC)
		4.5 GB (if .NET Framework is not already installed on PC)
64 bit	Hard Drive	200 MB (if .NET Framework is already installed on PC)
		4.5 GB (if .NET Framework is not already installed on PC)

To install BESTCOMS*Plus*, a Windows user must have Administrator rights.

Install BESTCOMS*Plus*®

Note

Do not connect a USB cable until setup completes successfully. Connecting a USB cable before setup is complete may result in unwanted or unexpected errors.

1. Download BESTCOMS*Plus* from www.basler.com.
2. Click the installation button for BESTCOMS*Plus*. The setup utility installs BESTCOMS*Plus*, the .NET Framework (if not already installed), the USB driver, and the BE1-FLEX plugin for BESTCOMS*Plus* on your PC.

When BESTCOMS*Plus* installation is complete, a Basler Electric folder is added to the Windows programs menu. This folder is accessed by clicking the Windows Start button and then accessing the Basler Electric folder in the Programs menu. The Basler Electric folder contains an icon that starts BESTCOMS*Plus* when clicked.

Connect the BE1-FLEX and Start BESTCOMSPlus®

The BE1-FLEX plugin is a module that runs inside the BESTCOMS*Plus* shell. The BE1-FLEX plugin contains specific operational and logic settings for only the BE1-FLEX.

Connect a USB Cable

The USB driver was copied to your PC during BESTCOMS*Plus* installation and is installed automatically after powering the BE1-FLEX. USB driver installation progress is shown in the Windows taskbar area. Windows will notify you when installation is complete.

Connect a USB cable between the PC and your BE1-FLEX. Apply operating power (per style chart in the *Introduction* chapter) to the BE1-FLEX. Refer to the *Hardware Configuration* chapter for power supply terminals. Wait until the boot sequence is complete.

Note
In some instances, the Found New Hardware Wizard will prompt you for the USB driver. If this happens, direct the wizard to the following folder: C:\Program Files\Basler Electric\USB Connect Driver\

If the USB driver does not install properly, refer to the *Troubleshooting* chapter.

Start BESTCOMS*Plus*®

To start BESTCOMS*Plus*, click the Start button, point to Programs, Basler Electric, and then click the BESTCOMS*Plus* icon. During initial startup, the BESTCOMS*Plus* Select Language screen is displayed (Figure 8-2). You can choose to have this screen displayed each time BESTCOMS*Plus* is started, or you can select a preferred language and this screen will be bypassed in the future. Click OK to continue. This screen can be accessed later by selecting Tools and Select Language from the menu bar.

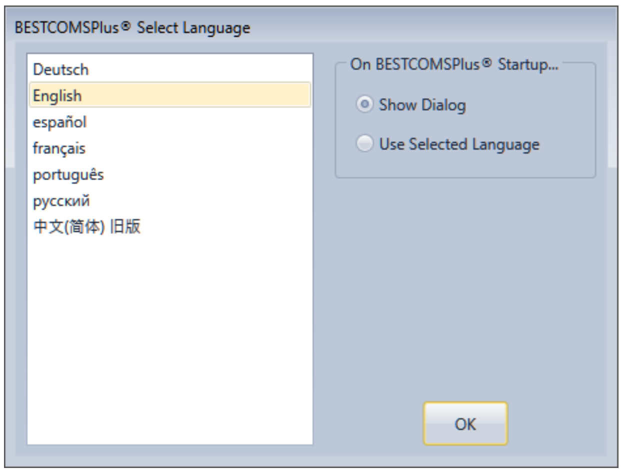


Figure 8-2. BESTCOMS*Plus* Select Language Screen

The BESTCOMS*Plus* platform window opens. Select New Connection from the Communication pull-down menu and select BE1-FLEX. See Figure 8-3.

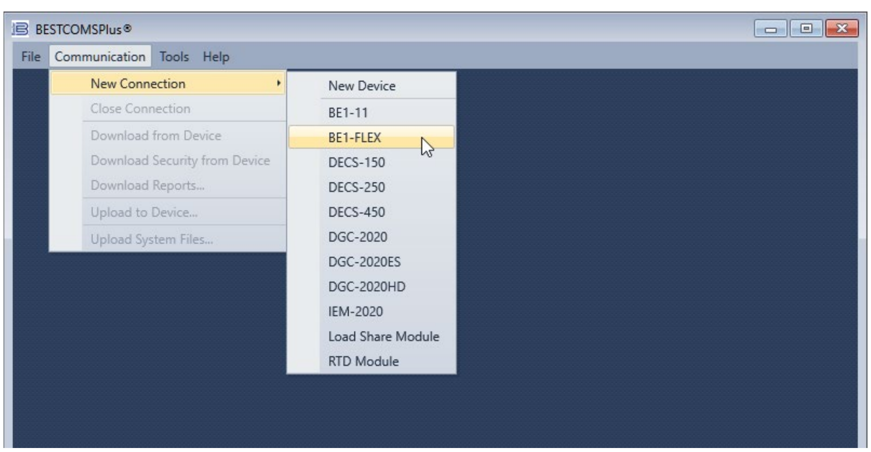


Figure 8-3. Communication Pull-Down Menu

The BE1-FLEX Connection screen shown in Figure 8-4 appears. Select USB Connection and then click the Connect button.

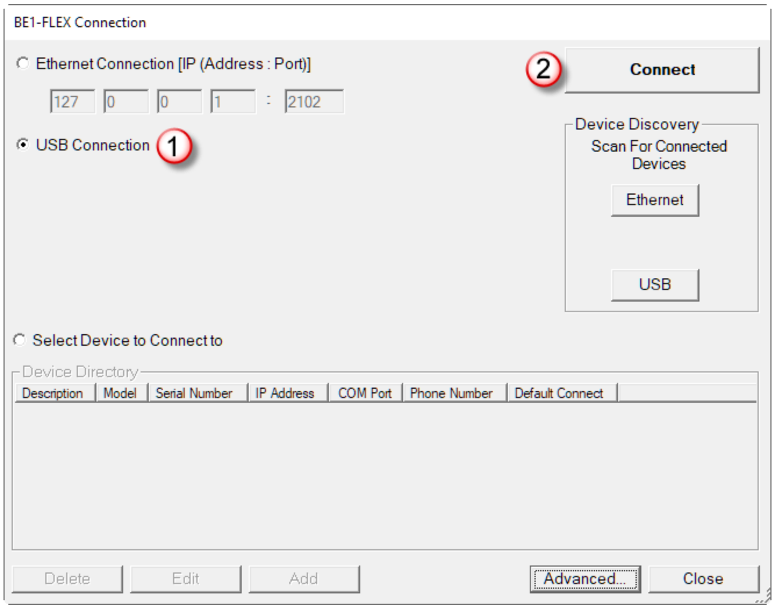


Figure 8-4. BE1-FLEX Connection Screen

Establishing Communication

Communication between BESTCOMS*Plus* and the BE1-FLEX is established by clicking on the Connect button on the BE1-FLEX Connection screen (see Figure 8-4) or by clicking on the Connect button on the lower menu bar of the main BESTCOMS*Plus* screen (Figure 8-1). If you receive an "Unable to Connect to Device" error message, verify that communications are configured properly. Only one Ethernet connection is allowed at one time. Download all settings and logic from the BE1-FLEX by selecting Download from Device from the Communication pull-down menu. BESTCOMS*Plus* will read all settings and logic from the BE1-FLEX and load them into BESTCOMS*Plus* memory. A confirmation (Figure 8-5) will appear when complete.

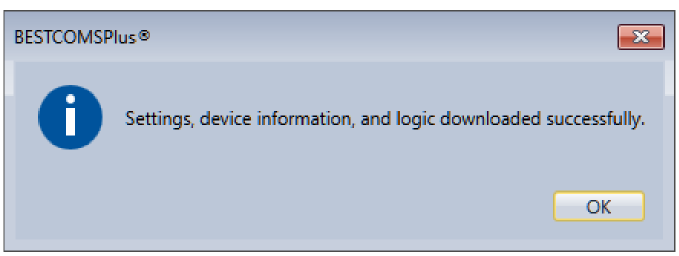


Figure 8-5. Downloaded Successfully

Advanced Properties

Click the Advanced button on the Connection screen to display the Advanced Properties dialog. Default settings are shown in Figure 8-6.

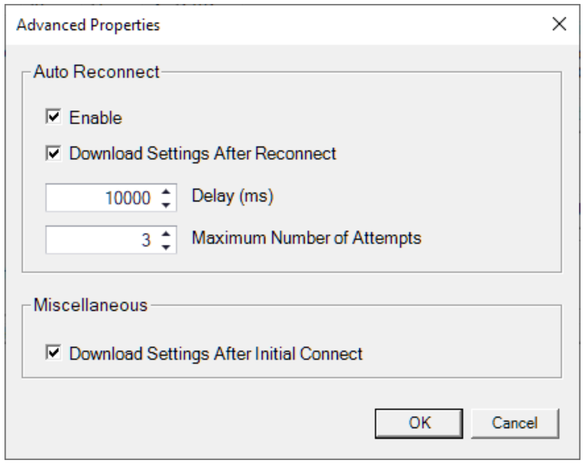


Figure 8-6. Advanced Properties Dialog

Menu Bars

The menu bars are located near the top of the BESTCOMS*Plus* screen (see Figure 8-1). The upper menu bar has four pull-down menus. With the upper menu bar, it is possible to manage settings files, configure communication settings, upload and download settings/security files, and compare settings files. The lower menu bar consists of clickable icons. The lower menu bar is used to change BESTCOMS*Plus* views, open a settings file, connect/disconnect, preview metering printout, export metering, switch to live mode, and upload settings after a change is made when not in live mode.

Upper Menu Bar (BESTCOMS*Plus*® Shell)

Upper menu bar functions are listed and described in Table 8-2.

Table 8-2. Upper Menu Bar (BESTCOMS*Plus* Shell)

Menu Item	Description
File	
New	Opens a new tab to create a new settings file
Open	Open an existing settings file
Close	Close settings file
Save	Save settings file
Save As	Save settings file with a different name
Export To File	Save settings as a *.csv file
Print	Print, export, or send a settings file
Properties	View properties of a settings file
History	View history of a settings file
Recent Files	Open a previously opened file
Exit	Close BESTCOMS*Plus* program
Communication	
New Connection	Choose new device or BE1-FLEX
Close Connection	Close communication between BESTCOMS*Plus* and BE1-FLEX
Download from Device	Choose to download settings, device information, and logic from the device

Menu Item	Description
Download Security from Device	Download security settings from the device
Download Reports	Choose to download settings, logic, device info, diagnostic log, sequence of events, fault records, security log, load profile, or real-time metering
Upload to Device	Choose to upload settings, logic, device information, or security to device
Upload System Files	Upload firmware or a style upgrade file to the device
Tools	
Select Language	Select BESTCOMS*Plus* language
Set File Password	Password protect a settings file
Compare Settings Files	Compare two settings files, device and logic files
Copy Settings Group	Copy Settings from Group to Group
Event Log - View	View the BESTCOMS*Plus* event log
Event Log - Verbose Logging	Enable/disable verbose logging
Event Log - Verbose Communications Logging	Enable/disable verbose communications logging
Change Password	Change the BE1-FLEX password
Restore Default Security	Restore device security to factory defaults
Device Security Setup	Set up device users, port access, and access control
Set Default Shell	Select the default product shell view for BESTCOMS*Plus*. Options include Classic view, Updated view, or Combined view.
Help	
Check for Updates	Check for BESTCOMS*Plus* updates via the internet
Check for Update Settings	Enable or change automatic checking for updates
About	View general, detailed build, and system information

Lower Menu Bar (BE1-FLEX Plugin)

Lower menu bar functions are listed and described in Table 8-3.

Table 8-3. Lower Menu Bar (BE1-FLEX Plugin)

Menu Button	Description
View	Enables you to show/hide the Metering Panel, Settings Panel, or Settings Info Panel. Opens and saves workspaces. Customized workspaces make switching between tasks easier and more efficient.
Open File	Opens a saved settings file.
Connect	Opens the BE1-FLEX Connection screen within the open plugin, which enables you to connect to the BE1-FLEX via USB or Ethernet. This button appears only when a BE1-FLEX is not connected.
Disconnect	Used to disconnect a connected BE1-FLEX. This button appears only when a BE1-FLEX is connected.
Log Out	Logs out of the BE1-FLEX immediately

Menu Button	Description
Preview Metering	Displays the Print Preview screen where a preview of the Metering printout is shown. Click on the printer button to send to a printer.
Export Metering	Exports all metering values into a PDF, RTF, CSV, XLS, or XLSX file.
Settings Group	A pull-down menu allowing group selection is available when making protection settings. The settings can be applied to Group 0, 1, 2, or 3. If a global setting is being changed, Global will appear in place of the drop-down menu.
Options	Displays a drop-down list entitled Live Mode Settings, which enables Live mode where settings are automatically sent to the device in real time as they are changed in BESTCOMS*Plus*. The changed device settings are saved to non-volatile memory by clicking on the Save button.
Upload to Device	Upload settings, logic, device information, and security to device.

Settings Explorer

The Settings Explorer is a convenient tool within BESTCOMS*Plus* used to navigate through the various settings screens of the BE1-FLEX plugin. Descriptions of these configuration settings are organized as follows:

- Configuration
- Device Information
- General Settings
- Protection
- Control
- BESTlogic*Plus* Programmable Logic
- Communications
- Advanced

Logic setup will be necessary after making certain setting changes. For more information, refer to the *BESTlogicPlus* chapter.

Settings Entry

When entering settings in BESTCOMS*Plus*, each setting is validated against prescribed limits. Entered settings that do not conform with the prescribed limits are accepted but flagged as noncompliant. Figure 8-7 illustrates an example of flagged, noncompliant settings (locator A) and the Setting Validation window (locator B) used to diagnose faulty settings.

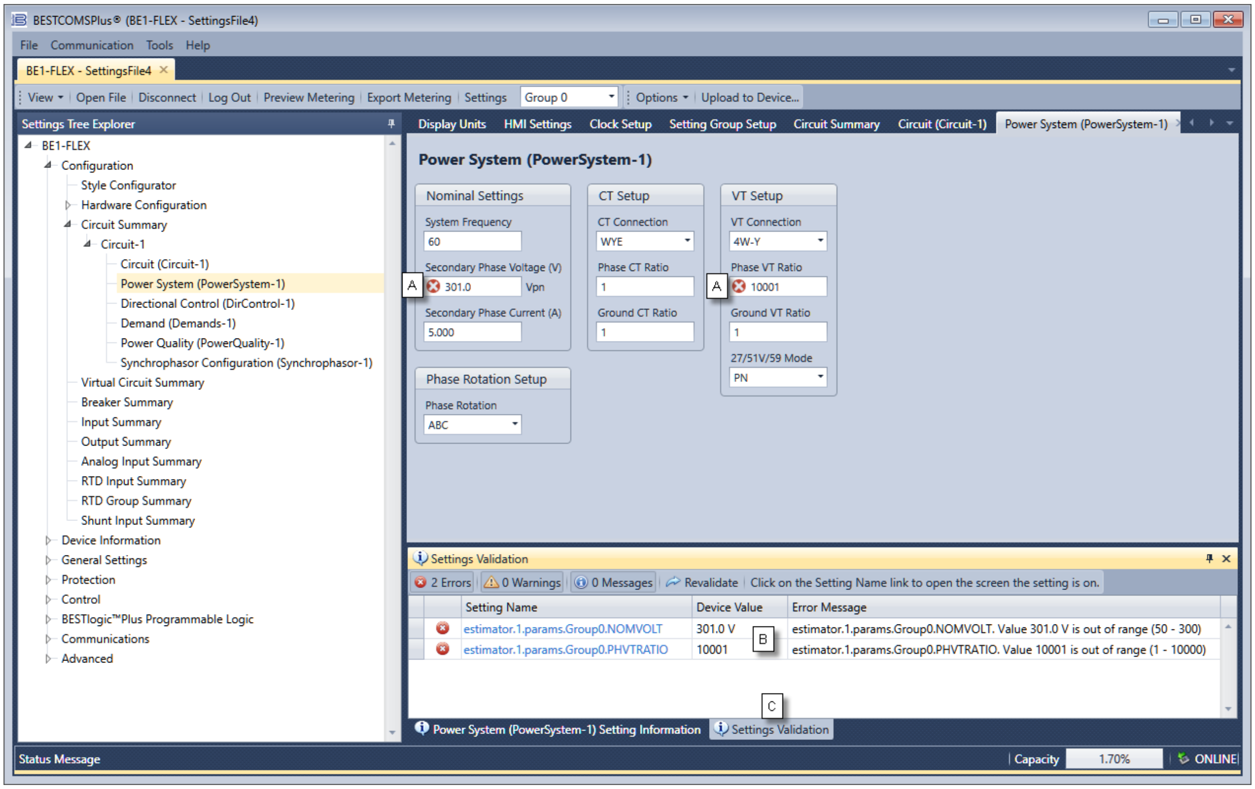


Figure 8-7. Flagged, Noncompliant Settings and the Seting Validation Window

The Setting Validation window, viewed by selecting the Setting Validation tab (locator C), displays three types of annunciations: errors, warnings, and messages. An error describes a problem such as a setting that is out of range. A warning describes a condition where supporting settings are invalid, causing other settings to be noncompliant with the prescribed limits. A message describes a minor setting issue that was automatically resolved by BESTCOMS*Plus*. An example of a condition triggering a message is entry of a settings value with a resolution that exceeds the limit imposed by BESTCOMS*Plus*. In this situation, the value is automatically rounded and a message is triggered. Each annunciation lists a hyperlinked name for the noncompliant setting and an error message describing the issue. Clicking the hyperlinked setting name takes you to the setting screen with the offending setting. Right clicking the hyperlinked setting name will restore the setting to its default value.

Note
It is possible to save a BE1-FLEX settings file in BESTCOMS*Plus* with noncompliant settings. However, it is not possible to upload noncompliant settings to the BE1-FLEX.

Metering Explorer

The Metering Explorer is described in the *Metering* chapter.

Settings File Management

Settings files contain all BE1-FLEX settings including logic. Settings files created in BESTCOMS*Plus* are given an extension of “bst4”.

It is possible to save only the BE1-FLEX logic displayed on the BESTlogic*Plus* Programmable Logic screen as a separate logic library file. This ability is helpful when similar logic is required for several BE1-FLEX systems. The file extension of a logic file created in BESTCOMS*Plus* will be “bsl4”.

It is important to note that settings and logic can be uploaded to the device separately or together, but are always downloaded together. For more information on logic files, refer to the *BESTlogicPlus* chapter.

Opening a Settings File

To open a BE1-FLEX settings file with BESTCOMS*Plus*, pull down the File menu and choose Open. The Open dialog box appears. This dialog box allows you to use normal Windows techniques to select the file that you want to open. Select the file and choose Open. You can also open a file by clicking on the Open File button on the lower menu bar. The settings file will be opened in a new tab.

Saving a Settings File

Select Save or Save As from the File pull-down menu. A dialog box pops up allowing you to enter a filename and location to save the file. Select the Save button to complete the save.

Upload Settings, Logic, Device Information, and/or Security to Device

To upload settings to the BE1-FLEX, open the file or create a new file through BESTCOMS*Plus*, pull down the Communication menu and select Upload to Device, and then select which settings you want to upload. You are prompted to enter the username and password. The default username is “a” and the default password is “a”. If the username and password are correct, the upload begins and the progress bar is shown.

Download Settings and Logic from Device

To download settings and logic from the BE1-FLEX, pull down the Communication menu and select Download from Device. If the settings in BESTCOMS*Plus* have changed, a dialog box will open asking if you want to save the current settings changes. You can choose Yes or No. After you have taken the required action to save or discard the current settings, downloading begins. BESTCOMS*Plus* reads all settings and logic from the BE1-FLEX and loads them into BESTCOMS*Plus* memory.

Printing a Settings File

To view a preview of the settings printout, select Print from the File pull-down menu. Select from Settings, DNP settings, and/or Modbus settings. Select the settings group to print then click Ok. A Print Preview dialog box opens. Change options as necessary and select Print.

Comparing Settings Files

BESTCOMS*Plus* has the ability to compare two settings files. To compare files, pull down the Tools menu and select Compare Settings Files. The BESTCOMS*Plus* Settings Compare Setup dialog box appears (Figure 8-8). Select the location of the first file under Left Settings Source and select the location of the second file under Right Settings Source. If you are comparing a settings file located on your PC hard drive or portable media, click the folder button and navigate to the file. If you want to compare settings from a unit, click the Download settings from unit button to set up the communication port. Click the Compare button to compare the selected settings files.

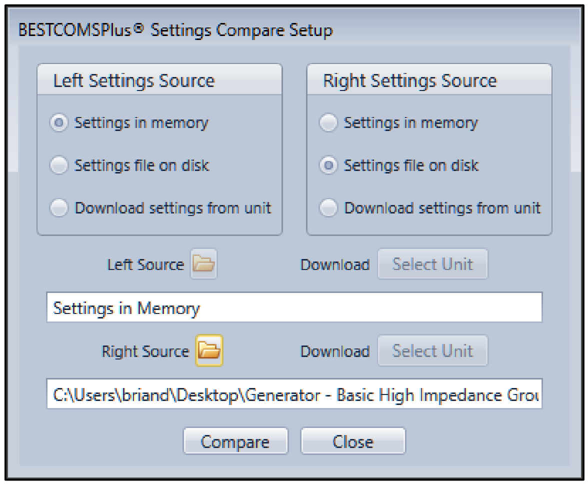


Figure 8-8. BESTCOMS*Plus* Settings Compare Setup

A dialog box will appear and notify you if any differences were found. The BESTCOMS*Plus* Settings Compare dialog box (Figure 8-9) is displayed where you can select different views. If a settings file based on an older version of firmware was uploaded into the BE1-FLEX, the BE1-FLEX could contain additional settings that did not exist when the original settings file was created. The settings compare function detects these differences and displays them when the Include Missing box is checked. Uncheck this box to ignore differences due to the additional settings. Click Print to print a report or click Close to close the window.

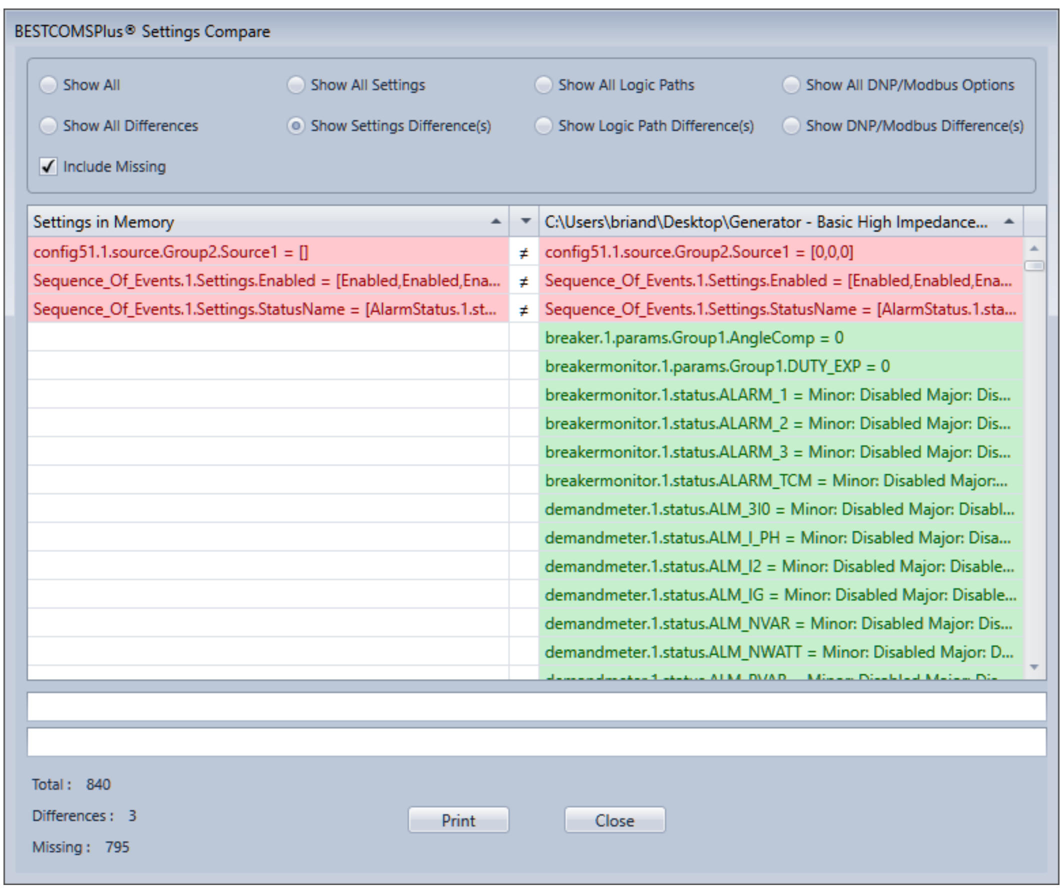


Figure 8-9. BESTCOMS*Plus* Settings Compare

BESTCOMS*Plus*® Updates

Ongoing BE1-FLEX functionality enhancements may make future BE1-FLEX firmware updates desirable. Enhancements to BE1-FLEX firmware typically coincide with enhancements to the BE1-FLEX plugin for BESTCOMS*Plus*. When a BE1-FLEX is updated with the latest version of firmware, the latest version of BESTCOMS*Plus* should also be obtained.

- You can download the latest version of BESTCOMS*Plus* by visiting www.basler.com.
- BESTCOMS*Plus* automatically checks for updates when Check Automatically is selected on the Check for Updates User Settings screen. This screen is accessed under the Help drop-down menu. (An internet connection is required.)
- You can use the manual "check for updates" function in BESTCOMS*Plus* to ensure that the latest version is installed by selecting Check for Updates in the Help drop-down menu. (An internet connection is required.)

Firmware Updates

For information on updating firmware, refer to the *Device Information* chapter.

9 • Security

Multiple levels of BE1-FLEX security give personnel the level of access appropriate for the tasks they routinely perform while securing critical settings from unauthorized access.

Note
The BE1-FLEX does not support factory password reset in the field and will need to be returned to Basler Electric for service if all Administrator passwords are lost or expired.

Security Files

Security settings are not included in the main settings file. They are separate files and upload as file type ".bss4". Use the File menu on the Device Security Setup screen to open and save security files. A security file password can be set from the Tools menu.

Access Levels

Passwords provide access security for seven distinct functional access levels. Access groups are sectionalized for specific operations and not incremental. Any user can be given full access but no single access level includes all functionality.

Each level can be assigned a unique password or one password can be assigned to multiple levels. Each access area is independent of one another. Passwords are never visible after they have been set. Non-administrator users can change only their own passwords. Administrator users can reset (change) any user password, but cannot see the original password. Table 9-1 lists the access levels and descriptions.

Table 9-1. Access Levels and Descriptions

Access Level	Description
Read Data and Settings	Can read all system status, metering, all configuration settings, and report data. Excludes security log and security settings.
Control Access	Can operate real time controls (including virtual switches, output override, control settings group) and set date and time, reset targets, alarms and accumulators, and erase event data.
Write Settings Access	Can change values of all settings, but cannot enter or edit logic equations.
Logic Design Access	Can create or change programmable logic.
Firmware Change Access	Can upgrade firmware.
Administrator Access	Can create, assign access, edit, reset passwords, and delete users and channel authorizations.
Security Audit Access	Can view and download security trail log.

Additional security is provided by controlling the functional areas that can be accessed through a particular communication port. For example, security can be configured so that front panel access is permitted at a one access level and BESTCOMS*Plus*® or Modbus® access is permitted at a different access level.

The communication ports and password parameters act as a two-dimensional control to limit changes. The entered password must be correct and the command must be entered through a valid port. The BE1-FLEX allows more than one user logged in with write access at one time.

If a port holding access sees no activity for the duration of the Timeout setting, access privileges will automatically be lowered to what that port's Unsecured Access it set to.

User Setup

The BE1-FLEX includes two default user accounts, which are stored in the device. A user with Administrator access is able to reset security to these three accounts if desired from the Tools menu of the main plugin. These users can be edited or deleted as desired. Default users 'a' and 'admin' are available with all access levels enabled. User 'a' is typically the standard Administrator and 'admin' is commonly maintained in case the credentials of the main account are lost.

1. Select Device Security Setup from the Tools menu. The Device Users tab will be on top. An administrator access level is required to set up user names and passwords. The default Administrator user name is "**a**" and the default Password is "**a**". The alternate Administrator user name is "admin" and the default password is "admin".

   Only an administrator can modify user names and passwords on the Device Users screen (Figure 9-1). With exception to the default password, complex user names and passwords 8 to 16 characters in length is required. Acceptable characters include uppercase letters, lowercase letters, numbers, and certain special characters.

Note

The BE1-FLEX supports this set of characters in passwords and user names:

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

a b c d e f g h I j k l m n o p q r s t u v w x y z

0 1 2 3 4 5 6 7 8 9

` ~ ! @ # $ % ^ & ( ) _ + - = { } [ ] \ : " ; ' < > ? . / ,

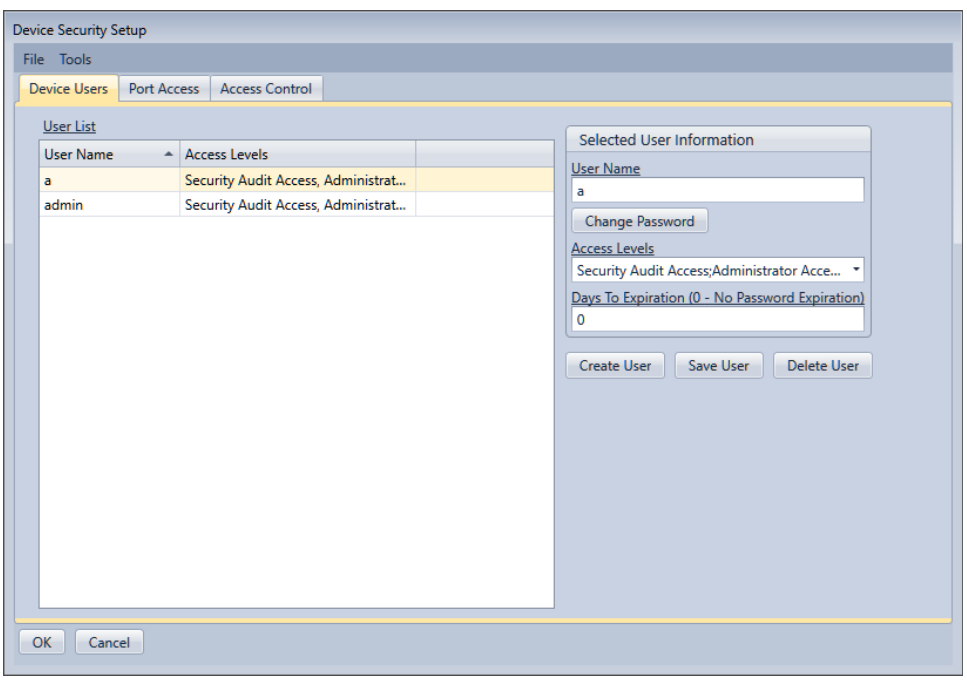


Figure 9-1. Device Users Screen

2. Click Create User to create a new user.
3. Enter a user name and a password. Enter the password again to verify.
4. Click OK.
5. Using Table 9-1 as a reference, select the access levels allowed for the user.
6. Enter the number of days to expiration of the password or leave at default (0) for no expiration.
7. Click the Save User button to confirm the Device User settings to the Users List.

Port Access Setup

1. Select the Port Access tab. See Figure 9-2.

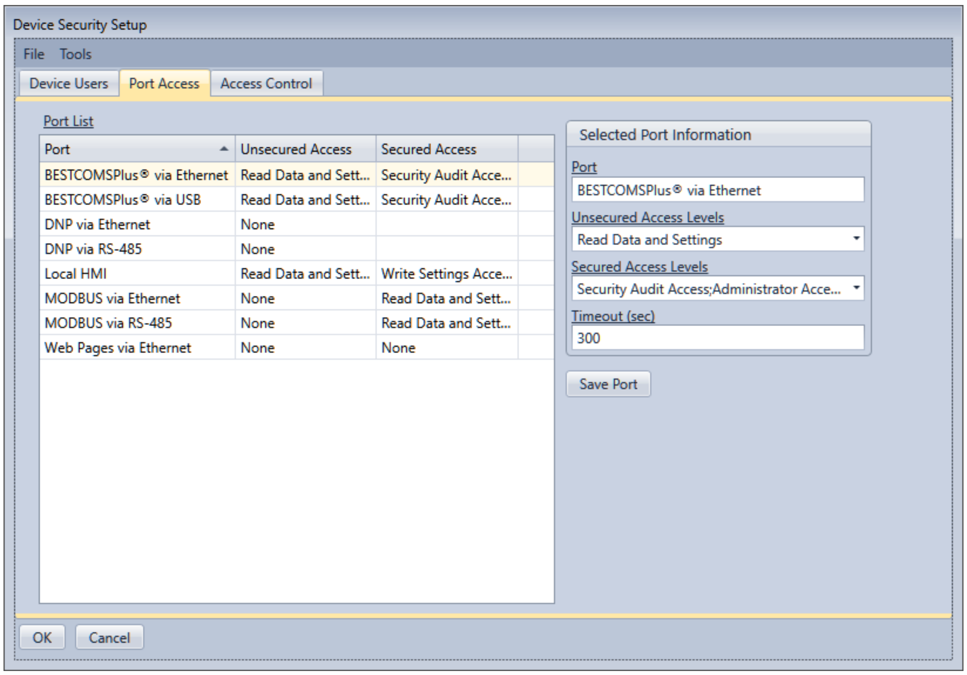


Figure 9-2. Port Access Screen

2. On the left side, highlight a port to change.
3. On the right side of the screen, use the drop-down menus to select the Unsecured Access Levels and Secured Access Levels for the highlighted port. The Unsecured Access Level setting sets the levels of access that can be gained without logging in. The Secured Access Level setting sets the levels of access that can be gained with logging in. Secured port access additionally requires a Device User with appropriate access.

> **Caution**
>
> Setting the Secured Access Level to None on any port will make that port unusable. If the Secured Access Level is set to None on all available ports, the BE1-FLEX must be returned to Basler Electric for repair.

4. Enter the Timeout before auto-logout from time of login.
5. Click the Save Port button to confirm the Port Settings to the Port Access list.

Access Control

Login Failure is determined by a user name or password that is entered incorrectly x times (Login Attempts) with less than y seconds (Login Time Window). When this occurs, secured access is prohibited for z seconds (Login Lockout Time).

When the HMI Login Required Reset setting is Login Not Required, targets and alarms can be reset from the touchscreen HMI without logging in when HMI Unsecured access includes Read Data and Settings access.

The BESTCOMS*Plus* Access Control screen is illustrated in Figure 9-3.

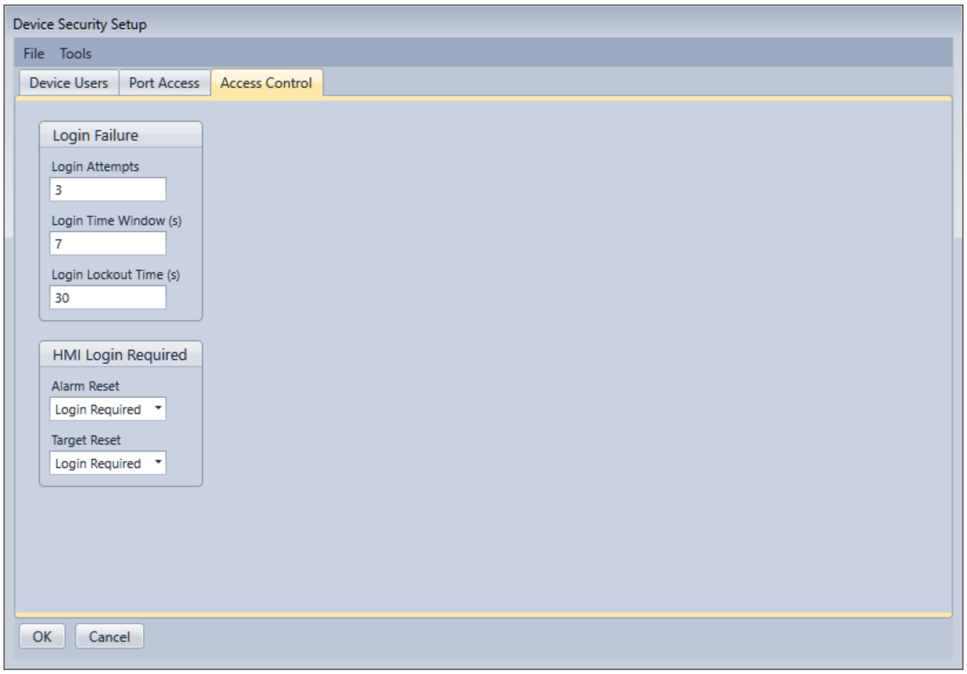


Figure 9-3. Access Control Screen

1. Select the Access Control tab. See Figure 9-3.
2. Configure Login Failure and HMI Login Required settings.

Save and Upload Security Settings

1. Click Save Security File from the File menu. Select save location and click Save.
2. Click OK at the bottom to save the security settings to BESTCOMS*Plus*. This step does not upload settings to the BE1-FLEX.
3. Pull down the Communication menu and select Upload to Device. Select Upload Security to Device. The Login dialog box pops up.
4. Enter the user name and password of a user with Administrator access and then click the Log In button. BESTCOMS*Plus* notifies you when the upload is successful.

Viewing the Security Log

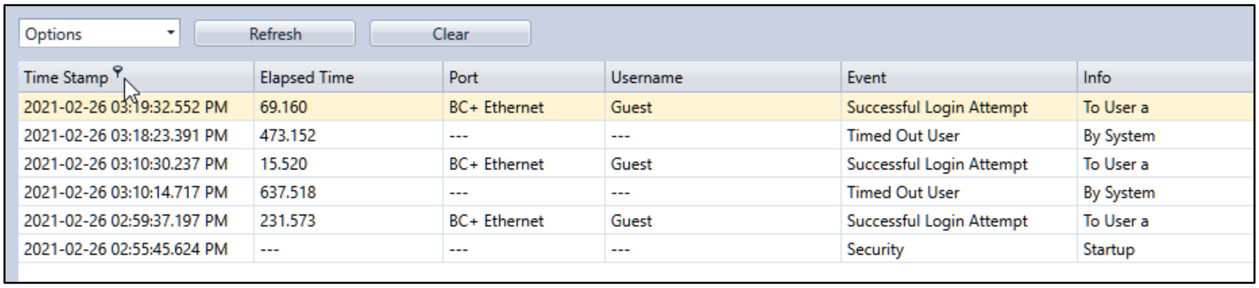
Navigation Path: Reports, Security Log

The BE1-FLEX records information about user logins including the port used to log in, the access level granted, the type of action performed, and the time of logout and creates security logs. A log will also be triggered when a user attempts to log in, but fails due to an invalid user name or incorrect password.

A maximum of 200 entries are stored in nonvolatile memory. When a new entry is generated, the BE1-FLEX discards the oldest entry and replaces it with a new one (first in, first out).

A User with Security Audit access on a Secured controlled port or access via a port with Unsecured access that includes Security Audit Access is required to view the Security Log.

Use the Metering Explorer to open the Reports, Security Log screen. If an active connection to a BE1-FLEX is present, the security log will automatically download. Using the Options button, you can copy, print, or save the security log. The Refresh button is used to refresh/update the security log. The Clear button clears the security log. Click on the filter icon on a column header to sort. See Figure 9-4.



Time Stamp	Elapsed Time	Port	Username	Event	Info
2021-02-26 03:19:32.552 PM	69.160	BC+ Ethernet	Guest	Successful Login Attempt	To User a
2021-02-26 03:18:23.391 PM	473.152	---	---	Timed Out User	By System
2021-02-26 03:10:30.237 PM	15.520	BC+ Ethernet	Guest	Successful Login Attempt	To User a
2021-02-26 03:10:14.717 PM	637.518	---	---	Timed Out User	By System
2021-02-26 02:59:37.197 PM	231.573	BC+ Ethernet	Guest	Successful Login Attempt	To User a
2021-02-26 02:55:45.624 PM	---	---	---	Security	Startup

Figure 9-4. Security Log

10 • Power System Configuration

Power system configuration includes setup of circuits, breakers, inputs, outputs, analog inputs, RTD inputs, and shunt inputs. The Style Configuration includes an Auto-Generate Instances function to automatically set up these components. The details below describe how to edit auto-generated instances or to create new components. Each instance includes a customizable Function Name to allow preferred terminology usage through the device.

Circuits

Navigation Path: Configuration, Circuit Summary

A BE1-FLEX circuit defines the power system measurement channels and configuration. A circuit must first be added using BESTCOMS*Plus* to be later utilized in protective functions, metering, and elsewhere. A circuit is defined on the Circuit Summary screen shown in Figure 10-1. A detailed description of the circuit can be entered in the Function Name box. Select a Function Instance and click the Add Function button to add a circuit. Click the Circuit State colored indicator or expand and click the newly created circuit in the Settings Tree Explorer to view circuit configuration (Figure 10-2). Click the Edit Circuit button to open the Circuit Editor (Figure 10-3).

Hardware channel VX can be set as a Phase or Ground in a circuit. Setting VX as phase allows for it to be used in a breaker instance, ultimately for Sync Check (25) and Auto-Synchronizing (25A) functions.

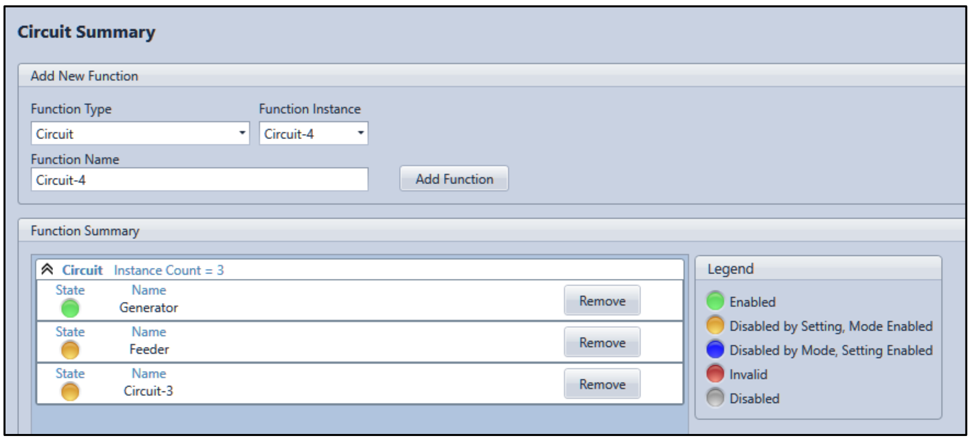


Figure 10-1. Circuit Summary Screen

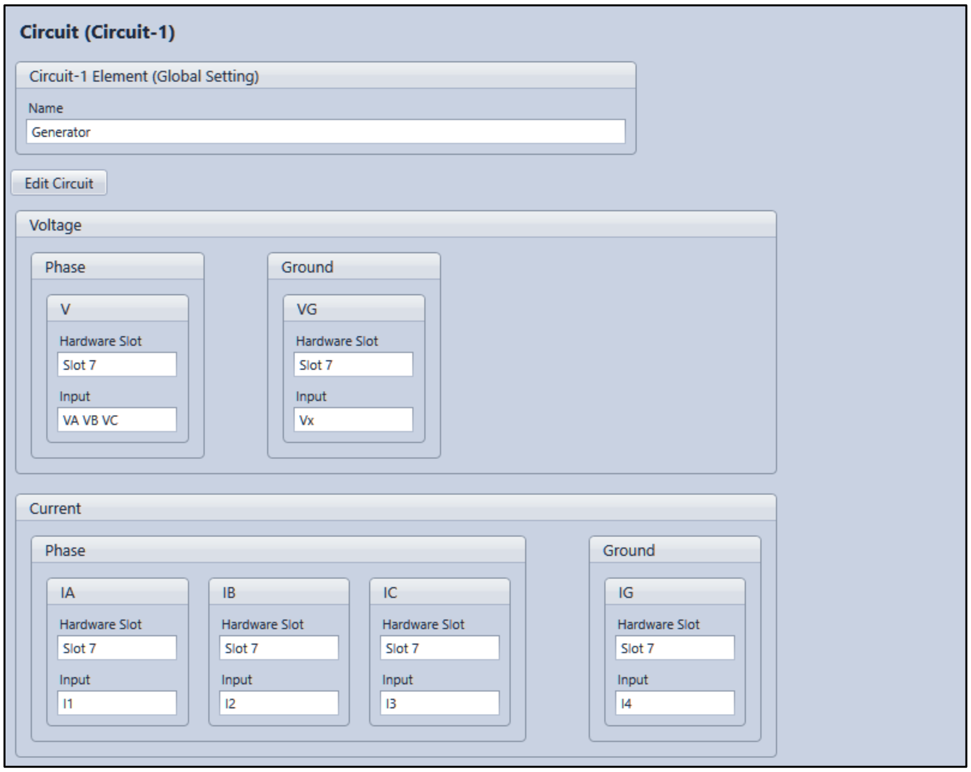


Figure 10-2. Circuit Configuration Screen

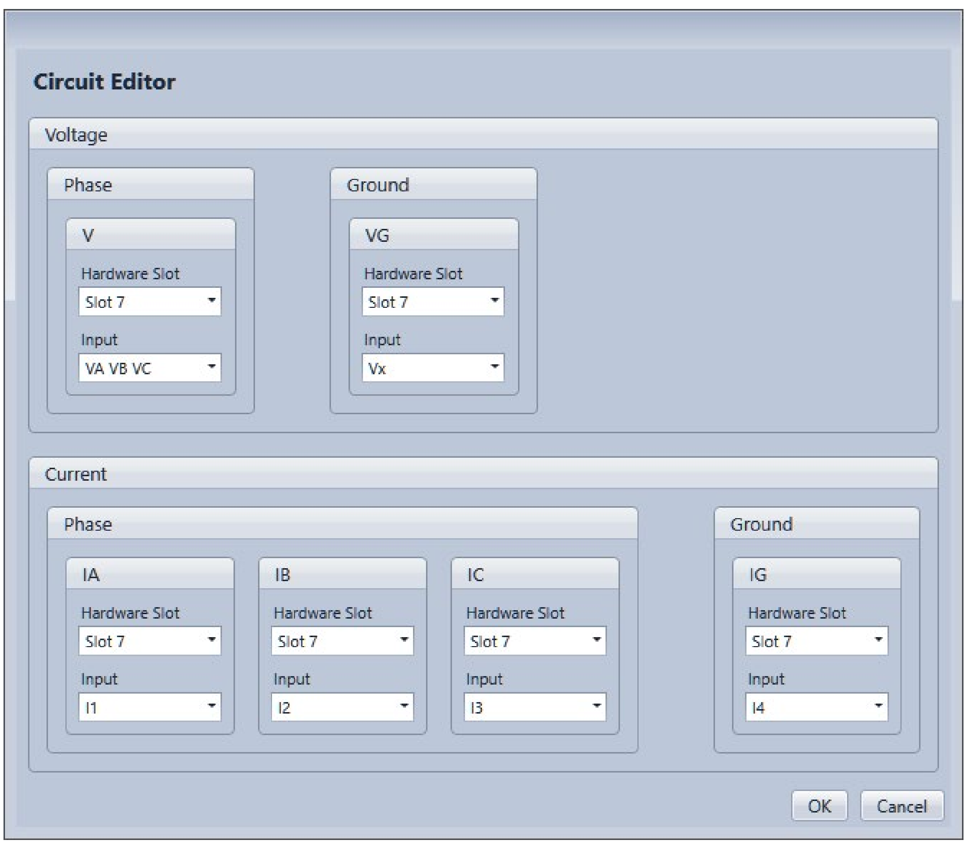


Figure 10-3. Circuit Editor Screen

Circuit Logic Settings

The Circuits logic block controls the 60FL function and provides outputs to be used in logic. Each circuit has its own 60FL function. The outputs of the logic block operate automatically within elements that call upon the circuit. These outputs are used to view circuit status or perform logic functions based upon conditions.

In some applications, such as generators, Breaker Status is commonly ignored by the 60FL to avoid false 60FL operation on a lightly loaded generator. In other applications such as feeders, it is often desired to use Breaker Status to arm the 60FL anytime the breaker is closed. 52a status into the Breaker Status input of the Circuit will perform as described in the Feeder application above. A Fixed or Logic 0 into the Circuit's 60FL Breaker Status input will cause the 60FL to ignore the breaker status and instead only arm the 60FL when positive sequence current greater than 8.8% nominal.

The Circuits logic block is illustrated in Figure 10-4. Logic inputs and outputs are summarized in Table 10-1.

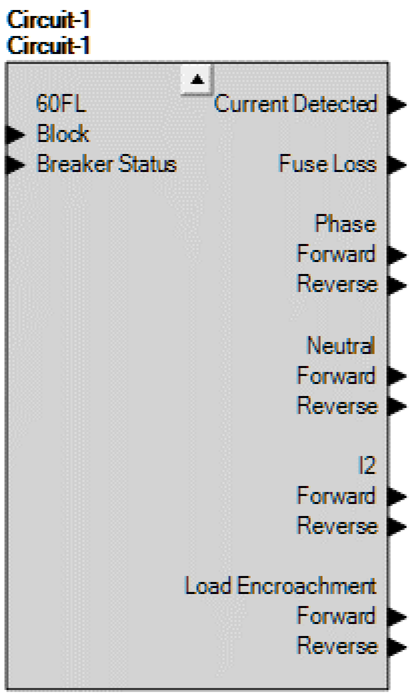


Figure 10-4. Circuits Logic Block

Table 10-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	When the 60FL Block input is high, the 60FL is disabled for this circuit.
Breaker Status	Input	Used when including Breaker Status in 60FL determination. See the 60FL logic diagram in the *Fuse Loss (60FL)* chapter.
Current Detected	Output	True when ac current is greater than approximately 100 mA as determined by the fast current detector.
Fuse Loss	Output	True when the Circuits 60FL algorithm is true.
Phase Forward	Output	True when the circuit's Phase directionality is determined to be forward per the directional control settings.
Phase Reverse	Output	True when the circuit's Phase directionality is determined to be reverse per the directional control settings.

Name	Logic Function	Purpose
Neutral Forward	Output	True when the circuit's Neutral directionality is determined to be forward per the directional control settings.
Neutral Reverse	Output	True when the circuit's Neutral directionality is determined to be reverse per the directional control settings.
I2 Forward	Output	True when the circuit's Negative Sequence current directionality is determined to be forward per the directional control settings.
I2 Reverse	Output	True when the circuit's Negative Sequence current directionality is determined to be reverse per the directional control settings.
Load Encroachment Forward	Output	True when the circuit's Load Encroachment is true in the forward direction per the advanced directional control settings.
Load Encroachment Reverse	Output	True when the circuit's Load Encroachment is true in the reverse direction per the advanced directional control settings.

Power System

Power system inputs are sampled 128 times per cycle by the BE1-FLEX. The BE1-FLEX measures the voltage and current from these samples and uses those measurements to calculate other quantities. Frequency is measured from a zero-crossing detector. Measured inputs are then recorded every quarter-cycle. If the applied voltage is greater than 10 volts, the BE1-FLEX measures the frequency and varies the sampling rate to maintain 128 samples per cycle. Frequency compensation applies to all power system measurements.

Current Measurement

Secondary current from power system equipment CTs is applied to current transformers inside the BE1-FLEX. These internal transformers provide isolation and reduce the monitored current to levels compatible with BE1-FLEX circuitry. Secondary current from each internal CT is converted to a voltage signal and then filtered by an analog, low-pass, anti-aliasing filter.

Current Measurement Functions

Input waveforms are sampled by an analog-to-digital converter (ADC) at 128 samples per cycle. The BE1-FLEX extracts the magnitude and angle of the fundamental components of each current input.

Positive-Sequence, Neutral and Negative-Sequence Current Measurement

Positive-sequence (I1), neutral (3I0), and negative-sequence (I2) components are calculated from the fundamental component of the three-phase current inputs. The BE1-FLEX can be set to accommodate ABC or ACB phase-sequence when calculating the positive- or negative-sequence component.

Fast Current Detector

A separate, fast current measurement algorithm is used by the breaker failure function and the breaker trip-speed monitoring function. This measurement algorithm has a sensitivity of approximately 100 mA and detects current interruption in the circuit breaker much faster than the regular current measurement functions. This measurement algorithm monitors only the phase current.

Voltage Measurement

Three-phase voltage inputs are reduced to internal signal levels by a precision resistor divider network. If the BE1-FLEX is set for single-phase or four-wire VT operation, the measuring elements are configured in wye. If the BE1-FLEX is set for three-wire VT operation, the measuring elements are configured in delta.

Voltage Measurement Functions

Input waveforms are sampled by an analog-to-digital converter (ADC) at 128 samples per cycle. The BE1-FLEX extracts the magnitude and angle of the fundamental components of each phase voltage input and the magnitude of the ground voltage input.

VT Connections

When four-wire VT connections are used, the BE1-FLEX measures the three-phase to neutral voltages and calculates the phase voltage quantities. Overvoltage (59) and Undervoltage (27) functions can be set to operate on either the phase-to-neutral (PN) or phase-to-phase (PP) quantities. Three-wire VT connections limit 27/59 operation to PP quantities. When single-phase VT connections are used, the 27/59 elements operate as appropriate for the single-phase voltage applied.

Neutral-Shift Voltage

When four-wire VT connections are used, the BE1-FLEX calculates the neutral-shift voltage (3V0). Neutral-shift voltage measurement should not be used when single-phase or three-wire VT connections are used. The 27 and 59 can be set to monitor the neutral-shift voltage.

Negative-Sequence Voltage

Negative-sequence voltage (V2) is calculated from the fundamental component of the three-phase voltage inputs. It should be used only on three-phase, three-wire, or three-phase, four-wire systems. V2 is calibrated to the phase-to-neutral base. Negative-sequence measurements accommodate either an ABC or ACB phase-sequence.

Positive-Sequence Voltage

Positive-sequence voltage (V1) is calculated from the fundamental component of the three-phase voltage inputs. It should be used only on three-phase, three-wire, or three-phase, four-wire systems. V1 is calibrated to the phase-to-neutral base. Positive-sequence measurements can accommodate either ABC or ACB phase-sequence.

Frequency Measurement

Circuit frequency is monitored on the A-phase voltage (VA or VX hardware), C-phase voltage, and I1 current hardware inputs. When the applied voltage or current is greater than 10 volts or 100 mA, the BE1-FLEX measures the frequency. The frequency is used for measurements and calculations. Frequency derived from circuit VA is used for the 81 function.

Frequency Compensation

After measuring the frequency, the BE1-FLEX varies the sampling rate to maintain 128 samples per cycle over a frequency of 10 to 125 hertz. If the signal is too low for accurate frequency measurement or if the measured frequency is out of range, the analog-to-digital (ADC) defaults to a sampling rate appropriate for the BE1-FLEX nominal frequency setting. The sampling rate is adjusted every 50 milliseconds (3 cycles).

Nominal Frequency

Nominal System Frequency can be set for 25 to 100 hertz power systems. When the voltage and current are too low for reliable frequency measurement, the ADC sample rate defaults to operation at the nominal frequency setting. Nominal frequency is also used in the volts/hertz (24) overexcitation calculation.

Power Measurement

The measured fundamental component of current and voltage as described previously in this chapter is used to calculate the power per the following equations:

For Sensing Type: Four-wire

$\text{Watts}_A = V_{AN} I_A \cos(\phi_A)$ $\text{Watts}_B = V_{BN} I_B \cos(\phi_B)$ $\text{Watts}_C = V_{CN} I_C \cos(\phi_C)$

$\text{Watts}_{3\phi} = W_A + W_B + W_C$

$\text{Vars}_A = V_{AN} I_A \sin(\phi_A)$ $\text{Vars}_B = V_{BN} I_B \sin(\phi_B)$ $\text{Vars}_{CA} = V_{CN} I_C \sin(\phi_C)$

$\text{Vars}_{3\phi} = \text{Vars}_A + \text{Vars}_B + \text{Vars}_C$

where: $\phi_P = \angle V_{PN} - \angle I_X$

For Sensing Type: Three-wire

In three-wire sensing mode, the equivalent LN voltages are determined from the LL voltages assuming 3V0 = 0V. This allows per-phase watts and vars to be determined and provides improved accuracy over a two-element method when neutral current is present.

$\hat{V}_{AN} = 1/3 \cdot (\hat{V}_{AB} - \hat{V}_{CA})$ $\hat{V}_{BN} = 1/3 \cdot (\hat{V}_{BC} - \hat{V}_{AB})$ $\hat{V}_{CN} = 1/3 \cdot (\hat{V}_{CA} - \hat{V}_{BC})$

Using the computed PN voltages, watts and vars are then computed using the equations listed under four-wire sensing type, above.

For Single Phase Sensing Types: AN, BN, CN, AB, BC, CA

In single-phase sensing mode, the unknown PN voltages are calculated. Assuming a balanced three-phase voltage is applied, the unknown PN voltages can be determined by scaling and rotating the measured voltage as follows:

ABC Rotation

AN Sensing: $V_{BN} = V_{AN} \cdot 1\angle -120°$ $V_{CN} = V_{AN} \cdot 1\angle 120°$

BN Sensing: $V_{AN} = V_{BN} \cdot 1\angle 120°$ $V_{CN} = V_{BN} \cdot 1\angle -120°$

CN Sensing: $V_{AN} = V_{CN} \cdot 1\angle -120°$ $V_{BN} = V_{CN} \cdot 1\angle 120°$

AB Sensing: $V_{AN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -30°$ $V_{BN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -150°$ $V_{CN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 90°$

BC Sensing: $V_{AN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 90°$ $V_{BN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -30°$ $V_{CN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -150°$

CA Sensing: $V_{AN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -150°$ $V_{BN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 90°$ $V_{CN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -30°$

ACB Rotation

AN Sensing: $V_{BN} = V_{AN} \cdot 1\angle 120°$ $V_{CN} = V_{AN} \cdot 1\angle -120°$

BN Sensing: $V_{AN} = V_{BN} \cdot 1\angle -120°$ $V_{CN} = V_{BN} \cdot 1\angle 120°$

CN Sensing: $V_{AN} = V_{CN} \cdot 1\angle 120°$ $V_{BN} = V_{CN} \cdot 1\angle -120°$

AB Sensing: $V_{AN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 30°$ $V_{BN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 150°$ $V_{CN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -90°$

BC Sensing: $V_{AN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -90^\circ$ $V_{BN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 30^\circ$ $V_{CN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 150^\circ$

CA Sensing: $V_{AN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 150^\circ$ $V_{BN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle -90^\circ$ $V_{CN} = \frac{1}{\sqrt{3}} V_{AB} \cdot 1\angle 30^\circ$

Using both the measured and calculated PN voltages, watts and vars are then computed using the equations listed under four-wire sensing type above.

Power System Settings

Navigation Path: Configuration, Circuit Summary, Circuit, Power System

The BE1-FLEX requires information about the power system to provide metering, fault reporting, fault location, and protective relaying.

Power system settings are configured on the Power System settings screen in BESTCOMS*Plus*®.

Nominal Settings

Frequency

Nominal Frequency can be set for 25 to 100 hertz power systems.

Phase Voltage

The nominal Secondary Phase Voltage setting is used by the 24, 25, 60FL, and 67 elements. The nominal secondary phase voltage is defined as the secondary phase-neutral voltage for all sensing connections. **That is, even if the user has selected 3-wire, AB, BC, or CA phase-phase sensing connections, the nominal secondary phase voltage must be set for the phase-neutral equivalent.** For example, if a 3-wire open delta voltage source with a phase-phase voltage rating of 120 volts is connected, the nominal secondary phase voltage must be set at $120/\sqrt{3}$ or 69.3 volts.

Current

The nominal Secondary Phase Current (I_{nom}) setting is used by the 60FL function, directional calculations for the 67 elements, and DNP3 analog event reporting functions. I_{nom} is also used in the volts/hertz (24) calculation and in the 46 time curve calculation (K factor) of the negative-sequence current (51) element and the (Max-Min)/Ave Unbalance overcurrent (50, 51) function. See 50 and 51 elements for more details on (Max-Min)/Ave details.

I_{nom} is the nominal phase current rating for the system corresponding to 1 pu current and is configured in secondary amperes. If 1 pu secondary current is unknown, then setting I_{nom} to the secondary CT rating (1 or 5 A) is acceptable for most applications. However, this could degrade the expectation (not accuracy) of the time curve for the 51 negative-sequence element as I_{nom} is used to directly compute multiple of pickup (MOP) and time delay.

Phase Rotation Setup

Normal phase rotation can be set for either ABC rotation or ACB rotation.

CT Setup

The BE1-FLEX requires setting information on the CT ratios. This setting is used by the metering and fault reporting functions to display measured quantities in primary units.

Connection

This setting is normally set to WYE. This setting can be set to DELTA to provide compensation if CTs are wired DELTA in a transformer differential application. DELTA CT connections are common in transformers protected by electromechanical relays. Digital relays in this application typically use WYE connections and internally compensate for the Power Transformer's DELTA/WYE conversion.

VT Setup

The BE1-FLEX requires setting information about the VT ratio, the phase connections, and the operating modes for the 27/59 and 51V functions. These settings are used by the metering and fault reporting functions to display measured quantities in primary units. The voltage input circuit settings also determine which power measurement calculations are used. Most of these connections such as 3W-D, 4W-Y, AN, or AB are self-explanatory.

Power system settings are configured on the Power System settings screen (Figure 10-5) in BESTCOMS*Plus*.

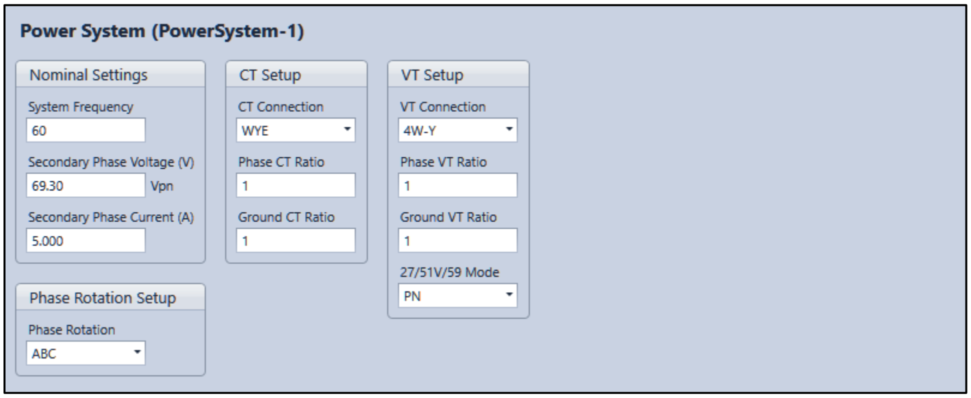


Figure 10-5. Power System Settings

Directional Control

Directional control provides directional supervision for the overcurrent and distance elements and distance to fault calculations in the Fault Reports. Two reference quantities for each polarizing method are compared to establish directional signals for controlling operation of the phase, neutral, and negative-sequence overcurrent elements. Directionality is derived from a comparison between internally calculated sequence voltages V1, V2, V0 (magnitude and angle) and calculated values of I1, I2, 3I0, I0, (magnitude and angle) and measured IG (magnitude and angle). Regardless of fault direction, the angle of the sequence voltages and the ground current source will always be the same while the angle of the currents (I1, I2, 3I0/IN, I0, IG operate) will change based on the direction of fault current flow.

Directional Control and Maximum Torque Angle

Directional algorithms use the maximum torque angle (MTA) as defined by the Power Line Parameter settings. There is an MTA setting for positive-sequence, negative-sequence calculations, and zero-sequence calculations. Multiple circuits can be created if different MTA settings are desired for Protection and Fault Reports.

Each MTA can be set over the range of 0° to 359.9° (I lag E) in 0.1° steps. These parameters are input into the BE1-FLEX using BESTCOMS*Plus* under Directional Control.

A fault current is considered to be in a forward direction when:

- I1 corrected offset angle is in phase with V1
- I2 corrected offset angle is out of phase with V2
- 3V0 corrected offset angle is out of phase with 3I0
- IG is in phase with 3I0

The Blinder Angle setting allows for extended directionality sensitivity. The default 180° setting equally splits the forward and reverse directions. Settings from 40° to 180° constrict the forward direction and similarly for 180 to 320 and reverse.

With a 180° blinder angle setting, the forward direction zone extends for approximately ±90° from the nominal line angle. A similar argument applies for the reverse direction with the current 180° out of phase from the voltage. The angle of Z1 is used during positive and Z2 is used during negative-sequence directional tests. Likewise, the angle of Z0 is used during the zero-sequence directional test. Angle compensation is not required for current polarization since the polarizing quantity IG is inherently compensated.

There is an MTA setting for positive-sequence, negative-sequence calculations, and zero-sequence calculations. Multiple circuits can be created if different MTA settings are desired for Protection and Fault Reports. A sample Forward and Reverse determination based upon MTA and Blinder Angles is shown in Figure 10-6.

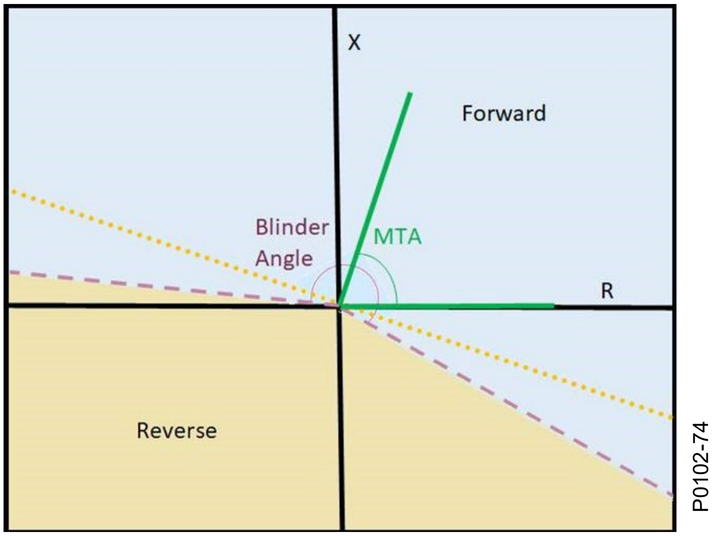


Figure 10-6. Sample MTA and Blinder Angle

Note that "not forward" does not necessarily imply reverse. Sufficient current and voltage must be present to declare direction. Time and Instantaneous Overcurrent elements can be set to failsafe in either direction if directionality cannot be determined. Failsafe direction is the direction it will assume if directionality is unknown. For example, if the element is set to Reverse and failsafe is set to Reverse, the element becomes non-directional when direction is not available. Alternatively, if the element mode is set to Reverse and failsafe is set to Forward, the element is disabled when direction cannot be determined. Internally, the BE1-FLEX also uses several constant limits to determine if the system levels are adequate to perform reliable directional tests and set directional bits. See Table 10-2.

50 and 51 elements include failsafe direction mode settings and circuit blocks in logic provide directional status outputs to provide advanced control when directionality is uncertain.

If the minimum levels are not met for a particular directional test, then the test is not run and the directional bits are cleared for that test. For instance, if 3*positive-sequence current is less than 0.50 A, the positive-sequence test is skipped and the positive-sequence directional bits are cleared.

The Sequence Ratio refers to the minimum ratio required between the positive-sequence current and either the negative or the zero-sequence current. A negative-sequence directional test would be allowed if the negative-sequence current were greater than 9% of the positive-sequence current. The same concept applies for the zero-sequence directional test.

Table 10-2. Internal Constants

Internal Constant	Purpose	Value
Positive-Sequence Current	Minimum I1 current threshold for Positive-Sequence test	10% of I nominal
Zero-Sequence Current	Minimum 3I0 current threshold for Current Polarization test	5% of I nominal
Ground current (IG)	Minimum Ground (IG) current threshold for Current Polarization test	0.1A for 5A and 1A CTs and 0.01A for SEF CTs
Negative-Sequence Voltage	Minimum V2 voltage threshold for Negative-Sequence test	1.2% of V nominal

Internal Constant	Purpose	Value
Zero-Sequence Voltage	Minimum V0 voltage threshold for Zero-Sequence test	0.75% of V nominal
External Zero-Sequence Voltage (VG)	Minimum external 3V0 voltage threshold for Zero-Sequence test	10% of V nominal
Negative-Sequence Ratio	Minimum ratio between I1 and I2 for Negative-Sequence test	9%
Zero-Sequence Ratio	Minimum ratio between I1 and 3I0 for Zero-Sequence test is 9%	9%

The directional tests are also supervised by the loss of potential function 60FL. If the 60FL bit is true, then voltage sensing was lost or is unreliable. Under this condition positive-, negative-, and zero-sequence directional tests are disabled and their bits are cleared. Current polarization is not affected by the 60FL since it does not rely on voltage sensing.

The direction bits are updated every 4 ms. Under sudden current reversal conditions, a directional 50 element with no intentional time delay will operate outputs in 28 milliseconds or less with standard contact output timing. See the *Timing Characteristics* chapter for full details.

Theory of Using Sequence Impedances for Fault Direction

When using real world impedances in the Z_{ABC} domain, it is apparent that faulted phase voltage approaches zero as one gets closer to the fault and that the same phase's voltage becomes larger the closer one gets to the source. However, in the sequence domain (zero-, positive-, negative-sequence), the above concept holds for positive-sequence voltage and current flow, but for negative- and zero-sequence current flow, the opposite condition occurs. Negative- and zero-sequence voltage is highest at the fault location, and lowest at the source. This affects how the BE1-FLEX uses the MTA to prevent tripping for unusual load flow.

For directional decisions, a BE1-FLEX is measuring the sequence impedance (Z_{012}=V_{012} / I_{012}) and comparing the angle that it calculates to the MTA with a window of ±90° as forward (or reverse, depending on the BE1-FLEX setup). Suppose a radial single source condition exists relative to the BE1-FLEX location. The source impedance is Z_{Source} and the fault is downstream on a line of impedance Z_{Line}. Given a source voltage of V_{Source} and a fault current of I_{Relay} the local substation voltage will be shown in the following equation. Note this equation is true independent of the fault type or the faulted phase.

$$\begin{bmatrix} V_{0,Relay} \\ V_{1,Relay} \\ V_{2,Relay} \end{bmatrix} = \begin{bmatrix} V_{0,Source} \\ V_{1,Source} \\ V_{2,Source} \end{bmatrix} - \begin{bmatrix} Z_{0,Source} & 0 & 0 \\ 0 & Z_{1,Source} & 0 \\ 0 & 0 & Z_{2,Source} \end{bmatrix} \begin{bmatrix} I_{0,Relay} \\ I_{1,Relay} \\ I_{2,Relay} \end{bmatrix}$$

The impedance seen by the BE1-FLEX is calculated in the following equation:

$$Z_{0,Relay} = \frac{V_{0,Relay}}{I_{0,Relay}} = \frac{V_{0,Source}}{I_{0,Relay}} - Z_{0,Source}$$

$$Z_{1,Relay} = \frac{V_{1,Relay}}{I_{1,Relay}} = \frac{V_{1,Source}}{I_{1,Relay}} - Z_{1,Source}$$

$$Z_{2,Relay} = \frac{V_{2,Relay}}{I_{2,Relay}} = \frac{V_{2,Source}}{I_{2,Relay}} - Z_{2,Source}$$

If $V_{0,Source}$ and $V_{2,Source}$ are very small:

$$Z_{0,Relay} \approx -Z_{0,Source}$$

$$Z_{2,Relay} \approx -Z_{2,Source}$$

The calculations in the BE1-FLEX account for the negative factor in the above equation and hence a 180° phase shift is implemented in the BE1-FLEX firmware so that a correct forward/reverse decision is made.

The positive-sequence impedance as seen by the BE1-FLEX is more complicated since $V_{1,Source}$ is not negligible. One simple application to study is the three-phase fault and the B to C phase fault (Equation 10-1):

$$Z_{1,Relay,3phase} = \frac{V_{1,Source}}{\frac{V_{1,Source}}{Z_{1,Source} + Z_{1,Line}}} - Z_{1,Source} = Z_{1,Line}$$

$$Z_{1,Relay,BC} = \frac{V_{1,Source}}{\frac{V_{1,Source}}{Z_{1,Source} + Z_{1,Line} + Z_{2,Source} + Z_{2,Line}}} - Z_{1,Source} = Z_{1,Line} + Z_{2,Source} + Z_{2,Line}$$

Equation 10-1. Three-Phase/B to C-Phase Faults

Directional relaying would not be of much value in a radial system where all current flow will be forward. In two source systems, as shown in Figure 10-7, a profile of sequence voltages in the system will show V_0 and V_2 at either source. V_0 and V_2 will still be negligible in normal operation, and show up only during fault conditions with their maximum value being at the fault location, with current flowing from X and Y in a current division rule applied to the symmetrical component network that represents the fault impedances and the fault type. Independent of the fault type and how the sequence currents divide in the system, the sequence voltages and hence sequence impedances measured by the BE1-FLEX will still be dependent on $V_{Relay}=V_{Source} - Z_{Source} I_{Source}$. The BE1-FLEX will sense the zero- and negative-sequence impedances in the opposite direction as the direction to the fault, looking back toward the source. However, for the three-phase fault the BE1-FLEX will sense the positive-sequence impedance in the line between the BE1-FLEX and the fault location. The sensed zero-sequence current can be shifted notably when zero-sequence coupling between adjacent lines is involved. However, since a large phase angle window of ±90° from the MTA is being utilized for directional decisions, the direction decision is not highly sensitive to zero-sequence coupling effects.

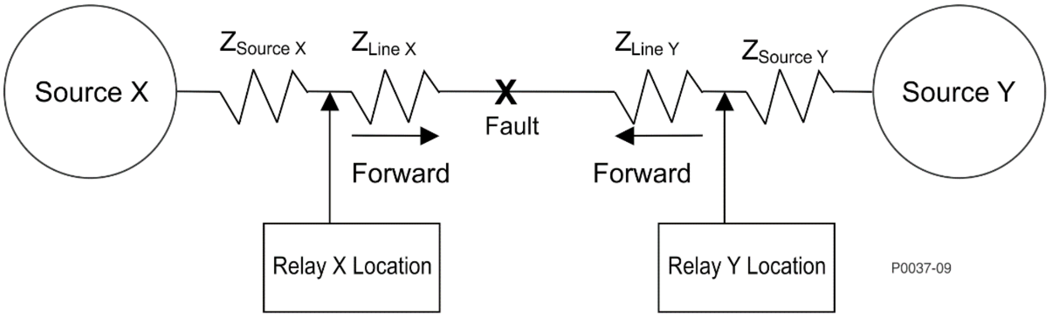


Figure 10-7. Directional Overcurrent Relaying

For more theory and mathematics of using sequence components for sensing direction to fault, see the paper, "*Directional Overcurrent Relaying in the Distributed Generation Environment*" available on the Basler Electric website (https://www.basler.com).

Neutral Polarization Methods

The polarization methods are as follows:

- Positive-Sequence Polarization – Forward direction is detected when the apparent Z_1 angle (angle of V_1/I_1) is equal to the positive-sequence maximum torque angle (MTA), ±90°. (See *Neutral Polarization Methods Notes*.)
- Zero-Sequence Current Polarization – Forward direction is detected is when the phase angle of current in the ground CT input (IG) is in phase with the calculated 3I0, ±90°. (See *Neutral Polarization Methods Notes*.)
- Negative-Sequence Polarization – Forward direction is detected is when the apparent Z_2 angle (angle of $-V_2/I_2$) is equal to the negative-sequence maximum torque angle (MTA), ±90°. (See *Neutral Polarization Methods Notes*.)
- Zero-Sequence Voltage Polarization – Forward direction is detected is when the apparent Z_0 angle (angle of V_0/I_0) is equal to the zero-sequence maximum torque angle (MTA), ±90°. (See *Neutral Polarization Methods Notes*.) However, the BE1-FLEX has two forms of zero-sequence voltage available to it (calculated V_0 from the phase voltages or VG measured from a broken delta VT) and two forms of zero-sequence current available to it (calculated I_0 from the phase currents or IG from a circuits IG). This results in four options for zero-sequence voltage polarization:
  - Calculated V_0 verses calculated I_0 – (VOIN)
  - Calculated V_0 verses IG – (VOIG)
  - VG verses calculated I_0 – (VGIN)
  - VG verses IG – (VGIG)
  - All four forms of zero-sequence voltage polarizations use the same MTA value.

Each of the four internal polarization methods has designated internal bits that are used in the BE1-FLEX for direction identification, one for forward direction and one for reverse direction. Combined, these eight bits are referred to as the directional status byte and are used to control the various overcurrent elements.

Neutral Polarization Methods Notes

The negative and zero-sequence MTA has a built in 180° phase shift that arises out of the calculation methods described at the end of this chapter. ±90° impacted by Blinder Angle setting.

Positive-Sequence Polarization is used to determine direction for three-phase faults. Under these conditions, very little negative or zero-sequence quantities are present, making the other polarization methods unreliable for this fault condition. For close-in faults, the BE1-FLEX will also need to depend on memory voltage to determine direction (see below). Positive-sequence bits are used to supervise the elements in single- or three-phase mode.

To provide memory, the positive-sequence voltage is stored continuously until a fault occurs. Memory voltage is used when the positive-sequence voltage falls below the minimum acceptable level of 12 volts. The BE1-FLEX maintains memory voltage for 15 cycles to allow tripping for close-in faults. When using memory voltage polarization, the BE1-FLEX assumes nominal system frequency.

Negative-Sequence Polarization is used to test directionally for all fault types except three-phase faults. Negative-sequence bits are used to supervise phase, neutral, and negative-sequence overcurrent modes. With load flow and low fault currents, it is possible for the positive-sequence bits to be set at the same time that the negative-sequence bits are true. Under these conditions, the negative-sequence bits have priority and the positive-sequence bits are cleared.

Zero-Sequence Voltage Polarization is used to test directionally for ground faults and is used to supervise only in neutral overcurrent mode (V0IN, V0IG, VXIN, or VXIG). The neutral overcurrent elements can be set to operate on either calculated I_0 or independent ground input IG. The four types of zero-sequence polarization methods were described above. Typical ac connections for external sources of V_0 (a broken delta VT) are provided in the *Typical Connections* chapter.

Zero-Sequence Current Polarization is also used to test directionally for ground faults and is used to supervise the neutral overcurrent elements.

Polarization summary for tripping elements is as follows:

- Phase mode: Positive-Sequence; Negative-Sequence
- Negative-Sequence mode: Negative-Sequence
- Neutral mode: Negative-Sequence; Zero-Sequence Volt; Zero-Sequence Current

The neutral overcurrent elements can be supervised by various polarization methods using either or both zero-sequence and negative-sequence quantities. This is necessary depending on the application and fault conditions applied to the BE1-FLEX. For example, negative-sequence polarizing can be used when zero-sequence mutual coupling effects cause zero-sequence polarizing elements to lose directionality. In addition, high impedance ground faults might cause values of zero-sequence voltage too low to measure during a fault, making zero-sequence polarization unreliable. A similar condition can occur with the negative-sequence voltage or current, although it is less likely. Under these conditions, a user might need to use current polarization or dual polarization to provide reliable directional tripping.

Neutral Polarization mode options are logical ORs and are used to set up dual or possibly triple polarization techniques for the neutral elements. Thus, if more than one directional supervision element is enabled, any element can enable tripping if the appropriate forward or reverse directional decision is made.

Load Encroachment

False tripping can occur on heavily loaded feeders during peak operation. The load encroachment feature is used to block the 50 and 51 elements when the impedance of the load is inside the load encroachment zone. Increases in current are differentiated between an increase due to load change versus a change due to a fault.

The Mode setting enables or disables load encroachment. Load encroachment can also be disabled in any direction. Setting the Minimum Forward Load setting to zero (0) disables load encroachment in the forward zone and setting the Minimum Reverse Load setting to zero (0) disables load encroachment in the reverse zone.

When load encroachment is enabled, the 50 and 51 elements utilizing the load encroachment enabled circuit will trip only if the current is in the proper direction and outside of the appropriate zone. The two shaded regions in Figure 10-8 represent the forward and reverse encroachment zones. Directional tripping of the 50 and 51 elements is blocked when the calculated positive-sequence impedance (Z1) is inside a particular zone. For example, if a 51 element is configured for reverse tripping, and Z1 is inside the reverse zone, the element will not trip even if the current is above the 51 pickup setting.

Forward Zone

The forward zone is constructed using the following settings:

- Minimum Forward Load
- Positive Forward Angle
- Negative Forward Angle

The impedance of the load is considered to be in the forward zone when both of the following are true:

- Minimum Forward Load setting <= Z1
- Negative Forward Angle setting <= Z1 angle <= Positive Forward Angle setting

Reverse Zone

The reverse zone is constructed using the following settings:

- Minimum Reverse Load
- Positive Reverse Angle
- Negative Reverse Angle

The impedance of the load is considered to be in the reverse zone when both of the following are true:

- Minimum Reverse Load setting <= Z1
- Negative Reverse Angle setting <= Z1 angle <= Positive Reverse Angle setting

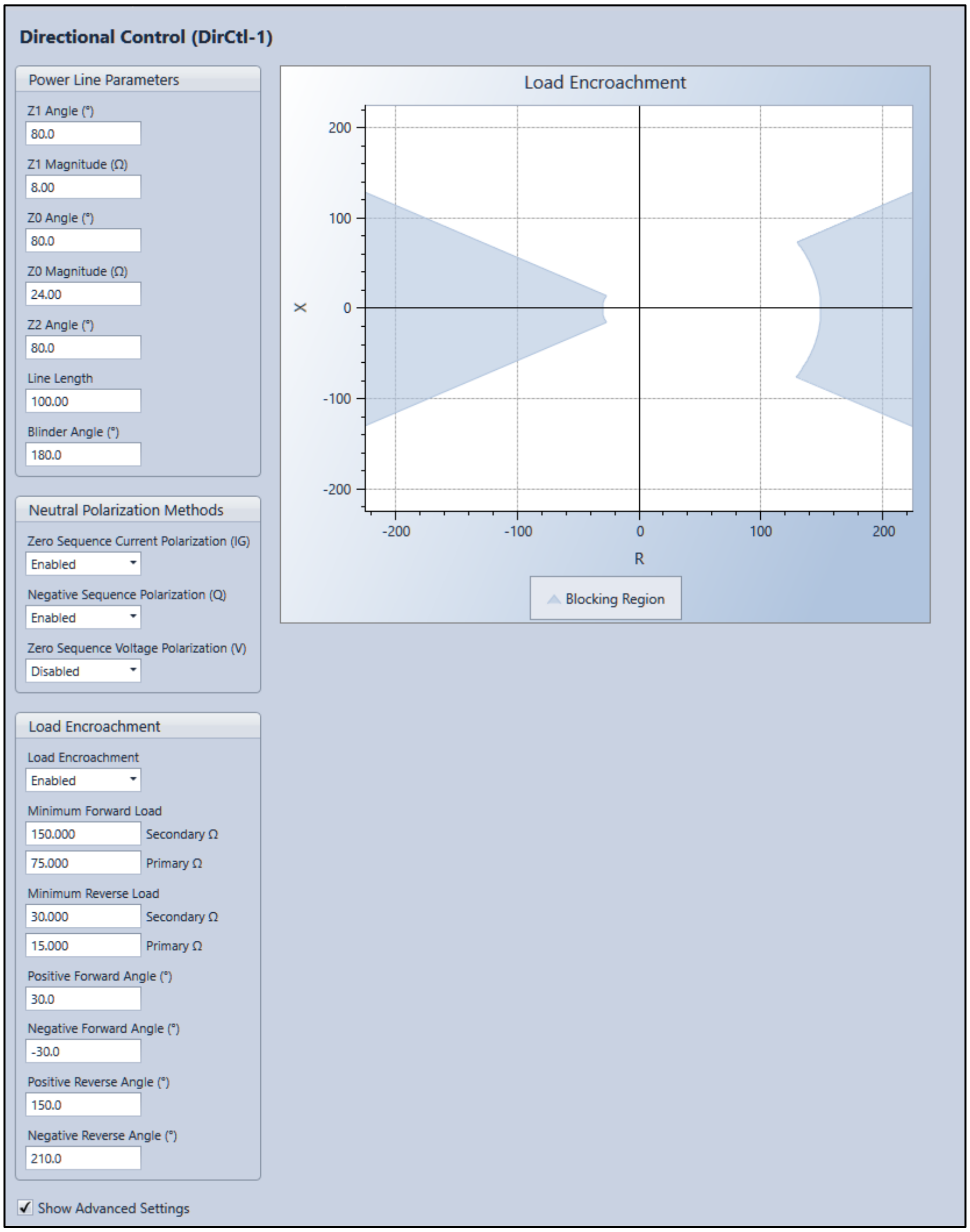


Figure 10-8. Directional Control Settings

Directional Control Settings

Navigation Path: Configuration, Circuit Summary, Circuit, Directional Control

Power line parameters, neutral polarization methods, and load encroachment settings are configured on the Directional Control settings screen (Figure 10-8) in BESTCOMS*Plus*. The Load Encroachment settings are shown by clicking Show Advanced Settings at the bottom of the screen.

Demands

Navigation Path: Configuration, Circuit Summary, Circuit, Demand

Demand values are continuously calculated for phase currents, neutral current (3I0), negative-sequence current (I2), ground current (IG), real power (watts), reactive power (var), and apparent power (VA).

Demand settings are configured on the Demand settings screen (Figure 10-9) in BESTCOMS*Plus*.

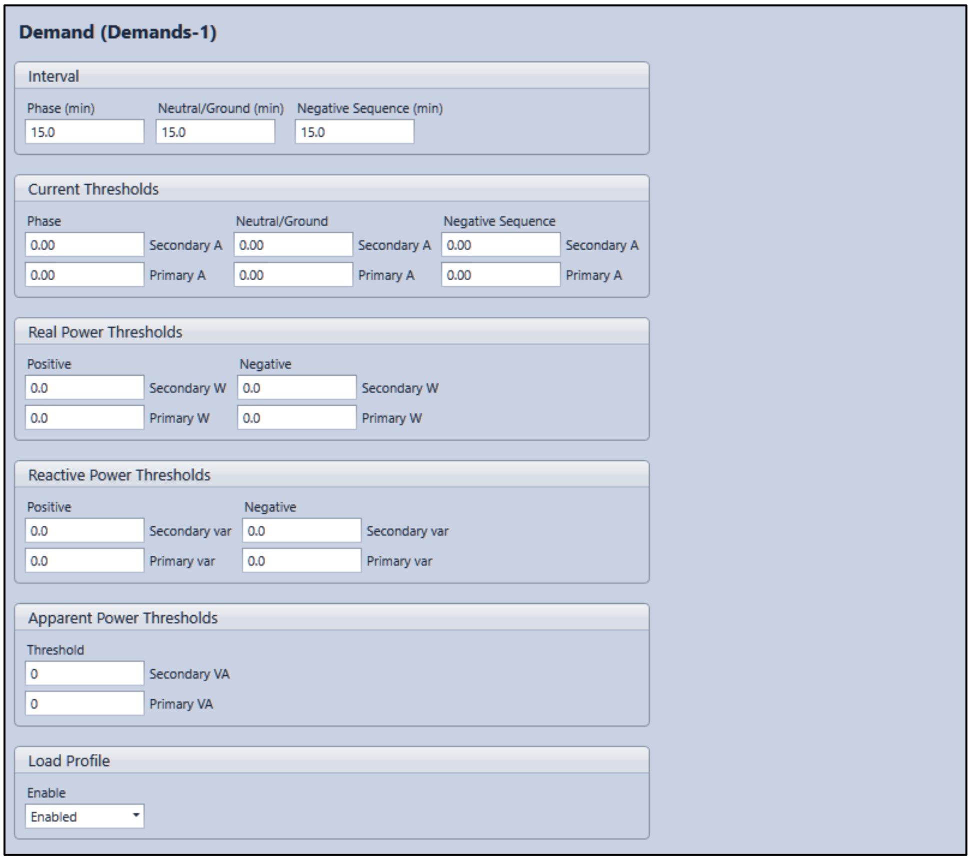


Figure 10-9. Demands Settings

Retrieving Demand Reporting Information

Navigation Path: Analog Metering, Circuit, Demand

Values and timestamps in the demand registers are reported in primary values. They can be read at the front-panel display, through BESTCOMS*Plus*, and through the web page interface.

Peak demand values can be preset by pressing the Edit key and changing the value. Write access to the Reports functional area is required to preset values at the front panel.

To access demand data through BESTCOMS*Plus*, use the Metering Explorer to open the Demand tree branch and select Demand Current (Figure 10-10), Demand Real Power, Demand Reactive Power, or Demand Apparent Power. The Demand Real Power, Demand Reactive Power, and Demand Apparent Power screens are similar.

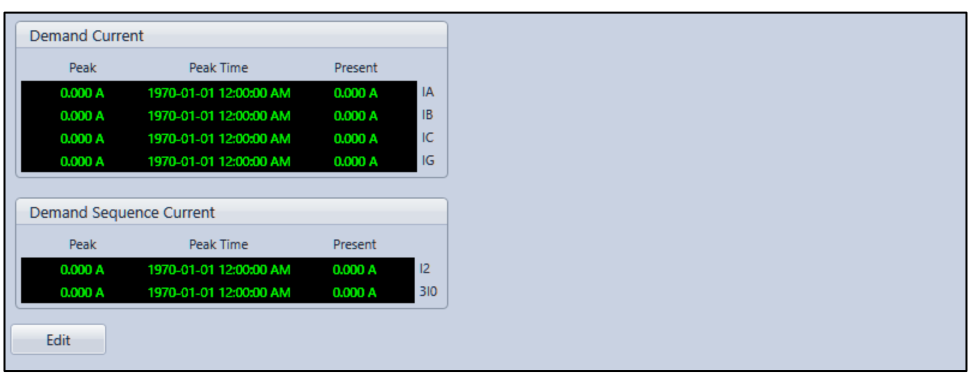


Figure 10-10. Demand Current Metering

Load Profile

The load profile recording function provides a running average of the demand and helps you determine when power factor is poor during certain times of the day, week, or month and they are paying a penalty for high peak consumption. The load profile recording function uses a 4,000-point data array for data storage of three-phase watt, three-phase var, and phase current demand readings.

At the specified (programmed) interval, the load profile function takes the data from the demand calculation register and places it in a data array. If the programmed interval is set to 15 minutes, it will take 41 days and 16 hours to generate 4,000 entries. Load profile data is smoothed by the demand calculation function. If a step change is made in primary current, with the demand interval set for fifteen minutes, and the load profile recording interval set for one minute, it would take approximately 15 minutes for the load (step change) to reach 90% of the final level.

Setting the Load Profile Recording Function

Navigation Path: Advanced, Load Profile

The load profile recording function is enabled per circuit on the configured circuit's Demand screen (Figure 10-9). Advanced configuration is performed on the Load Profile settings screen (Figure 10-11) in the Advanced folder of BESTCOMS*Plus*. The Demand Interval specifies the period that the data is averaged. The Advanced Load Profile settings define how frequently the Load Profile record is updated.

Figure 10-11. Load Profile Settings

Retrieving Load Profile Recorded Data

Recorded load profile data can be downloaded through BESTCOMS*Plus* on the Load Profile screen under Reports of the Metering Explorer.

Power Quality

Power quality data consists of voltage, distortion, dips/swells, and harmonics. Power quality is reported through BESTCOMS*Plus*®, the front-panel interface, and the web page interface. Power quality data is also available in Configurable Protection. Refer to the *Configurable Protection* chapter for high speed, automated control capabilities.

Operation

A dip event begins when any one phase decreases below the dip threshold and ends when all phases return above the dip threshold and dip hysteresis. A swell event begins when any one phase increases above the swell threshold and ends when all phases return below the swell threshold and swell hysteresis. A dip event reports dip duration and the residual voltage measured during the dip event. A swell event reports swell duration and the maximum voltage measured during the swell event. It is possible for a dip or swell event to begin on one phase and end on another. It is also possible for a dip and a swell to occur at the same time on different phases.

Reference Mode

In Sliding mode, dip and swell thresholds are calculated based on the sliding average voltage, which changes over time. In Fixed mode, dip and swell thresholds are calculated based on the system rated voltage.

Dip Hysteresis

This setting determines the hysteresis of the dip threshold. For example, a value of 1.02 sets the hysteresis to 2% of the dip threshold.

Dip Ratio

This setting determines the dip threshold. For example, a value of 0.90 sets the dip threshold to 90% of the reference voltage.

Swell Hysteresis

This setting determines the hysteresis of the swell threshold. For example, a value of 0.98 sets the hysteresis to 2% of the swell threshold.

Swell Ratio

This setting determines the swell threshold. For example, a value of 1.10 sets the swell threshold to 110% of the reference voltage.

Settings

Navigation Path: Configuration, Circuit Summary, Circuit, Power Quality

Settings are made using BESTCOMS*Plus*. The Power Quality settings screen is illustrated in Figure 10-12.

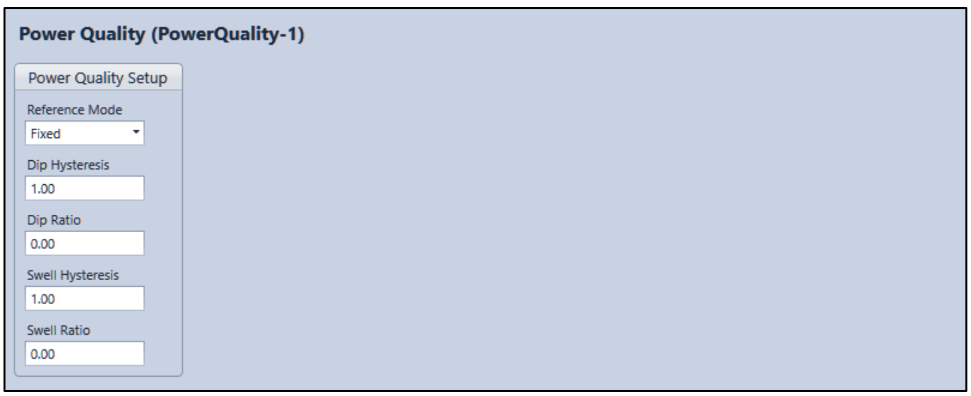


Figure 10-12. Power Quality Settings

Metering

Navigation Path: Analog Metering, Circuit, Power Quality

Power quality data can be viewed using BESTCOMS*Plus*, through the front-panel interface, and through the web page interface.

Voltage

Figure 10-13 illustrates the Power Quality, Voltage screen.

Figure 10-13. Power Quality, Voltage Metering

10-Second Frequency

A 10-second average of the frequency is calculated using Equation 10-2.

$$\frac{Number\ of\ Integral\ Cycles}{Total\ Duration\ of\ Integer\ Cycles}$$

Equation 10-2. 10-Second Frequency Calculation

Example

Number of integral cycles: 501 cycles over 10 s

Total duration of the 501 cycles: 9.998 s

10-Second Frequency = 501/9.998 = 50.1100 Hz

Distortion

The voltage during a dip is often distorted. This distortion may be important for understanding the effect of the dip on the system. The BE1-FLEX calculates distortion using Equation 10-3.

$$THD\% = \frac{\sqrt{V_{total}{}^2 - V_1{}^2}}{V_1} \times 100$$

Equation 10-3. Distortion Calculation

Figure 10-14 illustrates the Power Quality, Distortion screen.

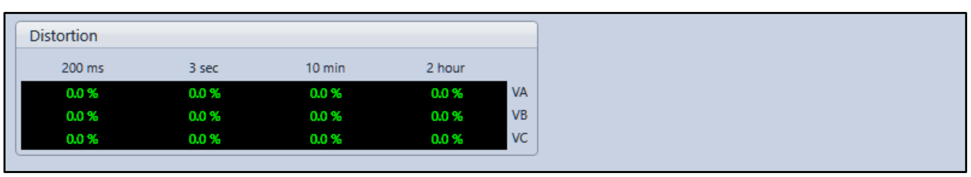


Figure 10-14. Power Quality, Distortion Metering

Dip/Swell

Figure 10-15 illustrates the Power Quality, Dip/Swell screen. Dip Status indicator and a Swell Status indicator turn red when the corresponding power quality setting is exceeded.

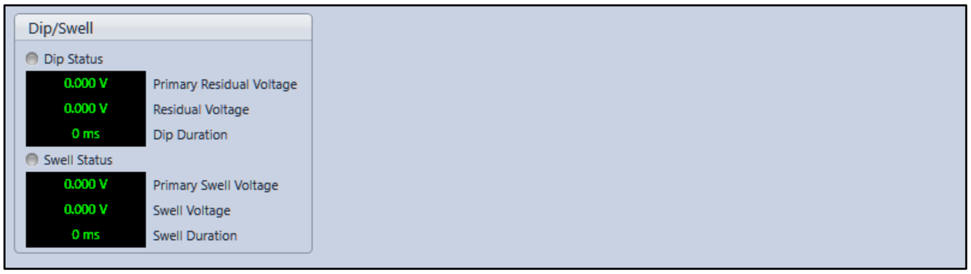


Figure 10-15. Power Quality, Dip/Swell Metering

Harmonics

Figure 10-16 illustrates the Power Quality, Harmonic Voltage screen. The Harmonic Current screen is similar. Metered harmonics are displayed to the 49th order.

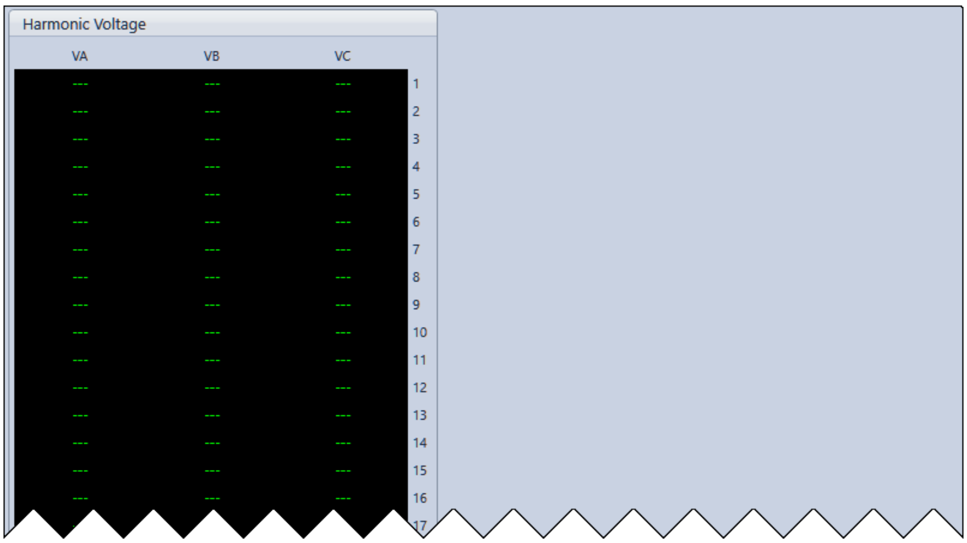


Figure 10-16. Power Quality, Harmonic Voltage Metering

Virtual Circuits

Navigation Path: Configuration, Virtual Circuit Summary

A Virtual Circuit is used to create a vector sum of currents from two or three, three-phase CT circuits. The current vector sum is utilized in conjunction with circuit voltage when present. These can be utilized to provide a source or connect a load to a common winding on a transformer. This is typically applied to avoid adding additional dedicated CTs to directly measure the transformer primary or secondary current. Virtual Circuits can simplify metering when cumulative circuit values are desired such as in a multiple mains system.

The Virtual Circuit is driven by primary phasors from the hardware circuits. Applying a CT or VT ratio in a Virtual Circuit applies a secondary scaling that may not be relative to actual CTs in the physical circuit as the physical CTs can have different turns ratios, but a Virtual Circuit ratio is often necessary to allow valid primary settings ranges of protective and demand functions. Protective elements from Virtual Circuits should generally be set in primary values. For example, a Virtual Circuit is driven by physical Circuit 1 with a 200:1 CT turns ratio and physical Circuit 2 with a 150:1 CT turns ratio, a reasonable Virtual CT turns ratio would be the cumulative turns ratio of 350:1.

Virtual Circuit functionality is similar to hardware Circuits, but excludes Impedance protective functions, Ground measurements, Power Quality, and Synchrophasor capabilities.

The Virtual Circuit Configuration screen is shown in Figure 10-17.

Figure 10-17. Virtual Circuit Settings

Breakers

Breaker monitoring helps manage equipment inspection and maintenance expenses by providing extensive monitoring and alarms for the circuit breaker. Breaker monitoring functions include breaker status and operations counter reporting, fault current interruption duty monitoring and trip-speed monitoring. Each function can be set up as a programmable alarm. The *Alarms* chapter has more information about the use of programmable alarms. The breaker trip circuit voltage and continuity monitor is a related function and is described in the *Trip Circuit Monitor (52TCM)* chapter.

Angle Compensation

The BE1-FLEX automatically accounts for differing voltage transformer connections by adjusting for angle difference. That is, on an ABC system if Source 1 is 4-wire and Source 2 is connected single phase-to-phase (AB), a value of 30° will be applied automatically. Additional compensation is possible with the Angle Compensation setting in Breaker configuration. Additional compensation is only needed when voltages are measuring actual system voltage that is not aligned. The most common example of this is a sync check across a delta/wye potential transformer.

Common system combinations are shown in Table 10-3. This table assumes no step-up or step-down transformer between the two measurement voltages. If the zone includes a step-up or step-down transformer, change the nominal voltages accordingly.

Table 10-3. Sample System Combinations

Circuit 1	Phase Rotation	Source 2	Circuit 2	Required Angle Compensation
WYE	ABC	DAB	30°	30°
WYE	ABC	DAC	–30°	30°
DAB	ABC	WYE	–30°	0°
DAC	ABC	WYE	30°	240°
WYE	ACB	DAB	–30°	0°
WYE	ACB	DAC	30°	240°
DAB	ACB	WYE	30°	0°
DAC	ACB	WYE	–30°	120°

Breaker Duty Monitor

When the breaker opens, the current interrupted in each pole of the circuit breaker is accumulated by the breaker duty monitor. Breaker opening is defined by the breaker status monitoring function (Breaker Status). See the *Fault Reporting* chapter for information on breaker status during a fault and protective trip.

Each time the breaker trips, the breaker duty monitor updates two sets of registers for each pole of the breaker. In the Accumulated I Duty registers, the breaker duty monitor adds the measured current in primary amperes. In the Accumulated I^2 Duty registers, the function adds the measured current in primary amperes squared. The user selects which of the two sets of duty registers are reported and monitored when setting up the breaker duty monitor.

Even though duty register values are calculated and stored in primary amperes or primary amperes-squared, the duty value is reported as a percent of maximum. The user sets the value that the BE1-FLEX will use for 100 percent duty (Max Duty). The Exponent setting allows for exponential influence to the duty value. The value set for maximum duty is used directly for reporting the accumulated duty. The exponent scaled of the value is used for reporting the accumulated duty.

Since the true measure of contact wear includes a factor for arcing time (t), an assumed arcing time for the breaker should be included when choosing the setting for 100 percent interruption duty (Max Duty).

Breaker Settings

Navigation Path: Configuration, Breaker Summary, Breaker

A breaker must first be added using BESTCOMS*Plus* to provide Breaker Status and Breaker Control for the 25 and 25A elements, and Breaker Operation details in Fault Reporting. The Breaker Summary screen is shown in Figure 10-18. Click the Add Function button to add a breaker. Click the Breaker State colored indicator or expand and click the newly created breaker in the settings tree explorer to view breaker settings (Figure 10-19).

Breaker instances only view Circuit Phase sources and ultimately require settings with two or more circuits created for sync check and auto-synchronization functions. It is common to apply VA, VB, VC hardware to the Circuit 1 and VX hardware set as Circuit 2 phase voltage for this purpose.

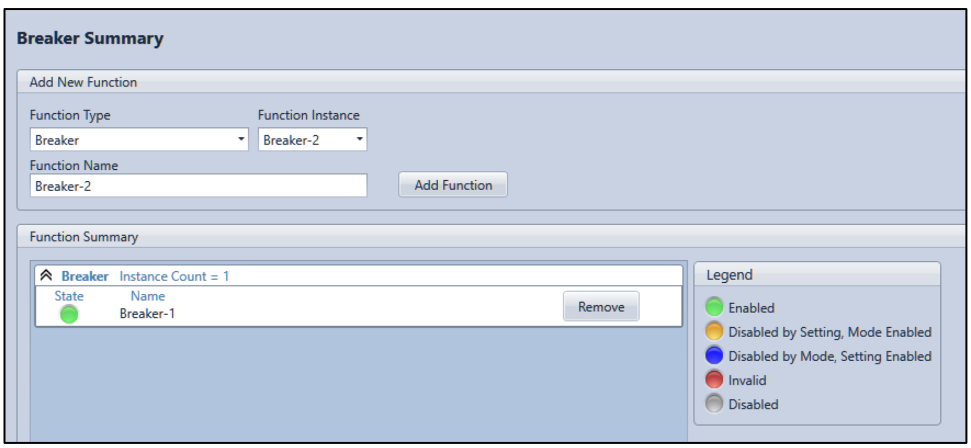


Figure 10-18. Breaker Summary Screen

Figure 10-19. Breaker Settings

The Breaker Monitor settings screen is shown in Figure 10-20.

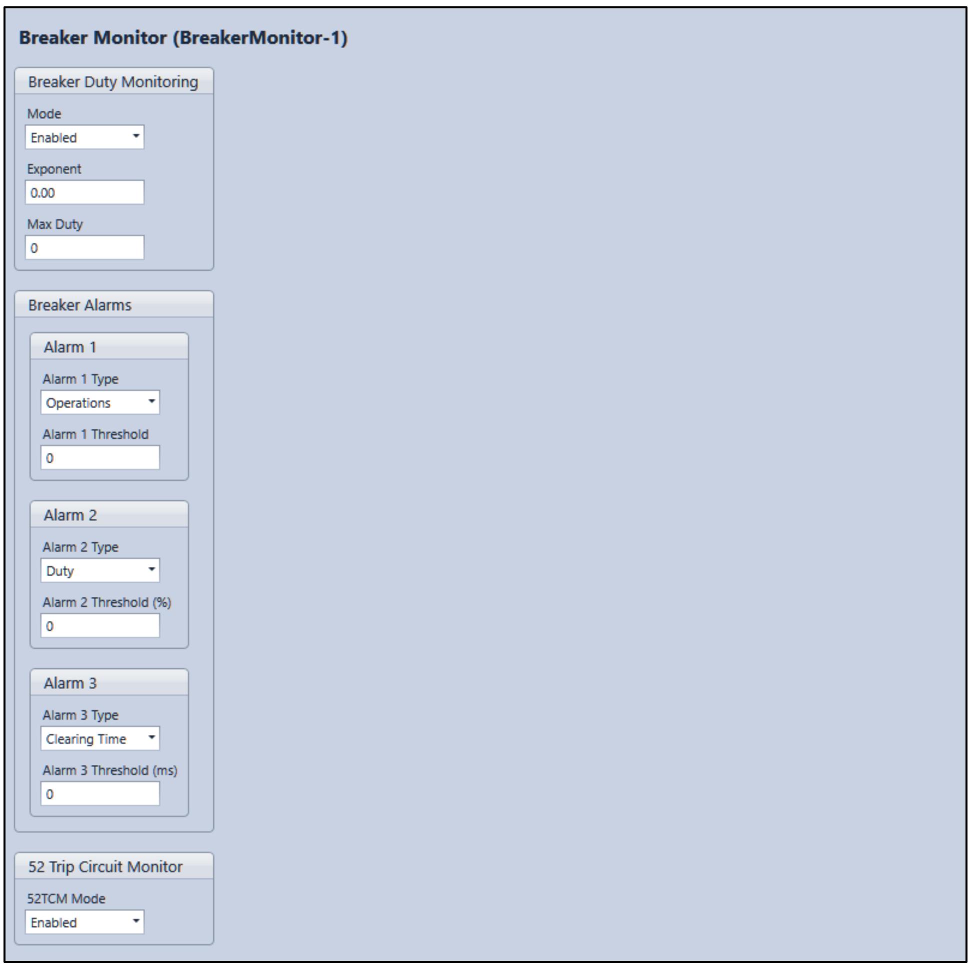


Figure 10-20. Breaker Monitor Settings

Table 10-4 summarizes the Breaker Duty Monitoring settings.

Table 10-4. Breaker Duty Monitoring Settings

Function	Purpose
Mode	Disabled or Enabled
Exponent	1 to 3 in increments of 0.01
Max Duty	0 to 42,000,000 in increments of 1 The Max Duty parameter represents the maximum duty that the breaker contact is designed to withstand before needing service. Max Duty is programmed in primary amperes using exponential floating-point format.

Breaker Alarms

Three alarm points are included in the programmable alarms for checking breaker monitoring functions. Each alarm point can be programmed to monitor any of the three breaker monitoring functions, operations counter, interruption duty, or clearing time. An alarm threshold can be programmed to monitor each function. Alternately, three different thresholds can be programmed to monitor one of the monitored functions. Multiple alarms are commonly implemented to alarm for increasingly more likely breaker failure conditions.

Breaker Monitor Logic Block

Breaker Monitor logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The Breaker Monitor logic block is illustrated in Figure 10-21. Logic inputs and outputs are summarized in Table 10-5.

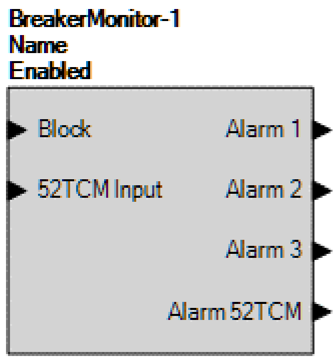


Figure 10-21. Breaker Monitor Logic Block

Table 10-5. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Blocks Breaker Duty accumulation
52TCM Input	Input	Contact sense input for Trip Circuit Monitoring functionality
Alarms 1, 2, 3	Output	True when the respective alarm threshold is met
Alarm 52TCM	Output	True when the Trip Circuit is determined to be non-continuous. Requires 52TCM Input

Breaker Status Reporting

Note
The Breaker Status logic node was updated in firmware version 1.01.00. If a settings file from a version prior to 1.01.00 is updated to version 1.01.00 or later and includes breaker status nodes, the original node will show as a validation error. To correct, delete the original Breaker Status logic block and replace it with the updated Breaker Status logic block in the Logic Elements library in BESTlogic*Plus* Programmable Logic.

The breaker status monitoring function monitors the position of the breaker for reporting and control purposes. Opening breaker strokes are counted and recorded in the breaker operations counter register. Circuit breaker status is used by the 50BF, 60FL, 25A, and 52TCM functions. The breaker status logic block is shown in Figure 10-22.

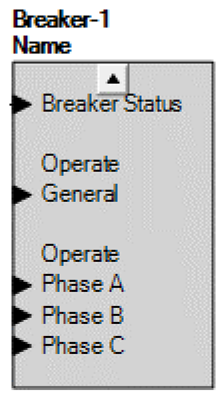


Figure 10-22. Breaker Status Logic Block

Since the BE1-FLEX is highly programmable, it is necessary to program which logic variable will monitor breaker status. Breaker status is programmed using BESTCOMS*Plus*®. Use the Settings Explorer to open the BESTlogic*Plus* Programmable Logic tree branch and select the Breaker logic block from the list of Elements. Use the drag and drop method to connect a variable or group of variables to the input. Refer to the *BESTlogicPlus* chapter for more information on setting BESTlogic*Plus* programmable logic. Breaker status is commonly determined by a 52a or 52b contact from the breaker to a BE1-FLEX contact input. A true Breaker Status input is considered a Closed breaker.

The Operate inputs of the Breaker Status logic block provide status to the IEC 61850 Op data objects of the associated PRTC node.

Retrieving Breaker Status Information

Navigation Path: Analog Metering, Breaker, Breaker

Breaker status can be viewed through BESTCOMS*Plus*, the front-panel display, and the web page interface. The Breaker Status metering screen is shown in Figure 10-23. To view breaker status at the front-panel display, navigate to Metering, Status, Breaker Monitor.

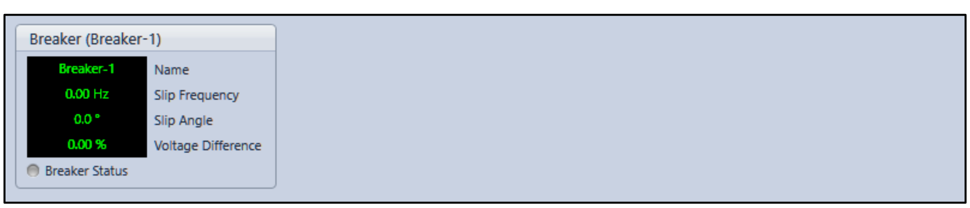


Figure 10-23. Breaker Status Metering

Retrieving Breaker Duty Operations Information

Navigation Path: Analog Metering, Breaker, Breaker Monitor

Breaker operations and duty can be viewed through BESTCOMS*Plus*, the front-panel display, and the web page interface. To view breaker status at the front-panel display, navigate to Metering, Status, Breaker Monitor. Duty values can be changed by using the touchscreen or BESTCOMS*Plus*. Write access to reports is required to edit breaker duty values. This allows the BE1-FLEX counter value to be matched to an existing mechanical cyclometer on a breaker mechanism.

The Breaker Monitor metering screen is shown in Figure 10-24.

Figure 10-24. Breaker Monitor Metering

Inputs

Over 50 programmable contact-sensing inputs are available by optional I/O boards. Contact sensing inputs with programmable signal conditioning provide a binary logic interface to the protection and control system. Each input function and label is programmable using BESTlogic*Plus*. A user-meaningful label can be assigned to each input and to each state (energized and de-energized) for use in reporting functions. All inputs are isolated, unless specifically noted to have a shared common. Each contact sensing input range is software selectable.

To enhance flexibility, the input circuits are designed to work on 24 V, 48 V, 125 V, or 250 V based on a per-board setting. If sensed input voltage is significantly higher than the setting, the BE1-FLEX will change the input burden to prevent damage and an alarm will be issued. In this alarm condition, noise immunity on the contact sensing may be reduced.

The contact input circuits are polarity sensitive. When an ac wetting voltage is applied, the input signal is half-wave rectified by the opto-isolator diodes. The hardware contact inputs are mapped to settings-configured Inputs (IN-1, IN-2…). Each contact input is completely programmable so meaningful labels can be assigned to each input and the logic-high and logic-low states.

Energizing levels for the contact-sensing inputs are software selectable per board. See Table 10-6 for the contact-sensing minimum turn-on voltages.

Table 10-6. Contact-Sensing Turn-On Voltages

Sensing Level	Contact Sensing Turn-On Voltage*
24 V	Approximately 5 Vdc
48 V	26 to 38 Vdc
125 V	69 to 100 Vdc 56 to 97 Vac
250 V	138 to 200 Vdc 112 to 194 Vac

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

Digital Input Conditioning Function

Status of the contact-sensing inputs is checked every 1 millisecond. User-settable digital contact recognition and de-bounce timers condition the signals applied to the inputs. These parameters can be adjusted to obtain the optimum compromise between speed and security for a specific application. (See Figure 10-25.)

If the sampled status of a monitored contact is detected as energized for the recognition time, the logic variable changes from a de-energized (logic 0 or false) state to an energized (logic 1 or true) state. Once contact closure is recognized, the logic variable remains in the energized state until the sampled status of the monitored contact is detected to be de-energized for a period that is longer than the debounce time. At this point, the logic variable will change from an energized (logic 1 or true) state to a de-energized (logic 0 or false) state.

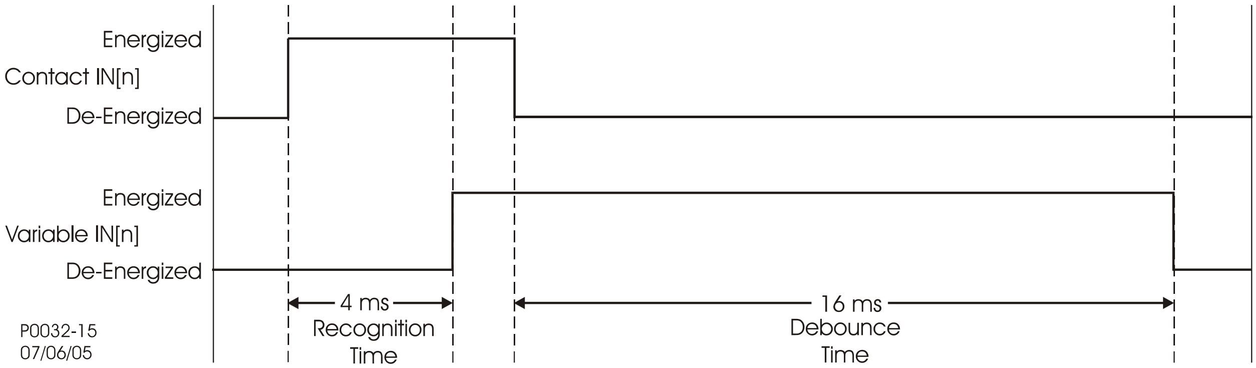


Figure 10-25. Digital Input Conditioning Timing Diagram

Input Range Configuration

Navigation Path: Configuration, Hardware Configuration, Hardware Info

Contact sensing input ranges are set on the Hardware Info settings screen as shown in Figure 10-26.

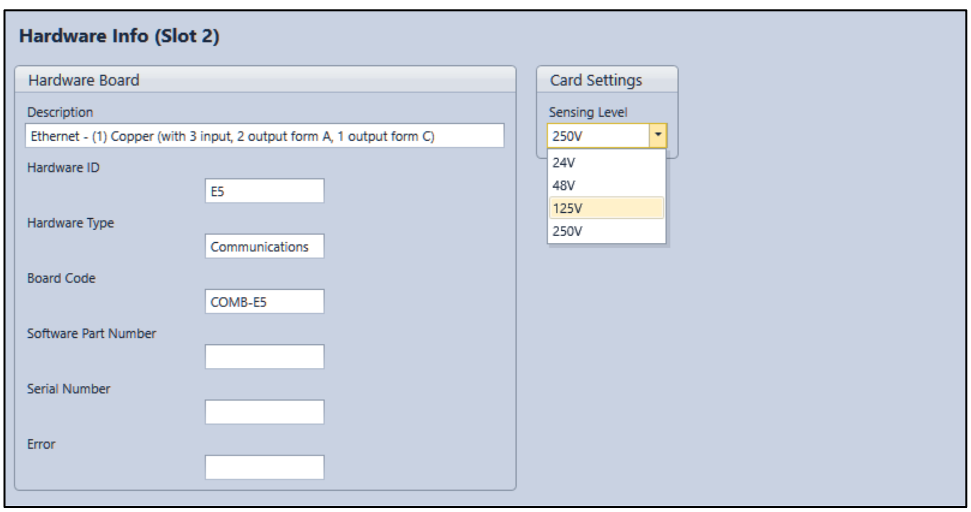


Figure 10-26. Hardware Info

Input Settings

Navigation Path: Configuration, Input Summary

A hardware input must first be mapped to a settings Input using BESTCOMS*Plus* to utilize it in logic or other control functions. The Input Summary screen is shown in Figure 10-27. Click the Input State colored indicator or expand and click the newly created Input in the settings tree explorer to view input settings (Figure 10-28).

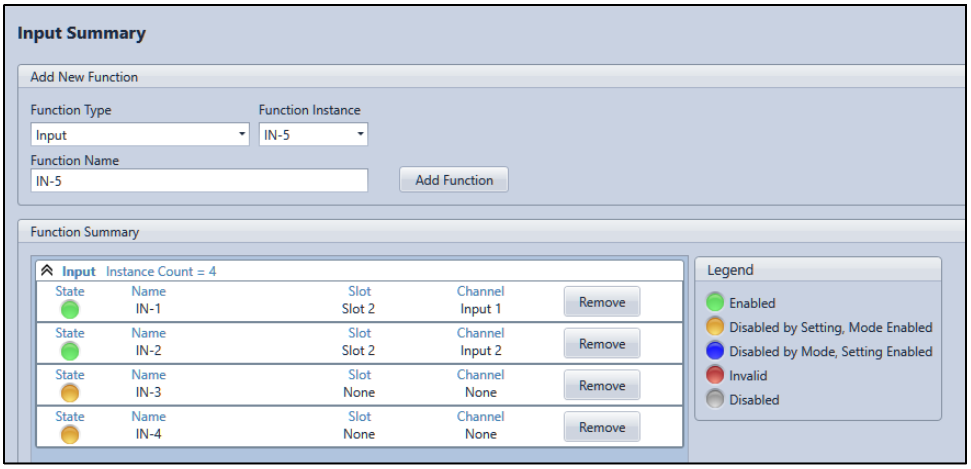


Figure 10-27. Input Summary

Settings and labels for the contact inputs are set using BESTCOMS*Plus*®. The settings are Recognition Time and Debounce Time. The labels include a label to describe the input, a label to describe the Energized State, and a label to describe the De-Energized State. Labels are used by the BE1-FLEX's reporting functions.

Figure 10-28. Input Settings

Table 10-7 lists the input setting parameters and their defaults.

Table 10-7. Contact Input Settings

Setting	Range	Increment	Unit	Default
Name	User programmable name for the input contact. Used by the reporting function to give meaningful identification to the input contact. This name can be up to 64 characters long.			
Recognition Time	4 to 255	1 *	milliseconds	4
Debounce Time	4 to 255	1 *	milliseconds	16
Energized State	User programmable label for the energized state of the contact. Used by the reporting function to give meaningful identification to the state of the input contact. This label can be up to 64 characters long.			
De-Energized State	User programmable label for the de-energized state of the contact. Used by the reporting function to give meaningful identification to the state of the input contact. This label can be up to 64 characters long.			

* Since the input conditioning function is evaluated every quarter cycle, the setting is internally rounded to the nearest multiple of 4.16 milliseconds (60 Hz systems) or 5 milliseconds (50 Hz systems).

If you are concerned about ac voltage being coupled into the contact sensing circuits, the recognition time can be set higher than one-half of the power system cycle period. This will take advantage of the half-wave rectification provided by the input circuitry.

If an ac wetting voltage is used, the recognition time can be set to less than one-half of the power system cycle period and the debounce timer can be set to greater than one-half of the power system cycle period. The extended debounce time will keep the input energized during the negative half-cycle. The default settings of 4 and 16 milliseconds are compatible with ac wetting voltages.

Settings for contact inputs can also be entered through the front panel.

See the *Hardware Configuration* chapter for an illustration of the input terminals. Contact input electrical ratings are listed in the *Specifications* chapter.

Retrieving Contact-Sensing Input Status

Contact input status can be seen through BESTCOMS*Plus* by using the Metering Explorer BESTlogic*Plus* view when incorporated into logic and all points via Status-Input metering. BESTCOMS*Plus* must be online with the BE1-FLEX to view contact input status. Alternately, status can be determined through the front-panel display by navigating to Metering > Status > Inputs. Contact Sense inputs are commonly also applied to HMI Indicators for annunciation.

Outputs

The BE1-FLEX's wide range of board populations allows it to have a wide variety of contact output counts. Board options are available for Form A, Form C, or a combination of Form A and Form C outputs. Form A outputs are all normally open. Form C contacts have both a normally open and normally closed contact.

See the *Terminals and Connectors* chapter for an illustration of the programmable output terminals. Contact output electrical ratings are listed in the *Specifications* chapter.

Similar to Inputs, hardware outputs are mapped to settings Outputs in settings Configuration. Each output is isolated and rated for tripping duty. The use of each contact output is completely programmable so you can assign meaningful labels to each output and to the logic 0 and logic 1 states of each output. The *BESTlogicPlus* chapter has more information about programming output expressions in your programmable logic schemes.

BESTlogic*Plus* expressions for Outputs drive contact outputs. The state of the contact outputs can vary from the state of the output logic expressions for any one of three reasons:

1. The relay trouble alarm disables all hardware outputs and they return to their normal state,
2. The programmable hold timer is active, or
3. The select-before-operate function overrides a virtual output.

Figure 10-29 shows a diagram of the contact output logic for the general-purpose contact outputs. The OUT-1 relay closes when the 50-1 element is in a trip condition.

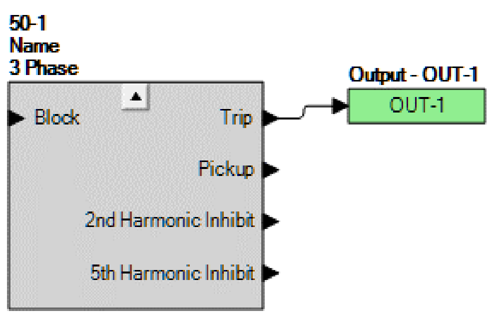


Figure 10-29. Output Logic, General Purpose Contact Outputs

Programmable Hold Timer—Hold Attribute

Historically, electromechanical relays have provided trip contact seal-in circuits. These seal-in circuits consisted of a dc coil in series with the relay trip contact and a seal-in contact in parallel with the trip contact. The seal-in feature serves several purposes for electromechanical relays. One purpose is to provide mechanical energy to drop the target. A second purpose is to carry the dc tripping current from the induction disk contact, which may not have significant closing torque for a low resistance connection. A third purpose is to prevent the relay contact from dropping out until the current has been interrupted by the 52a contacts in series with the trip coil. If the tripping contact opens before the dc current is interrupted, the contact may be damaged. Of the three items, only item three is an issue for electronic protection systems like the BE1-FLEX and is increasingly important with legacy breakers with longer clearing times. Output hold default is enabled to 200 ms. When enabled, the settings range is 4 to 2,000 ms.

Contact Output Seal-In Logic

To prevent the output relay contacts from opening prematurely, a hold timer (4 to 2,000 ms) can be set with BESTCOMS*Plus*. If desired, seal-in logic with feedback from the breaker position logic can provide this function by modifying the logic for the tripping output. To do this, use one of the general purpose timers (62) and set it for Pickup/Dropout mode. Set the timer logic so that it is initiated by the breaker position input and set the timer for 2 cycles pickup and 2 cycles dropout. The same can be done for the closing output. Figure 10-30 provides a seal-in logic diagram.

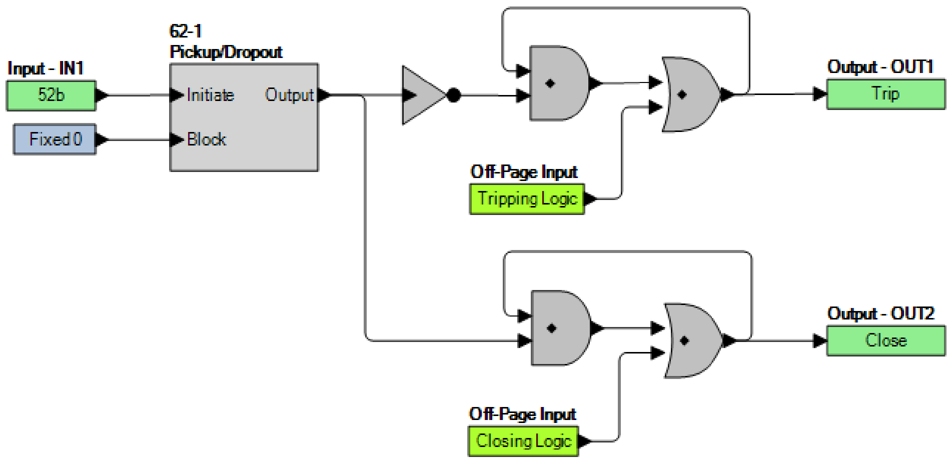


Figure 10-30. Contact Output Seal-In Logic Diagram

Output Settings

Navigation Path: Configuration, Output Summary

An output must first be added using BESTCOMS*Plus* to utilize in logic and drive physical outputs. The Output Summary screen is shown in Figure 10-31. Click the Output State colored indicator or expand and click the newly Output in the settings tree explorer to view output settings (Figure 10-32).

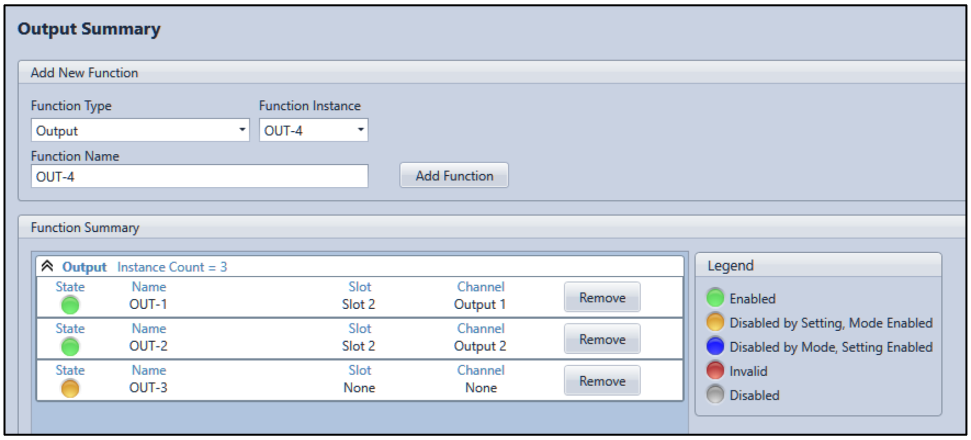


Figure 10-31. Output Summary

Settings and labels for the contact outputs are set using BESTCOMS*Plus*®. The labels include a label to describe the output, a label to describe the Energized State, and a label to describe the De-Energized State. Labels are used by the BE1-FLEX's reporting functions. See Figure 10-32.

Figure 10-32. Output Settings

Alarm Output

Any output can be configured as an alarm output. It is common to use the normally-closed contact of a Form C output for an alarm so that the contact is closed during relay trouble conditions as well as when the relay is powered off due to control power or power supply conditions. A NOT or NOR gate is used to open a normally closed contact when the BE1-FLEX is powered on and does not have a relay trouble or alarm condition. See Figure 10-33.

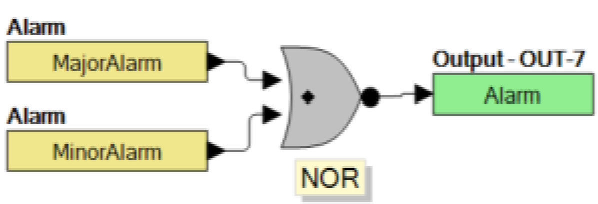


Figure 10-33. Alarm Logic

Contact Output Logic Override Control

Navigation Path: Control, Output Override

Each contact output can be controlled directly using the output control function. The output logic expression that normally controls the state of an output can be overridden and the contact pulsed, held open, or held closed. This function is useful for testing or manual control purposes. An alarm point is available in the programmable alarm function for monitoring when the output logic has been overridden. See the *Alarms* chapter for more information about programmable alarms. Output logic override control is achieved using the front-panel interface or BESTCOMS*Plus*. Use the Metering Explorer to open the Control, Output Override screen. Refer to Figure 10-34.

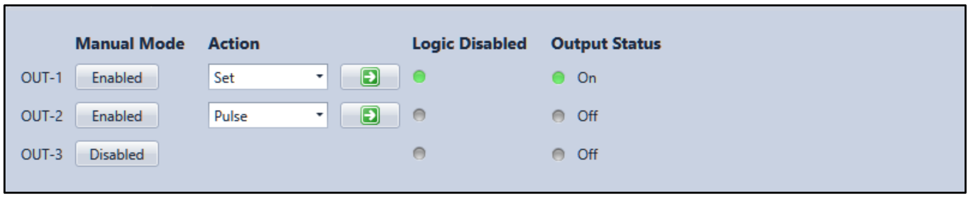


Figure 10-34. Output Override Screen

Enabling Logic Override Control

By default, logic override control is disabled. Output logic override must be enabled before the control can be used. It can be enabled through a communication port using BESTCOMS*Plus* (Figure 10-34). Click the Disabled button next to the output you want to control. This button will change to Enabled and the following three action choices will appear to the right: Reset, Set, and Pulse. Logic Override Control can also be enabled through the front-panel interface on the Control, Output Override screen.

Pulsing a Contact Output

Pulsing BE1-FLEX outputs provides the user the ability to test the operability of an output without energizing a measuring or timing element. This feature is useful when testing the control circuit continuity and contact health. When pulsed, an output changes from the current state (as determined by the virtual output logic expression) to the opposite state for 200 milliseconds. After 200 milliseconds, the output is returned automatically to logic control.

In the Action column, select Pulse from the drop-down menu and click on the green arrow to the right. Pulse override control can also be accessed at the Control, Output Override screen of the front-panel display by selecting Pulse in the Action field for the output contact to be pulsed.

Changing the State of a Contact Output

Outputs can be forced to an energized (logic 1 or true) state or to a de-energized (logic 0 or false) state. This feature can be used to disable a contact during testing.

In the Action column, select Set or Reset from the drop-down menu and click on the green arrow to the right. Contact output override control can also be accessed at the Control, Output Override screen of the front-panel display by selecting Set or Reset in the Action field for the contact output to be controlled.

Returning a Contact Output to Logic Control

When the output logic has been overridden and the contact is held in an energized or de-energized state, it is necessary to return the output to logic control.

Click the Enabled button next to the output you want to change to logic control. This button changes to Disabled and the action choices disappear. Logic control can also be achieved at the Control, Output Override screen of the front-panel display by setting Enabled to Disabled.

Retrieving Contact Output Status

Output status is determined through BESTCOMS*Plus* by using the Metering Explorer to open the Status, Output tree branch. BESTCOMS*Plus* must be online with the BE1-FLEX to view contact output status. Alternately, status can be determined through the front-panel display by navigating to Metering, Status, Outputs.

Analog Inputs

Analog transducers can provide analog metering and communications when digital is impractical, unavailable and in legacy systems. Analog inputs utilize 0 to 10 V and 4 to 20 mA signals to linearly scale any desired parameter, such as Pressure (PSI). When measured by the BE1-FLEX, the value can be scaled and labeled as desired to real values for digital communication, recording, alarm, and protection.

Analog inputs can be selected in Configurable Protection. See the *Configurable Protection* chapter for details.

Analog Input Settings

Navigation Path: Configuration, Analog Input Summary

An analog must first be added using BESTCOMS*Plus* to utilize through the remainder of the settings and metering. The Analog Input Summary screen is shown in Figure 10-35. Click the Analog Input State colored indicator or expand and click the newly created Analog Input in the settings tree explorer to view analog input settings (Figure 10-36).

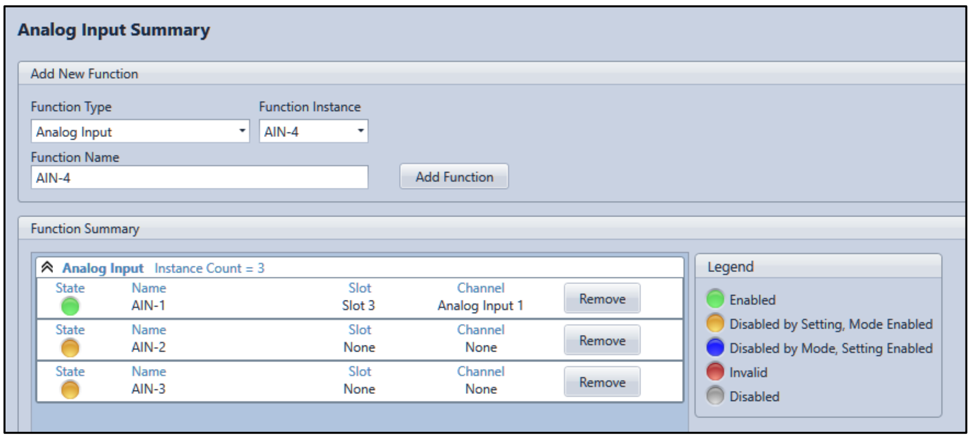


Figure 10-35. Analog Input Summary

Enter a Name for the analog input as desired. Select the Input Slot and Channel. Set the Analog Input Type to either Voltage or Current. Enter the Parameter Minimum/Maximum and Minimum/Maximum Voltage or Current.

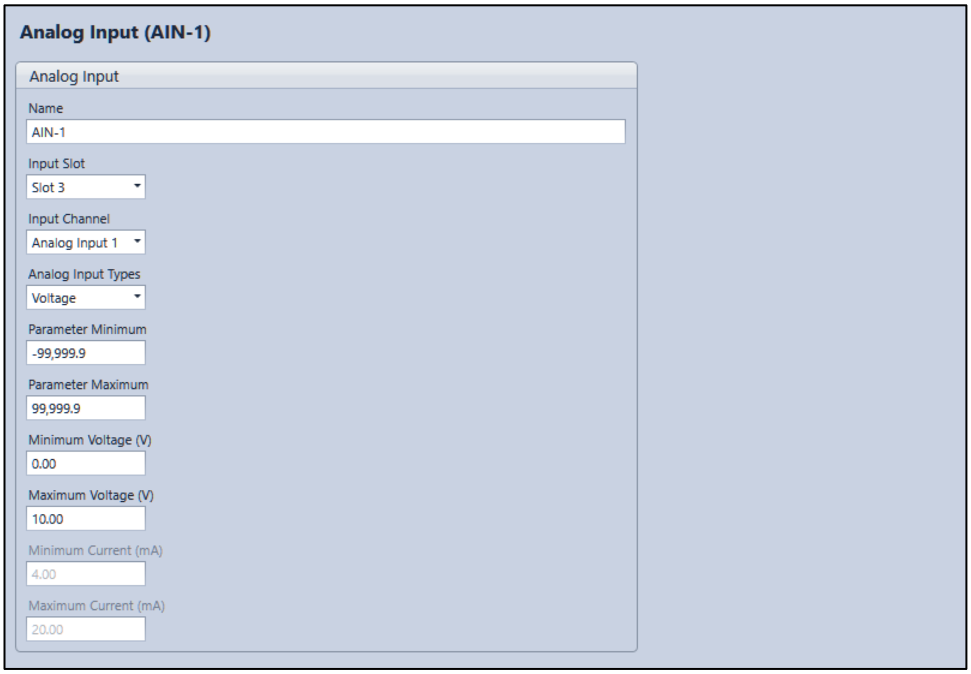


Figure 10-36. Analog Input Settings

Analog Input Metering

Analog input metering values, as raw and scaled values, are obtained through BESTCOMS*Plus* by using the Metering Explorer to open the Analog Metering, Analog Input tree branch shown in Figure 10-37. BESTCOMS*Plus* must be online with the BE1-FLEX to view analog input metering. Alternately, values can be obtained through the front-panel display by navigating to the Metering, Analog Metering, Analog Input screen.

Exceeding the range indicates that the Analog Input may be shorted or open and cannot be relied on to provide reliable protection or control. An Out of Range Alarm is available to detect this condition.

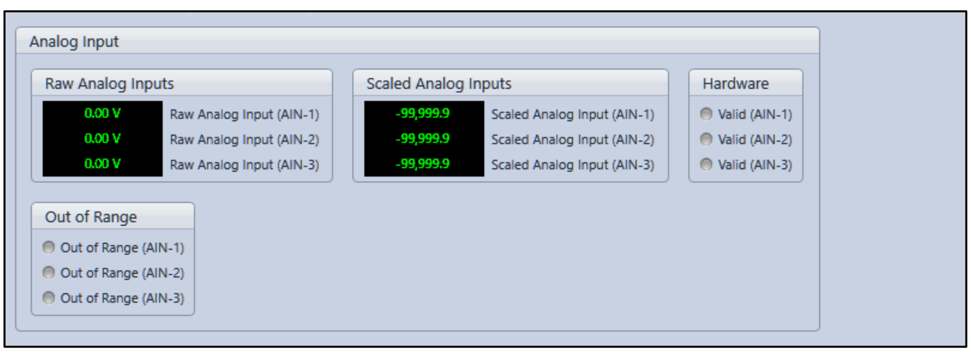


Figure 10-37. Analog Input Metering

RTD Inputs and Groups

Resistance Temperature Detector (RTD) sensors transmit temperature information to a device such as the BE1-FLEX for metering, recording, alarm, and protection. Temperature measurements are used in a wide variety of applications, including Transformer, Motor, Generator, Ambient, and other applications not directly Power System related.

RTD Inputs are viewed and utilized as individual measurements. Temperature is commonly measured at several points for reliability purposes and grouped, commonly with rotating machine stators and bearings. Using Group RTDs allows cumulative reliability decision making. RTD Groups provide individual and maximum of the group values for metering and protection.

RTD inputs and groups can be selected in Configurable Protection and 49RTD elements. See the *Configurable Protection* and *Resistance Temperature Detector (49RTD)* chapters for details.

RTD Input Settings

Navigation Path: Configuration, RTD Input Summary

An RTD input must first be added using BESTCOMS*Plus* to utilize through the remainder of the settings and metering. The RTD Input Summary screen is shown in Figure 10-38. Click the RTD Input State colored indicator or expand and click the newly created RTD Input in the settings tree explorer to view RTD input settings (Figure 10-39).

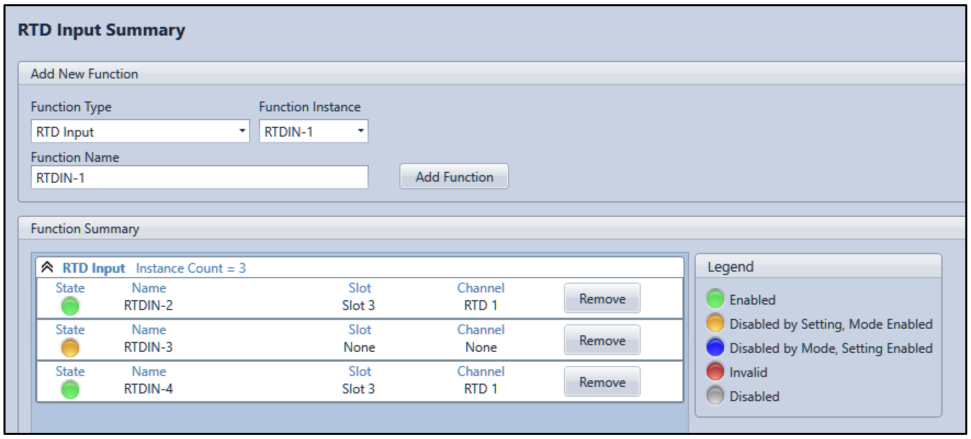


Figure 10-38. RTD Input Summary

Enter a Name for the RTD input. Select the Input Slot and Channel. Select the RTD ratings (Copper, Platinum, Nickel 100, or Nickel 120).

Figure 10-39. RTD Input Settings

The range of operation possible before indicating an Out of Range condition for each RTD type is detailed in Table 10-8. Exceeding the range indicates that the RTD may be shorted or open and cannot be relied on to provide reliable protection and control. An Out of Range Alarm is available to detect this condition.

Table 10-8. RTD Ranges

Type	Min Temp (°C)	Max Temp (°C)	Min Temp (°F)	Max Temp (°F)
Copper	–100	260	–148	500
Platinum	–200	660	–328	1220
Nickel 100	–60	180	–76	356
Nickel 120	–80	225	–112	437

Display Units

Navigation Path: General Settings, Display Units

The temperature values in BESTCOMS*Plus* metering and on the front-panel HMI can be set to display Fahrenheit or Celsius values. The Display Units setting screen is show in Figure 10-40.

Figure 10-40. Display Units Setting

RTD Input Metering

Navigation Path: Analog Metering, RTD Input

RTD input metering values are obtained through BESTCOMS*Plus* by using the Metering Explorer to open the Analog Metering, RTD Input tree branch shown in Figure 10-41. BESTCOMS*Plus* must be online with the BE1-FLEX to view RTD input metering. Alternately, values can be obtained through the front-panel display by navigating to the Metering, Analog Metering, RTD Input screen.

Figure 10-41. RTD Input Metering

RTD Group Settings

Navigation Path: Configuration, RTD Group Summary

An RTD group must first be added using BESTCOMS*Plus*. The RTD Group Summary screen is shown in Figure 10-42. Click the RTD Group State colored indicator or expand and click the newly created RTD Group in the settings tree explorer to view RTD group settings (Figure 10-43).

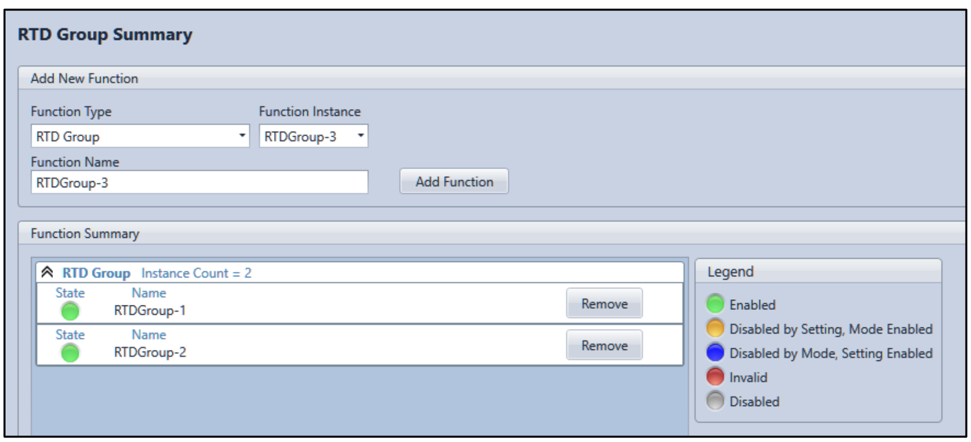


Figure 10-42. RTD Group Summary

Enter a Name for the RTD group. Select the RTD Inputs to add to the group.

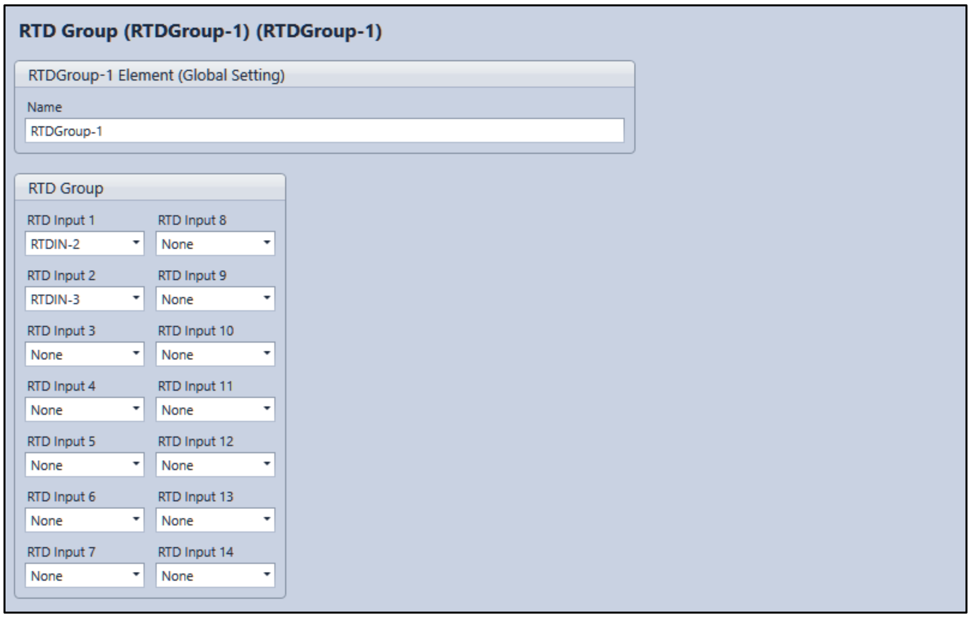


Figure 10-43. RTD Group Settings

RTD Group Metering

Navigation Path: Analog Metering, RTD Group

RTD group metering values are obtained through BESTCOMS*Plus* by using the Metering Explorer to open the Analog Metering, RTD Group tree branch shown in Figure 10-44. BESTCOMS*Plus* must be online with the BE1-FLEX to view RTD group metering. Alternately, values can be obtained through the front-panel display by navigating to the Metering, Analog Metering, RTD Group screen.

Figure 10-44. RTD Group Metering

Shunt Inputs

Similar to Current Transformers for ac circuits, shunts are typically utilized to measure direct current (dc) in a variety of applications such as synchronous machine fields. The mV shunt inputs on the BE1-FLEX are suitable for systems with rated voltage with respect to ground up to 200 Vdc or 200 Vac rms and dc power systems. Applications with higher voltages require external electrical isolation.

Shunt inputs and groups can be selected in the 76 and Configurable Protection elements. See the *DC Overcurrent (76)* and *Configurable Protection* chapters for details.

Shunt Input Settings

Navigation Path: Configuration, Shunt Input Summary

A shunt input must first be added using BESTCOMS*Plus* to utilize through the remainder of the settings and metering. The Shunt Input Summary screen is shown in Figure 10-45. Click the Shunt Input State colored indicator or expand and click the newly created Shunt Input in the settings tree explorer to view shunt input settings (Figure 10-46).

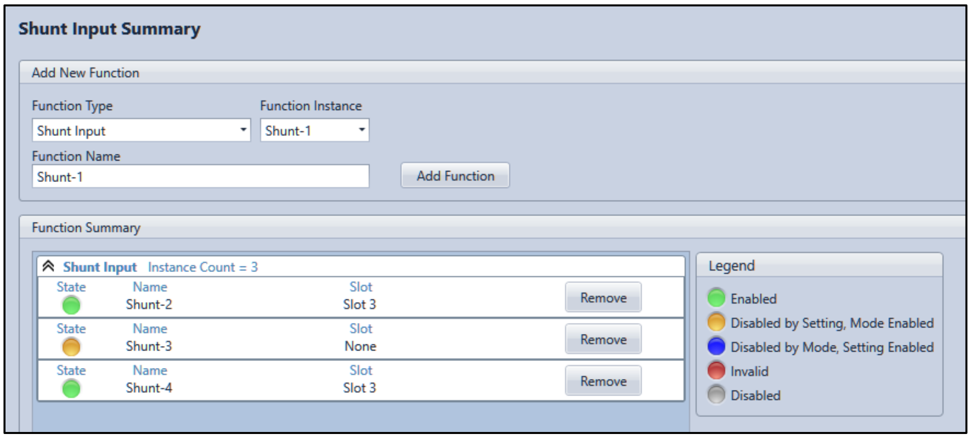


Figure 10-45. Shunt Input Summary

Enter a Name for the shunt input. Select the Input Slot, Shunt Rating (50 or 100 mV), and full-scale value (at shunt rating) of rated current.

Figure 10-46. Shunt Input Settings

Shunt Input Metering

Navigation Path: Analog Metering, Shunt Input

Shunt input metering values are obtained through BESTCOMS*Plus* by using the Metering Explorer to open the Analog Metering, Shunt Input tree branch shown in Figure 10-47. BESTCOMS*Plus* must be online with the BE1-FLEX to view shunt input metering. Alternately, values can be obtained through the front-panel display by navigating to the Metering, Analog Metering, Shunt Input screen.

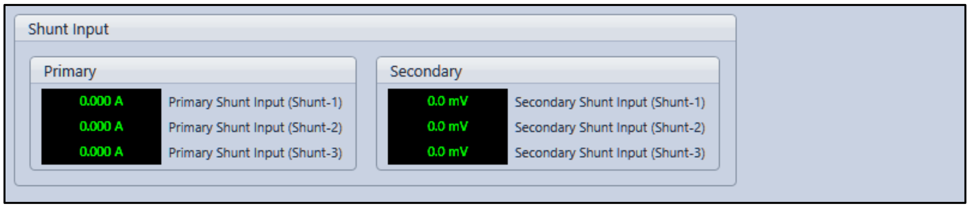


Figure 10-47. Shunt Input Metering

11 • Device Information

BE1-FLEX identification labels, firmware version, serial number, and style number are found on the Device Info screen in BESTCOMS*Plus*®.

Device Info

Unlike protection settings and logic, items such as Network IP addresses cannot be equal across multiple devices in a system. For this reason, Device Information is a subset to the full settings that are typically unique to an individual device. Device info settings can be included or excluded from a settings file upload as desired.

Information about a BE1-FLEX communicating with BESTCOMS*Plus* can be obtained on the Device Info screen of BESTCOMS*Plus* after downloading settings from the device.

To correctly show available settings, the application version must be selected when configuring BE1-FLEX settings offline. The application version will default to the most recent version known to the BESTCOMS*Plus* version used. When online, read-only information includes the application version, application date, application part number, boot version, boot date, model number, serial number, and style number.

BE1-FLEX systems have three identification fields: Device ID, Station ID, and User ID. These fields are used in the header information lines of the Fault Reports, Oscillograph Records, and Sequence of Events Records to avoid confusion over where a fault file originated. Device ID settings, such as “Feeder A1”, are typically unique within a system.

The BESTCOMS*Plus* Device Info screen is illustrated in Figure 11-1.

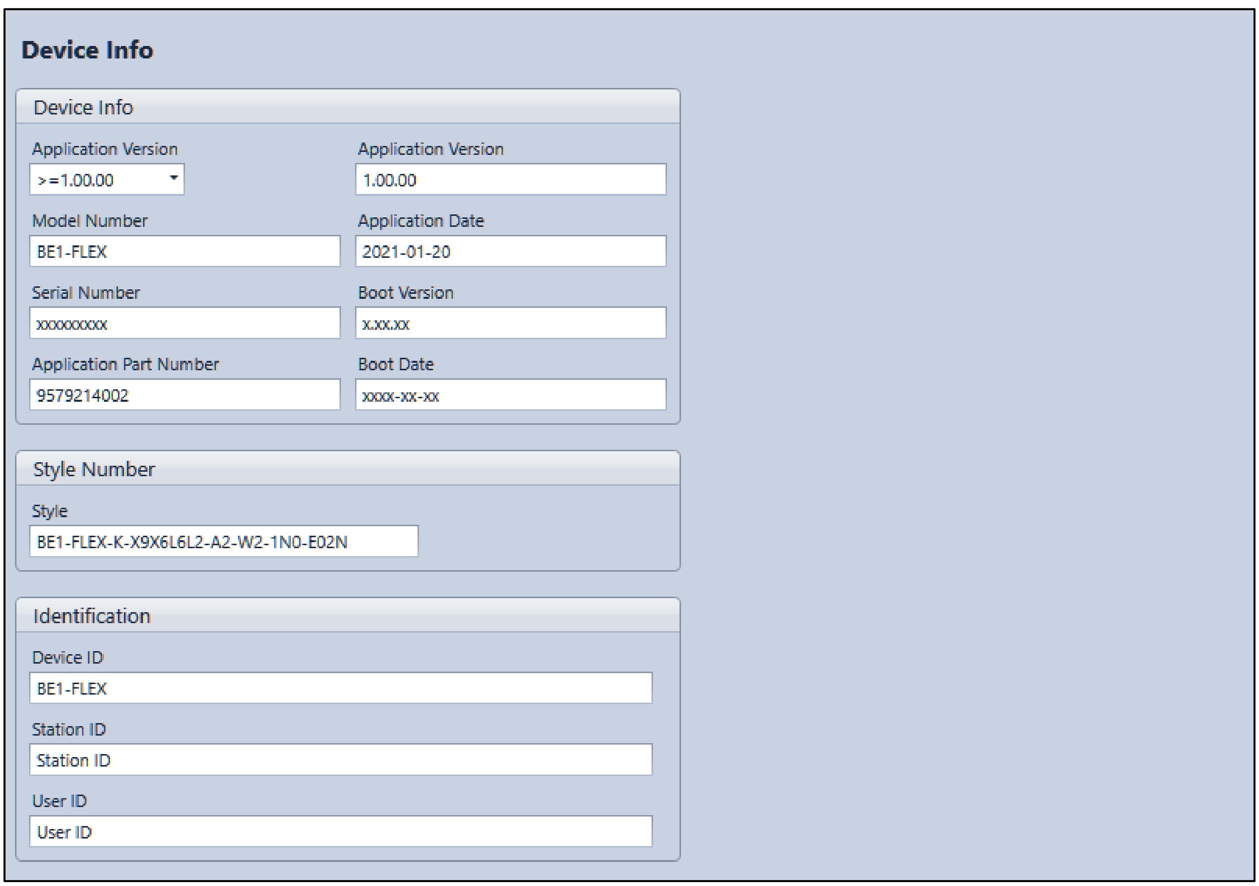


Figure 11-1. Device Info Screen

Network Configuration

Network configuration settings are described below.

Common Network Settings

Settings common to all Ethernet ports are configured on the Common Network Settings screen (Figure 11-2) in BESTCOMS*Plus*.

Domain Name System (DNS) and Allowed Web Server origins can be configured. If enabled in at least one circuit configuration, Synchrophasor communications is directed to Ethernet Port 1 or Ethernet Port 2 based upon the Synchrophasor Port setting.

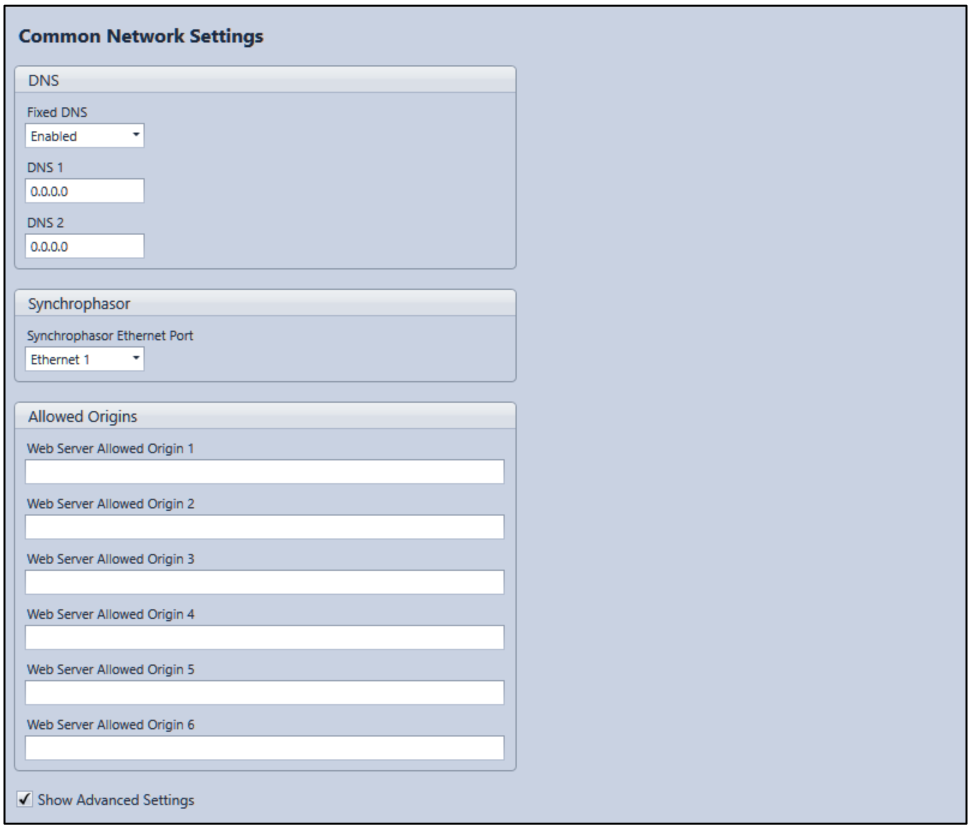


Figure 11-2. Common Network Settings Screen

Ethernet 1 and 2 Settings

Ethernet 1 and 2 settings are configured on the Ethernet Settings screens (Figure 11-3) in BESTCOMS*Plus*.

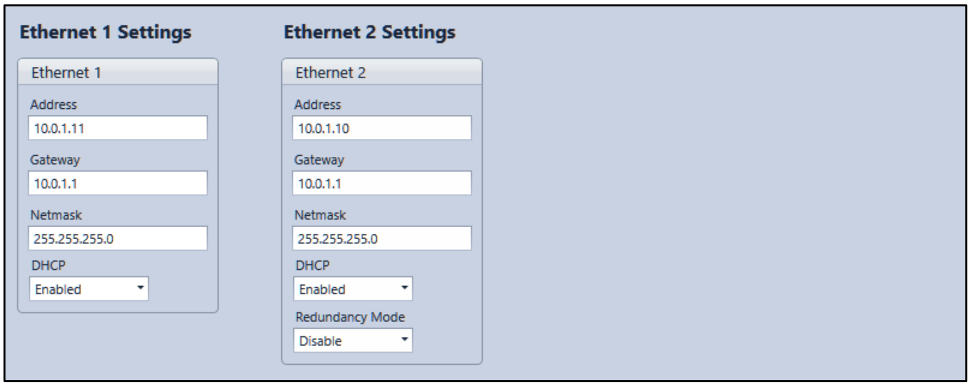


Figure 11-3. Ethernet 1 and 2 Settings Screens

Style Configurator

The model number, together with the style number, describes the options included in a specific device and appears on labels located on the front panel and inside the case.

The style number of the BE1-FLEX is displayed on the BESTCOMS*Plus* Style Configurator screen after downloading settings from the device. When configuring BE1-FLEX settings offline, the style number for the unit to be configured can be entered into BESTCOMS*Plus* to enable configuration of the required settings. Using the up and down arrows per board and button method to populate a style number is recommended for simplicity and consistency. BESTCOMS*Plus* automatically populates the style string in the same sequence as manufacturing unless overridden by the Style Configurator advanced settings method.

The BE1-FLEX uses abbreviated part numbers as a Style Code to simplify the style number. If BESTCOMS*Plus* recognizes the style code, it will populate the field. The full-configured style can be updated per the style code by using the Update Style button.

The Auto-Generate Instance button simplifies hardware to software configuration. Clicking the button will prompt creation of instances for Circuits, Inputs, Outputs, Analog Inputs, RTD Inputs, and Shunt Inputs based upon the displayed style. Instances can also be removed for functions invalid to the shown style number. Any removed or created instance block can be independently selected as shown in Figure 11-5. BESTCOMS*Plus* will prompt the user to auto-generation if navigating away from the Style Configuration page and instance configuration has not yet been updated.

The Update Instance button will save the displayed configuration to allow the style options to be utilized in the settings file.

The BESTCOMS*Plus* Style Configurator screen is illustrated in Figure 11-4.

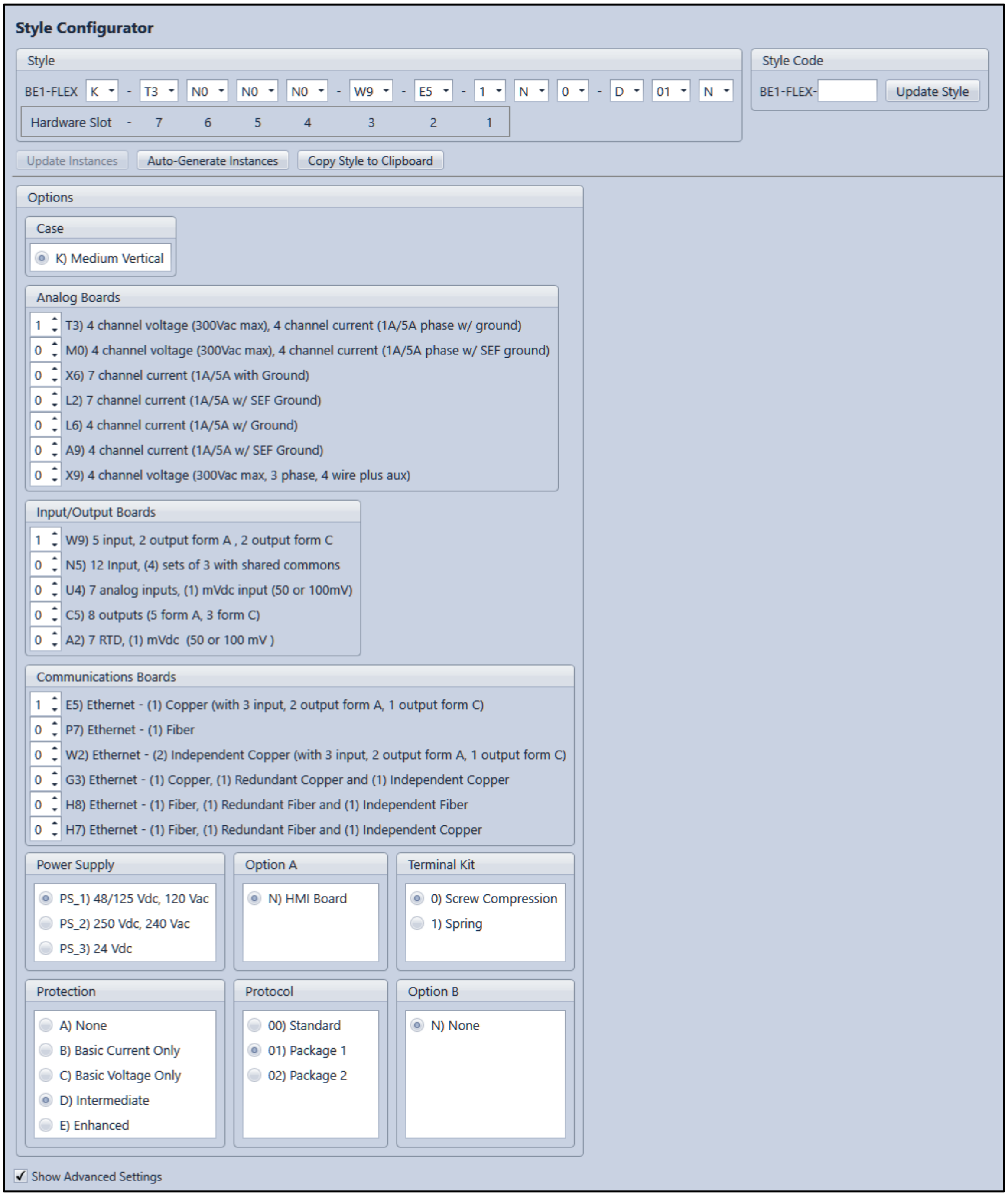


Figure 11-4. Style Configurator Screen

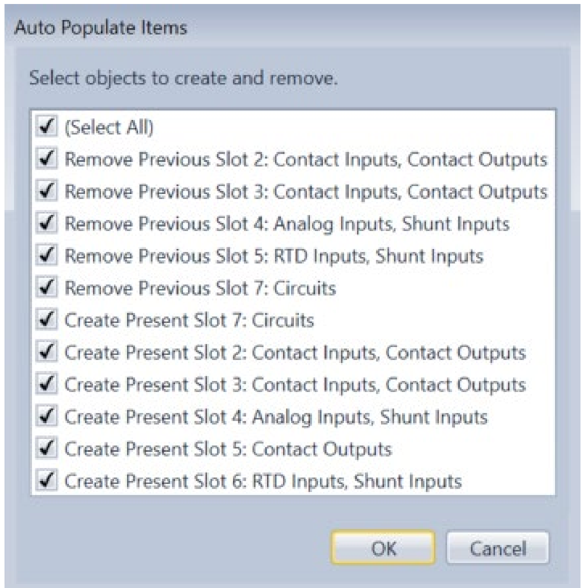


Figure 11-5. Auto-Generate Instance Screen

Firmware Update and Style Upgrade

Caution
Default settings will be loaded into the BE1-FLEX, reports and events will be cleared, and the BE1-FLEX will reboot when firmware is updated. BESTCOMS*Plus* can be used to download settings and save the settings in a file so that they can be restored after updating firmware. Refer to *Settings File Management* in the *BESTCOMSPlus Software* chapter for help with saving a settings file.

Maintaining the latest version of BE1-FLEX firmware ensures worry-free operation using the latest features and functions. If you have obtained a package file containing an updated firmware file for your device, you can upload it by selecting Upload System Files from the Communication pull-down menu on the main screen in BESTCOMS*Plus*. The System Files screen will appear. See Figure 11-6.

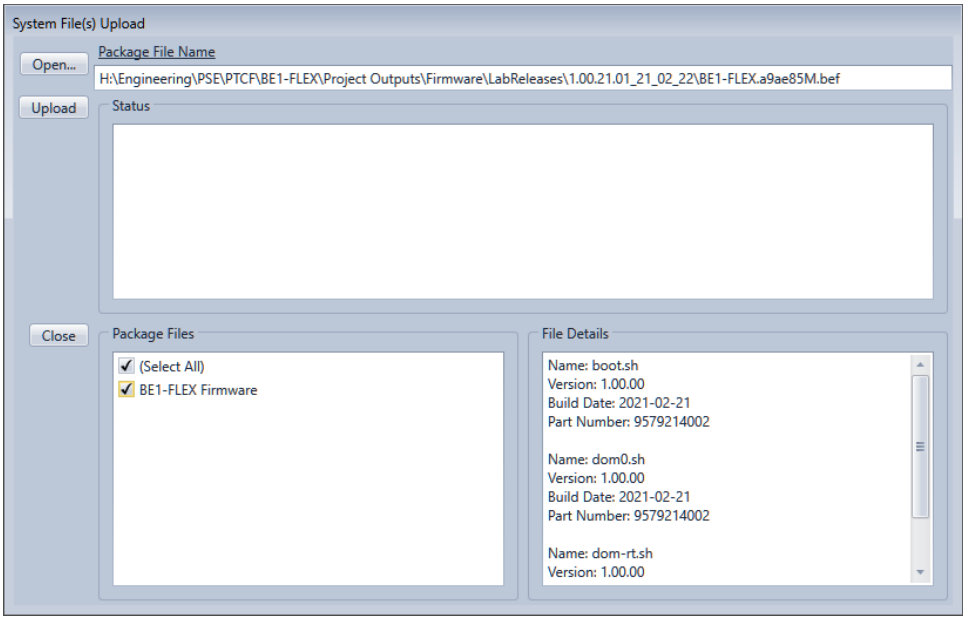


Figure 11-6. System Files Upload Screen

Use the Open button to browse for the device file that you obtained from Basler Electric. Place a checkmark next to the file you want to upload. Click the Upload button. The BE1-FLEX will reboot automatically after the firmware upload is complete.

After rebooting, the Relay Trouble LED on the front panel is lit and Defaults Loaded is displayed on the Relay Alarms screen. To reset the alarm, use the Metering Explorer in BESTCOMS*Plus* to navigate to the Status, Alarms screen and click the Reset Relay Trouble Alarms button. This alarm can also be reset through the front panel by navigating to Reports > Targets & Alarms and pressing the Reset Targets & Alarms button. Administrator access is required to reset the Defaults Loaded alarm. The default username is “**a**” and the default password is “**a**”. Alarm reset can also be set outside of security control, allowing reset without logging in. Refer to the *Security* chapter for more information. Upload your settings file to the BE1-FLEX.

12 • Timekeeping

The BE1-FLEX provides a real-time clock with capacitor backup that is capable of operating the clock for up to 24 hours after power is removed from the BE1-FLEX. As the capacitor nears depletion, an internal backup battery takes over and maintains timekeeping. The backup battery is standard and will maintain the clock for more than five years, depending on conditions.

The clock is used by the demand reporting function, the fault reporting function, the oscillography recording function, and the sequence of events recorder function to time-stamp events.

Clock Setup

Navigation Path: General Settings, Clock Setup

Clock settings are made through the communication ports using BESTCOMS*Plus*® or through the front-panel interface. Write access to ports is required to program the clock. An alarm point is provided in the programmable alarms to detect when the BE1-FLEX has powered up and the clock has not been set.

The clock settings are made through BESTCOMS*Plus* by selecting Clock Setup under General Settings. The BESTCOMS*Plus* Clock Setup screen is illustrated in Figure 12-1.

The date and time format and the local time zone are configured on this screen. The Time Zone Offset is the local offset to UTC (Coordinated Universal Time). The Time Zone Offset is required if NTP or IRIG-B is used for time synchronization or when the Start/End Time Reference is set to UTC. The Start/End Time Reference is set to UTC time if required by local DST (Daylight Savings Time) rules. The Start/End Hour/Minute settings determine the time when the DST will go into effect. The Bias setting is the amount of time that the clock moves forward or backward. The default settings are configured for the Central Time Zone in the United States as shown in Figure 12-1. Using these settings, the clock would move forward 1 hour at 2:00 a.m. on the second Sunday in March and move backward 1 hour at 2:00 AM on the first Sunday in November. DST can also be configured for a specific day of the month by selecting Fixed Dates under DST Configuration.

Protocols

There are three available protocols (DNP, NTP, and IRIG-B). The BE1-FLEX will combine measurements from the highest quality sources to update time. Typically, IRIG-B is the highest quality and will be used if available. NTP will be used if IRIG is unavailable (Disabled/Failed/Unstable). DNP will be used if no other time sources are active.

DNP3

DNP3 (Distributed Network Protocol 3) synchronizes the real-time clock to a DNP3 communications processor receiving IRIG-B when DNP3 is enabled in the BE1-FLEX.

DNP time synchronization can be set to Disabled, UTC, or Local Time. Setting to UTC will set the DNP time as UTC. Setting to Local Time will follow the Time Zone offset time.

NTP

NTP (Network Time Protocol) synchronizes the real-time clock to a network time server when an Ethernet cable is connected. An address of a valid NTP server must be entered. Up to four NTP sources can be entered.

IRIG-B

The relay accepts a demodulated IRIG-B time code input, which synchronizes the real-time clock when IRIG is connected.

When set to Standard, the year field is decoded in the IRIG signal. When set to Short, the year field is not decoded. Refer to the manufacturer of your equipment to determine if the year field is being sent to the BE1-FLEX.

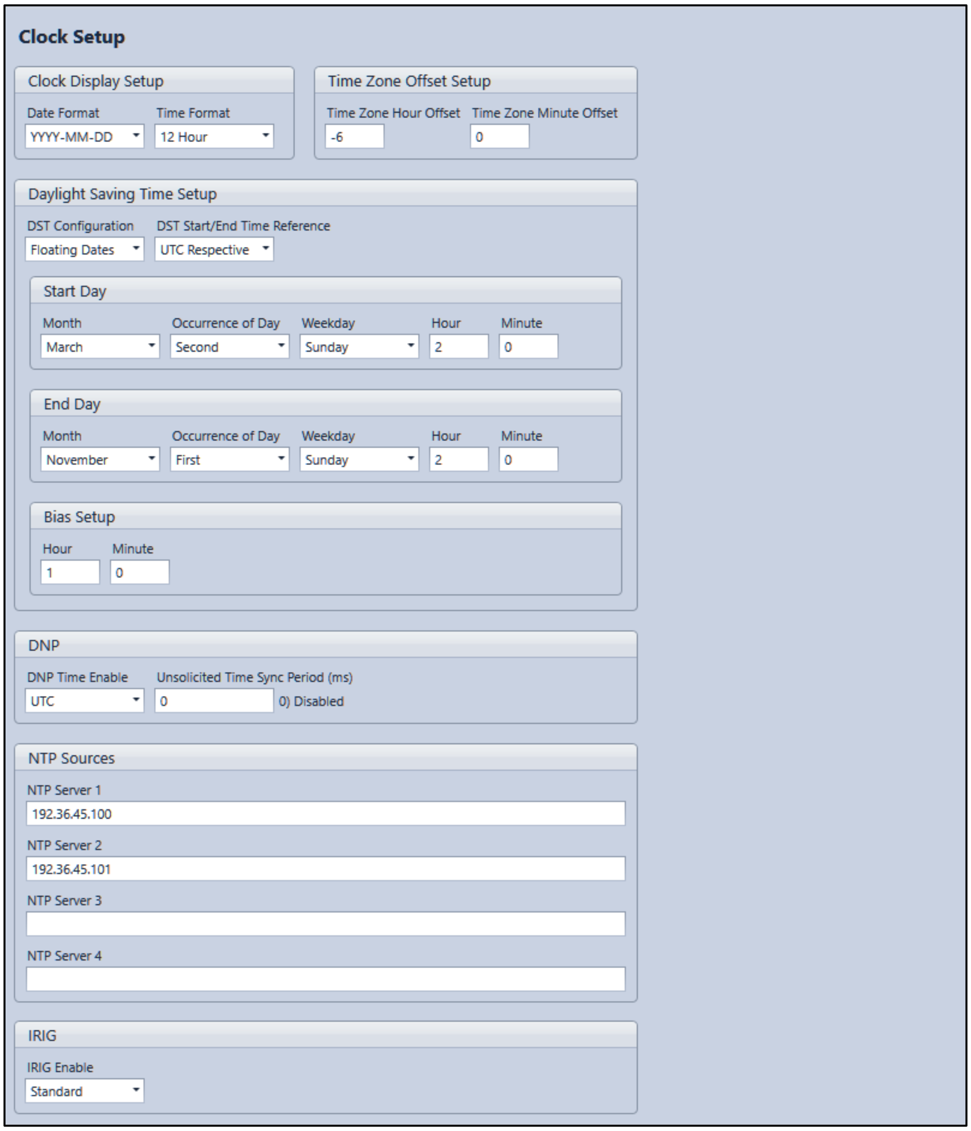


Figure 12-1. Clock Setup Screen

Setting the Time and Date

Navigation Path: Status, Real Time Clock

Time and date settings can be made through BESTCOMS*Plus* on the Real Time Clock screen (Figure 12-2) under the Status branch of the Metering Explorer. Settings can also be made through the front panel.

Figure 12-2. Status, Real Time Clock Screen

IRIG Port

IRIG time code signal connections are located on the power supply board. When a valid time code signal is detected at the port and IRIG-B is enabled in the Clock Setup, it is used to synchronize the clock function. Note that the IRIG time code signal received from older IRIG receivers does not contain year information. If this is the case, it will be necessary to enter the date manually. Year information is stored in nonvolatile memory so that when operating power is restored after an outage and the clock is re-synchronized the current year is restored. When the clock rolls over to a new year, the year is automatically incremented in nonvolatile memory. The year will not be updated in this condition if the device is powered off when the year increments in real time. An alarm bit is included in the programmable alarm function for loss of IRIG signal. The alarm point monitors for IRIG signal loss once a valid signal is detected at the IRIG port.

Connections

IRIG connections are located on the power supply board. Terminal designations and functions are shown in Table 12-1.

Table 12-1. IRIG Terminal Assignments

Terminal	Function
IRIG +	(+) Signal
IRIG –	(–) Reference

Specifications

Interface supports IRIG Standard 200-04, Format B006.

Input Signal .... Demodulated dc. Level-shifted, digital signal
Input Voltage Range .... ±10 Vdc maximum
Input Resistance .... Nonlinear, approximately 4 kΩ at 3.5 Vdc, approximately 3 kΩ at 10 Vdc

Logic Voltage Threshold

High .... 3.5 Vdc minimum
Low .... 0.5 Vdc maximum

Real-Time Clock Specifications

Resolution .... 1 s
Accuracy (without IRIG-B, NTP, DNP setup) .... ±1.73 seconds/days at 77°F (25°C)

Clock Holdup

Capacitor Holdup Time .... Up to 24 hours, depending on conditions
Battery Holdup Time .... Greater than 5 years, depending on conditions
Battery Type .... BR2032 or CR2032, coin-type, 3 Vdc, 195 mAh Basler Electric P/N 38526

Backup Battery for the Real-Time Clock

The backup battery for the real time clock is a standard feature of the BE1-FLEX. A battery is used to maintain clock function during loss of power supply voltage. In mobile substation and generator applications, the primary battery system that supplies the BE1-FLEX power supply may be disconnected for extended periods (weeks, months) between uses. Without battery backup for the real time clock, clock functions will cease if battery input power is removed.

The backup battery has a life expectancy of greater than five years, depending on conditions. After this time, you should contact Basler Electric to order a new battery, Basler Electric P/N 38526.

Caution

Replacement of the backup battery for the real-time clock should be performed only by qualified personnel.

Do not short-circuit the battery, reverse battery polarity, or attempt to recharge the battery. Observe polarity markings on the battery socket when inserting a new battery. The battery polarity must be correct in order to provide backup for the real-time clock.

Note

Failure to replace the battery with Basler Electric P/N 38526 may void the warranty.

Battery Replacement Procedure

Battery access is located behind the front panel of the BE1-FLEX on the motherboard.

Step 1: Remove the BE1-FLEX from service.

Step 2: Use a 7/64” hex tool to remove the front panel screws and remove the front panel. The chassis can remain mounted in place.

Step 3: Locate the battery holder/tray and battery on the motherboard (Figure 12-3). Remove the battery from the holder/tray. Consult your local ordinance for proper battery disposal.

Step 4: Insert the new battery so that the polarity markings on the battery match the polarity markings on the battery holder/tray and circuit board.

Step 5: Reattach the front panel by aligning the jumper PCB and then pressing equally and firmly around all sides of the front panel. Using a 7/64” hex tool, tighten the front panel screws to 10 in-lb (1.12 N•m).

Step 6: Return the BE1-FLEX to service.

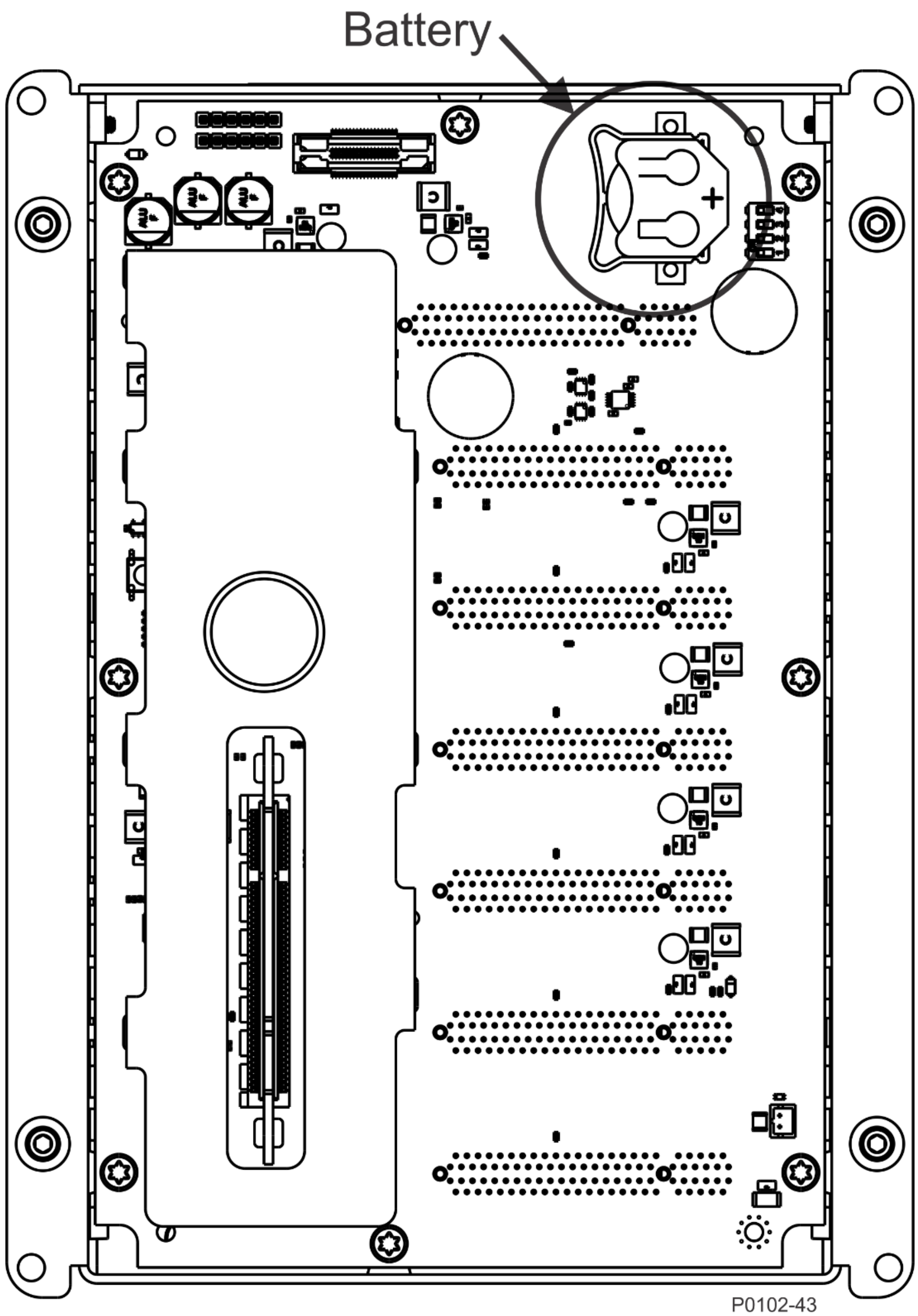


Figure 12-3. Battery Location on Motherboard

13 • Setting Groups

With the ability to have nearly any number and any combination of protective features in a BE1-FLEX, multiple settings groups may no longer be necessary for many applications. Applications that heavily shift settings requirements (such as a pumped storage motor/generator or portable distributed generation intertie protection) can benefit by using settings groups for greater settings clarity per mode. Four setting groups allow for adapting the settings. Sensitivity and time coordination settings can be adjusted to optimize sensitivity or clearing time based upon source conditions or to improve security during overload conditions.

The four setting groups are designated Setting Group 0, Setting Group 1, Setting Group 2, and Setting Group 3. Setting group logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and setting group operational settings are configured on the Setting Group Setup screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: General Settings, Setting Group Setup

Setting Group Functions

The group of settings that is active at any point in time is controlled by the setting group selection logic and Settings Group Setup's automatic switch threshold settings.

Logic Inputs

The function monitors logic inputs D0 through D3 and changes the active setting group according to the status of these inputs. These inputs can be connected to logic expressions such as contact sensing outputs.

Logic Outputs

The function logic has four logic variable outputs, SG0 through SG3. The appropriate variable is asserted when each setting group is active. These logic variables can be used in programmable logic to modify the logic based upon which setting group is active or to annunciate on external devices or the HMI.

The SGC Active logic output is asserted when setting group control is active. The SGC Logic Override logic output is asserted when setting group control is overridden by logic.

Changing Setting Groups

When the BE1-FLEX switches to a new setting group, all functions are reset and initialized with the new operating parameters. The settings change occurs instantaneously so at no time is the BE1-FLEX off line. The active setting group is saved in nonvolatile memory so that the BE1-FLEX will power up using the same setting group that was active when it was powered down. Since the BE1-FLEX is completely programmable, the fault condition is defined by the pickup logic expression in the fault reporting functions. See the *Fault Reporting* chapter for more information.

Setting Group Selection

Selection of the active setting group provided by this function logic can also be overridden. When logic override is used, a setting group is made active and the BE1-FLEX stays in that group regardless of the state of the manual logic control conditions.

Manual (logic) selection reads the status of the logic inputs to the setting group selection function block to determine what setting group should be active. For the logic inputs to determine which setting group should be active, the Automatic input must be logic 0. The function block operational mode setting determines how it reads these logic inputs. There are three possible logic modes as shown in Table 13-3.

Discrete Inputs

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

Figure 13-1 shows an example of how the inputs are read when the setting group selection function mode is enabled for discrete Inputs. Note that a pulse on the D3 input while D0 is also active does not cause a setting group change to SG3 because the AUTOMATIC input is active.

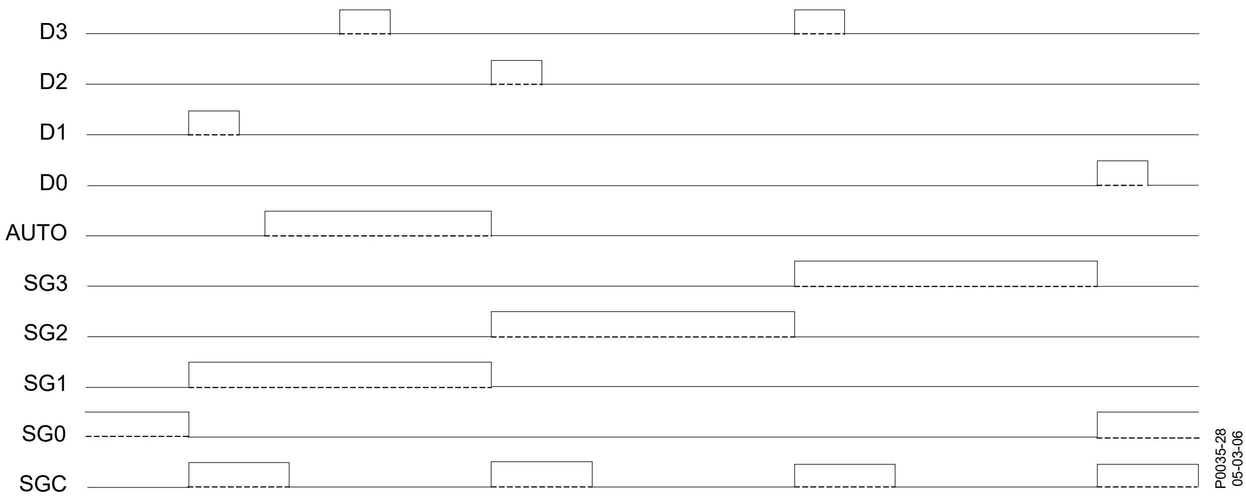


Figure 13-1. Input Control Discrete Inputs

Binary Inputs

When the setting group selection function block is enabled for Binary Inputs, the inputs on D0 and D1 are read as binary encoded (Table 13-1). Inputs D2 and D3 are ignored. A new coded input must be stable for approximately one second for the setting group change to occur. After a setting group change occurs, no setting group change can occur within two times the SGC alarm on time.

Table 13-1. Setting Group Binary Codes

Binary Code		Setting Group
D1	D0	
0	0	SG0
0	1	SG1
1	0	SG2
1	1	SG3

When the setting group selection function mode is enabled for Binary Inputs, the active setting group is controlled by a binary signal applied to discrete inputs D0 and D1. This requires separate logic equations for only D0 and D1 if all setting groups are to be used. Figure 13-2 shows how the active setting group follows the binary sum of the D0 and D1 inputs except when blocked by the Automatic input. Note that a pulse on the D1 input while D0 is also active does not cause a setting change to SG3 because the Automatic input is active.

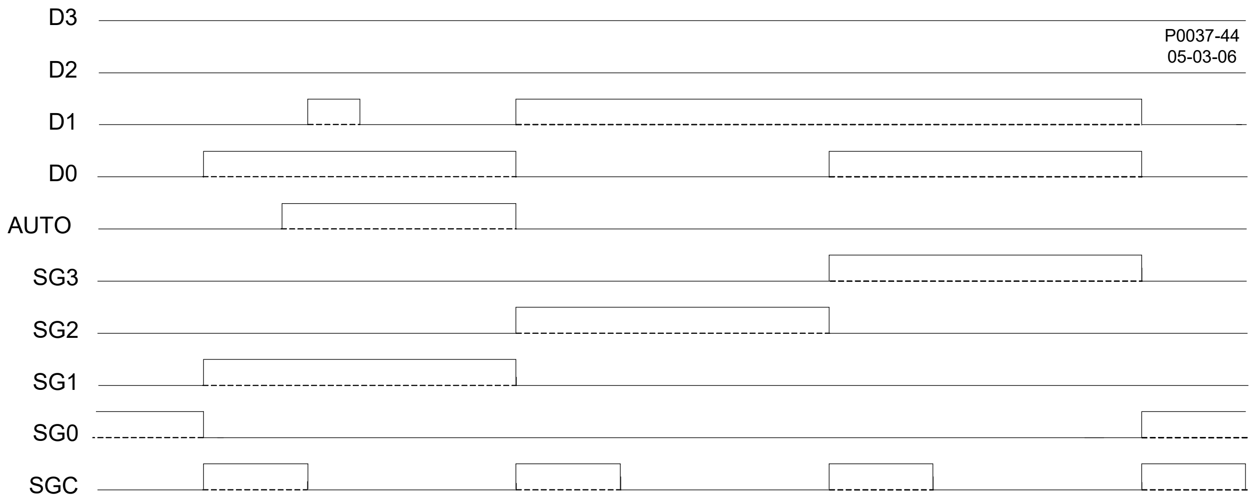


Figure 13-2. Input Control Binary Inputs

Alarm and Timer

The SGC Active (Setting Group Change Active) alarm output is typically used to provide an external acknowledgment that a setting group change has occurred. If SCADA (Supervisory Control and Data Acquisition) is used to change the active group, then this signal could be monitored to verify that the operation occurred. The SGC Active alarm output ON time is user programmable and should be set greater than the SCADA scan rate. This can be set through BESTCOMS*Plus*®.

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

Automatic Setting Group Selection

The setting group element has the built-in ability to automatically change setting groups. One method is based on the history of the current sensed by the BE1-FLEX. Another method is based upon the status of the fuse loss logic (60FL). To enable automatic change of setting groups, setting group selection must be enabled and the Automatic input must be logic 1.

When automatic selection is enabled, it takes precedence over all manual logic control.

The automatic setting group selection can be used to force the BE1-FLEX to change to settings that will automatically compensate for cold-load pickup conditions. For instance, if the BE1-FLEX senses current drop below a very small threshold for a period of time—indicating an open breaker—then the BE1-FLEX will move to an alternate setting group that will allow for the large inrush of current the next time the load is energized. After current has returned to measurable levels for some period of time, the BE1-FLEX returns to the normal settings. Another application is to prevent the BE1-FLEX from seeing an overload condition as a fault. If the BE1-FLEX sees sustained high level phase or unbalanced currents that are encroaching on normal trip levels (indicative of an overload or load imbalance rather than a fault), the BE1-FLEX will move to an alternate setting group that can accommodate the condition. The BE1-FLEX can be set to alarm for this condition using the programmable logic alarms.

The BE1-FLEX has the logic to automatically change setting groups based upon the status of the fuse loss (60FL) function.

Automatic Settings Group control monitors one circuit per the Source setting on the Setting Group Setup page.

Automatic Control by Monitoring Line Current

The setting group Switch Threshold and Return Threshold settings determine how the function selects the active setting group when automatic selection is enabled.

Automatic control of the active setting group allows the BE1-FLEX to automatically change configuration for optimum protection based on the current system conditions. For example, in locations where seasonal changes can cause large variations in loading, the overcurrent protection can be set with sensitive settings during the majority of the time and switch to a setting group with lower sensitivity (higher pickups) during the few days of the year when the loading is at peak.

The BE1-FLEX will switch to a setting group when current rises above the "switch threshold" for the "switch time" and will return from the setting group when current falls below the "return threshold" for the "return time." However, if the Switch Threshold is 0 and a nonzero switch-to time is entered, the BE1-FLEX will change to the indicated setting group after the switch-to time.

If a group's switch threshold is zero, the group’s switch time delay is zero, and current is being monitored, then the BE1-FLEX will never automatically switch to that setting group.

Five settings for each group are used for automatic control. Each group has a Switch Threshold and Switch Time, a Return Threshold and Return Time, and a Monitor setting. The Switch and Return thresholds are set in amperes. If you wish to switch settings based upon loading, you could set the Monitor setting to Max Phase Current. If you wish to switch settings based upon unbalance, you could set it to Neutral Current, or Negative-Sequence Current.

This function can also be used to automatically change the active setting group for cold load pickup conditions. If the Switch Threshold for a group is set to 0 amps, the function will switch to that group when there is no current flow for the time delay period, indicating that the breaker is open or the circuit source is out of service.

Note the difference in operation when a switch threshold of 0.5 amps is used. For this setting, the group is selected when current rises above 0.5 amps.

When the Switch criteria are met for more than one setting group at a time, the function will use the numerically higher of the enabled setting groups. If the switch-to time delay setting is set to 0 for a setting group, automatic control for that group is disabled. If the return time delay setting is set to 0 for a setting group, automatic return for that group is disabled and the BE1-FLEX will remain in that setting group until returned manually by logic override control.

Group Control by Monitoring Fuse Loss Status

The active setting group can also be controlled by the status of the fuse loss function (60FL) of the source circuit. If the monitored element is 60FL, the switch threshold, return time, and return threshold are ignored.

Logic Connections

Setting group logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The setting group logic block is illustrated in Figure 13-3. Logic inputs and outputs are summarized in Table 13-2.

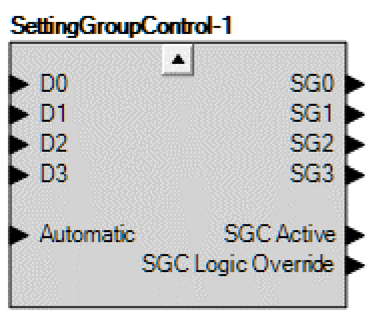


Figure 13-3. Setting Group Control Logic Block

Table 13-2. Logic Inputs and Outputs

Name	Logic Function	Purpose
D0, D1, D2, D3	Inputs	Meaning depends upon the Mode setting
Automatic	Input	True for automatic control and false logic control
SG0, SG1, SG2, SG3	Outputs	True for the active setting group
SGC Active	Output	True when Setting Group Control is Active
SGC Logic Override	Output	True when Setting Group Control is overridden from logic (not controlled by logic)

Operational Settings

Setting group operational settings are configured on the Setting Group Setup screen (Figure 13-4) in BESTCOMS*Plus*. Setting ranges and defaults are summarized in Table 13-3.

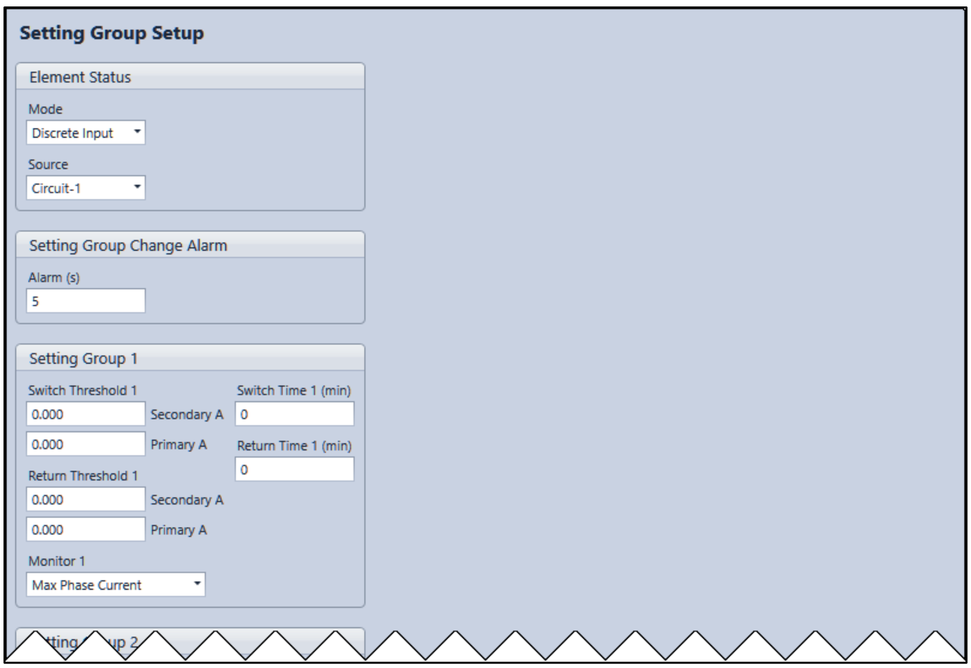


Figure 13-4. Setting Group Setup Screen

Table 13-3. Operational Settings

Setting	Purpose
Mode	Sets the mode of the setting group selection function. (If Auto mode is desired, logic mode must be either set to Discrete or Binary.)
Source	Selects the circuit to monitor.
Setting Group Change Alarm	Measured in seconds, the SGC alarm timer sets the amount of time the alarm is on.
Switch Threshold	Measured current of the Settings Group Monitor Setting that must be exceeded for a setting group change to occur. (Set in increments of 0.01A, secondary amps.)
Switch Time	Time, in minutes, that determines when a setting change occurs once the Switch Threshold setting is exceeded.

Setting	Purpose
Return Threshold	Measured current of the Settings Group Monitor Setting that the monitored current must decrease below in order for a return to Settings Group 0. (Set in increments of 0.01A, secondary amps.)
Return Time	Time, in minutes, that determines when a return to Settings Group 0 will occur once the monitored current has decreased below the Return Threshold setting.
Monitor	Determines when automatic setting group changes occur. Ground Current (IG), Max Phase, Neutral Phase (3I0), or Negative Sequence (I2) can be selected so that setting group changes are based on measured current. Fuse Loss (60FL) can also be used to switch setting groups. If 60FL is entered as the Monitor Setting, the Switch Time, Switch Threshold, Return Time, and Return Threshold parameters are not required.

Logic Override of the Setting Group Selection Function

Setting group control can be overridden to allow manual setting group control.

Navigation Path: Control, Setting Group Override

The Control, Setting Group Override screen is shown in Figure 13-5. Select a setting group to change to or return to logic control. The Active Setting Group is also displayed on this screen.

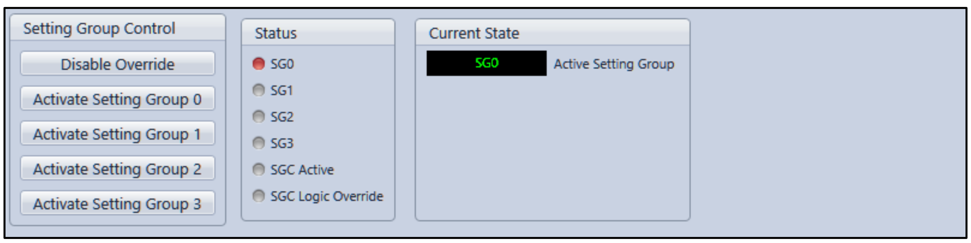


Figure 13-5. Setting Group Control Screen

Manual setting group control can also be achieved by navigating to the Control, Setting Group Control screen on the front-panel display.

14 • Metering

The BE1-FLEX measures the voltage, current, analog inputs, RTD inputs, and shunt inputs, displays those values in real time, records those values every quarter-second, and calculates other quantities such as power and impedance from the measured inputs. Refer to the appropriate chapters in this manual for information on device information, protection metering, status, reports, control, and BESTlogic*Plus*. Live status of every logic point streamlines troubleshooting and commissioning.

Metering Explorer

The Metering Explorer is a convenient tool within BESTCOMS*Plus*® that contains device information, analog metering, protection metering, status, reports, control, and BESTlogic*Plus*. Control screens include virtual switches, breaker control switch, output override, and setting group control. Details of the Analog Metering branch are described in this chapter. Metering values can be exported to a CSV (comma-separated values) file.

The Metering Explorer has a “docking” feature allowing the user to arrange and dock metering screens. A blue transparent square representing the screen being moved and five arrow buttons appear when holding down the primary mouse button on a metering tab and dragging it to an arrow box used for docking.

Holding the left mouse button down on a metering tab and dragging it anywhere other than an arrow box will place it as a floating metering screen.

See Figure 14-1. Table 14-1 explains the call-outs in Figure 14-1.

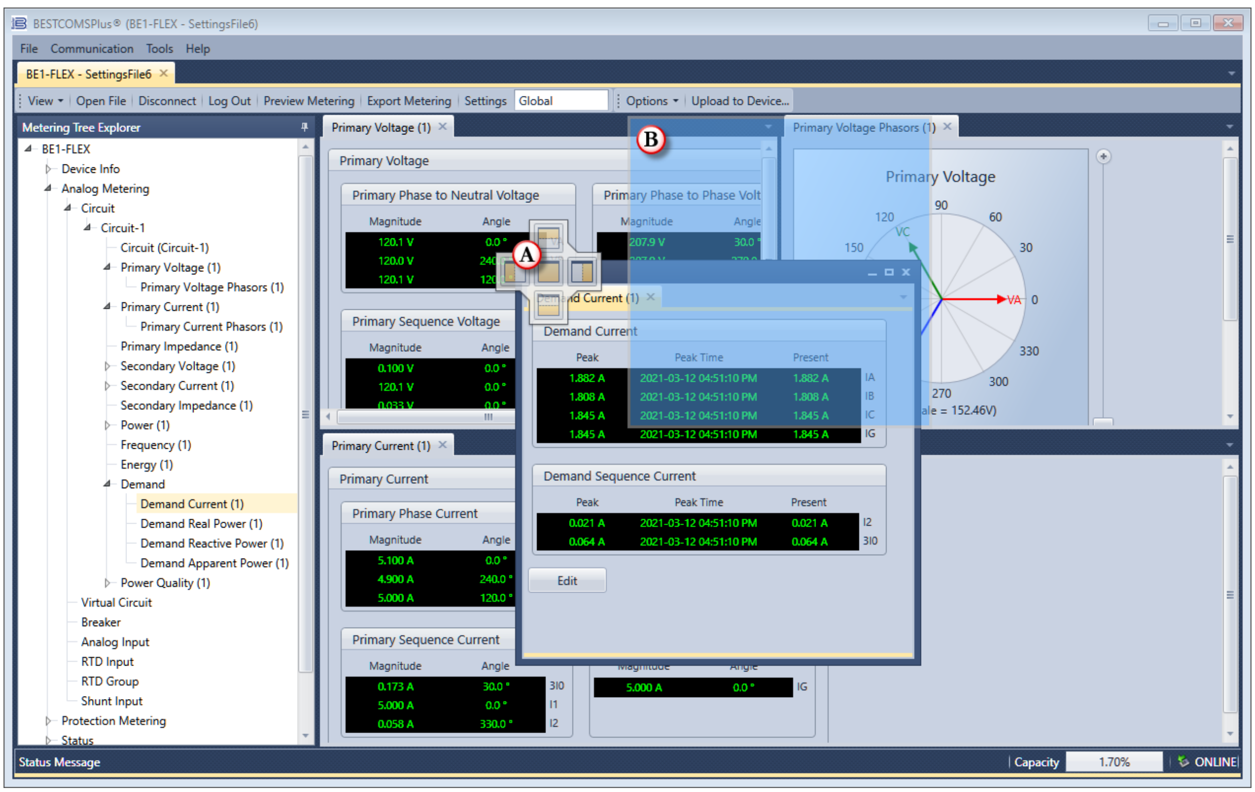


Figure 14-1. Metering, Docking Options

Table 14-1. Explanation of Figure 14-1 Call-Outs

Call-Out	Explanation
A	Holding the left mouse button down on a metering tab and dragging it to one of the four arrow boxes will place it inside the selected window on the location selected. To place the metering tab as a tab inside the selected window, drop it on the tabs button in the center of the arrow buttons.
B	This blue transparent square represents the screen being moved.

Analog Metering

BE1-FLEX analog metering functions include circuits and virtual circuits (voltage, current, impedance, power, frequency, energy, demand, and power quality), breakers, analog inputs, RTD inputs, RTD groups, and shunt inputs. Metered values are viewed through the Metering Explorer in BESTCOMS*Plus*, the front-panel display, or the web page interface on Ethernet equipped protection systems. For information on power, VA, and var calculations, refer to the *Power System Configuration* chapter.

Metering Screens

The following metering screens are available in BESTCOMS*Plus*. The Circuit Voltage and Voltage Phasors screens are shown below for an example. See Figure 14-2 and Figure 14-3.

- Analog Metering
    - Circuits and Virtual Circuits
        - Voltage – Primary and Secondary
            - Voltage Phasors – Primary and Secondary
        - Current – Primary and Secondary
            - Current Phasors – Primary and Secondary
        - Impedance – Primary and Secondary
        - Power
            - Power Phasors
        - Frequency
        - Energy
        - Demand
            - Demand Current
            - Demand Real Power
            - Demand Reactive Power
            - Demand Apparent Power
        - Power Quality
            - Voltage
            - Distortion
            - Dip/Swell
            - Harmonics
                - Harmonic Voltage
                - Harmonic Current
    - Breaker
        - Breaker Monitor
    - Analog Input
    - RTD Input
    - RTD Group
    - Shunt Input
- Protection Metering
    - Phase Differential (87)
    - Neutral Differential (87N)

    - Configurable Protection
    - Control Power Monitor
- Status
    - Real Time Clock
    - Input
    - Output
    - Alarms
    - Targets
    - Logic Timer (62)
    - Recloser (79)
    - Virtual Lockout Function (86)
    - Indicator
- Reports
    - Sequence of Events
    - Fault Records
    - Load Profile
    - Security Log
    - Transformer Damage (51TF)
    - Advanced
        - Diagnostic Log
- Control
    - Virtual Control Switch (43)
    - Breaker Control Switch (101)
    - Output Override
    - Setting Group Override
- BESTlogic™*Plus* Programmable Logic

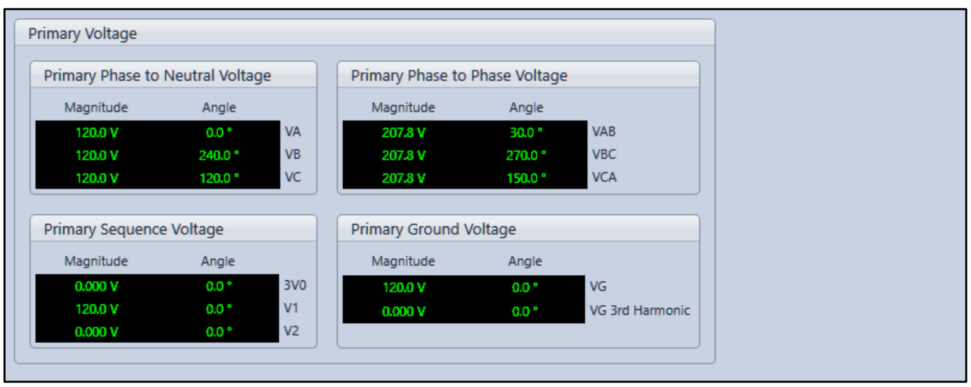


Figure 14-2. Primary Voltage Metering Screen

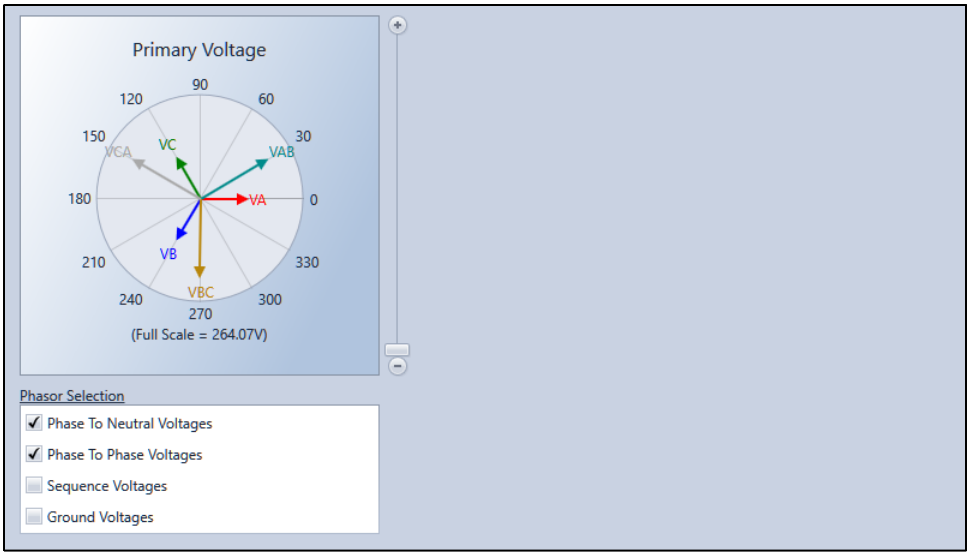


Figure 14-3. Primary Voltage Phasors Metering Screen

BESTlogic™*Plus* Programmable Logic Metering

Live status of every logic point streamlines troubleshooting and commissioning. Figure 14-4 shows the BESTlogic*Plus* Programmable Logic metering screen available in the Metering Explorer.

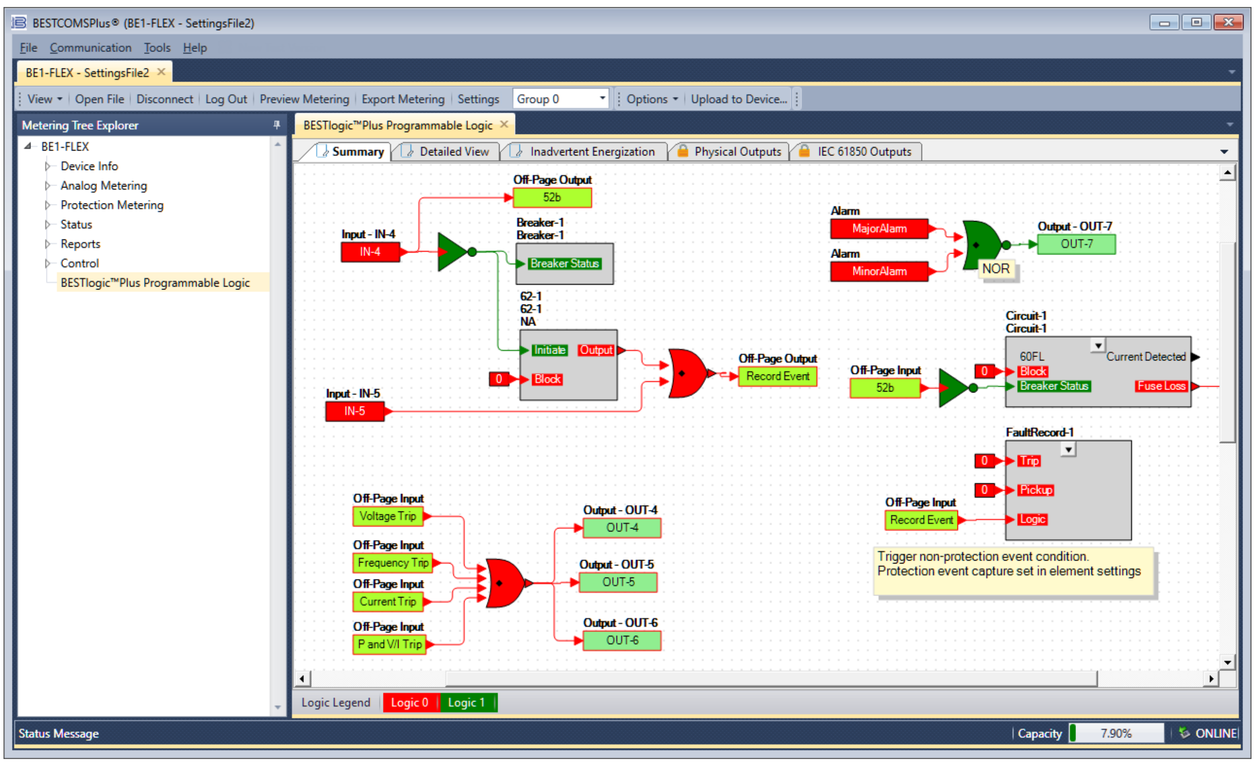


Figure 14-4. BESTlogic*Plus* Metering Screen

15 • Phase Distance (21P)

The Phase Distance (21P) elements use the calculated impedance of a fault to determine the fault location. Additional phase distance instances can provide backup protection for external faults that are not cleared by external protective relaying due to a failure of the external system protection scheme or equipment.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Phase Distance settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Impedance, Phase Distance (21P)

Element Operation

Phase distance protection is common in applications where inverse time overcurrent protection cannot provide adequate protection. Distance elements may provide faster operation and greater coordination when fault current is variable based upon dynamic system configuration.

The zone of protection for the phase distance element may be set (using a mho circle) to include a transformer.

For generator applications, to include the generator in the Phase Distance (21P) backup zone of protection, use CTs located on the neutral side of the generator. If neutral CTs are not provided, the BE1-FLEX may be connected to CTs located at the generator terminals. With this connection, the generator is not included in the protection system's zone of protection, but system backup protection is provided.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Delta/Wye Compensation

For applications where the zone of protection includes a delta/wye DAB transformer in an ABC rotation system, delta/wye compensation should be enabled when current and voltage transformers are located on the delta side to provide compensation for the differences in the current components on the wye and the delta side of the step-up transformer.

Torque Angle

A Torque Angle (or characteristic angle) setting represents the angle between voltage and fault current on a zero (0) ohm fault. The torque angle is used for impedance calculations. Directionality is determined by the Maximum Torque Angle's Positive Sequence - Z1 setting. See Circuit *Directional Control*.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when the calculated impedance falls within the zone established by the mho circle. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the 21P element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other fault occurrences.

Trip

The Trip output becomes true if a pickup condition exists for the duration of the element Time Delay. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Phase Distance (21P) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Phase Distance (21P) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Phase distance element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The phase distance element logic block is illustrated in Figure 15-1. Logic inputs and outputs are summarized in Table 15-1.

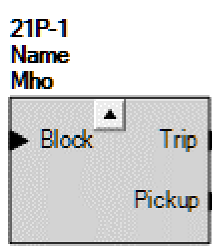


Figure 15-1. Phase Distance Element Logic Block

Table 15-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 21P function when true
Trip	Output	True when the 21P element is in a trip condition
Pickup	Output	True when the 21P element is in a pickup condition

Operational Settings

Phase distance element operational settings are configured on the Phase Distance (21P) settings screen (Figure 15-2) in BESTCOMS*Plus*.

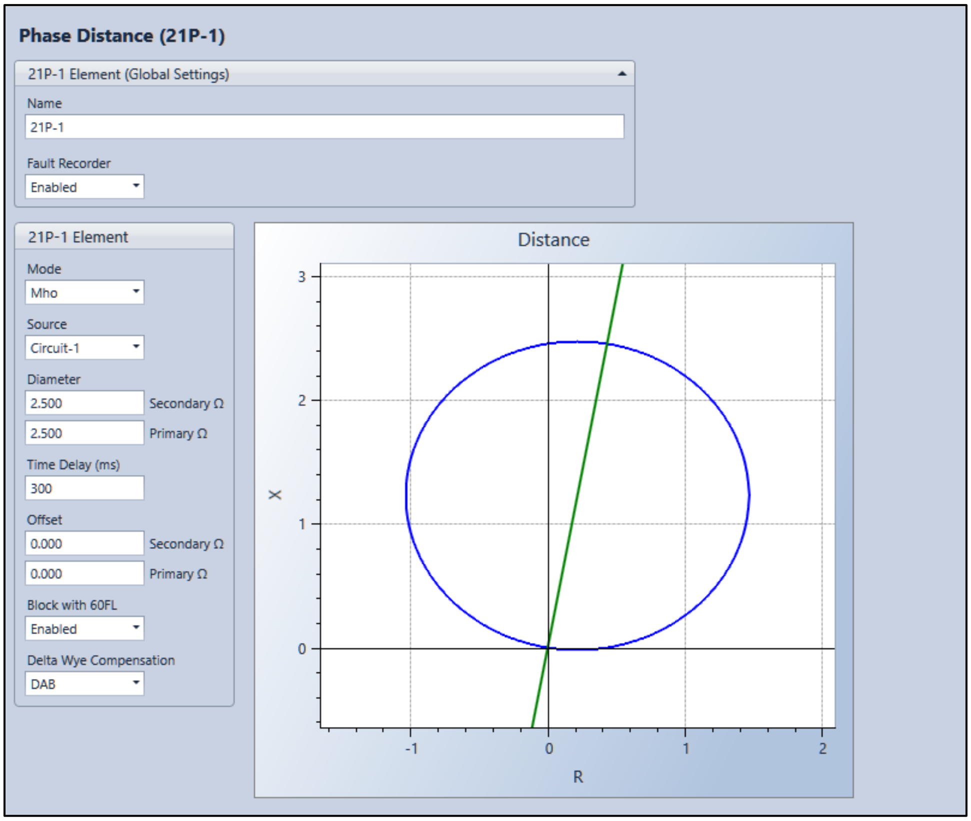


Figure 15-2. Phase Distance Settings Screen

16 • Neutral Distance (21N)

The Neutral Distance (21N) elements use the calculated impedance of a fault to determine the fault location. Additional neutral distance instances can provide backup protection for external faults that are not cleared by external protective relaying due to a failure of the external system protection scheme or equipment.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Neutral Distance settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Impedance, Neutral Distance (21N)

Element Operation

Neutral distance protection is common in applications where inverse time overcurrent protection cannot provide adequate protection. Distance elements may provide faster operation and greater coordination when fault current is variable based upon dynamic system configuration.

Neutral distance elements detect all single-phase-to-ground faults with single-phase and residual overcurrent supervision. Multiple instances can be utilized for multi-zone protection.

The quadrilateral characteristic requires four tests:

- Reactance test (top line)
- Positive and negative resistance tests (two sides)
- Directional test (bottom)

The proper selection of the polarizing quantity is required to estimate the reactance and the fault resistance to a phase-to-ground fault. Using the faulted phase current as a polarizing reference is inconsistent as this current is not always in-phase with the total fault current. Negative-sequence or residual currents are more reliable sources for this condition.

The polarizing signal reference (I_{POL} = IA + IB + IC) from the measured residual current at relay location (IR), can be expressed in terms of the total fault current (IF), the line zero-sequence impedance, and the zero sequence impedances of the sources at both line ends, i.e., Z0L, Z0S and Z0R. In this way, the reactance element measurement is insensitive to load flow conditions. Furthermore, for homogeneous systems, for which Z0L, Z0S and Z0R angles are the same, IR angle equals that of IF, regardless of load condition and fault resistance magnitude.

When the zero-sequence source impedance angles are significantly different from the line impedance angle, the effect of fault resistance on the ground reactance reach must be taken into account. Therefore, the angle of the ground reactance element reach (Tilt Angle) is corrected to compensate for source impedance ‘inhomogeneity.’

The purpose of a resistive element is to limit the resistive coverage of a quadrilateral zone of protection. The fault resistance element measurement is unaffected by load flow conditions, allowing resistive boundary settings greater than the minimum load impedance.

Because the quadrilateral characteristics are inherently non-directional and since the operating quantities for all ground distance elements include residual current, a reverse A-phase to ground fault produces a residual current that is also used in the phase-ground distance elements for B and C phases. This residual current can cause a forward-reaching decision in the B-phase and C-phase ground distance elements. To ensure security for this condition and to provide directionality, the quadrilateral neutral distance elements are supervised by a negative-sequence directional element. The advantages of using negative sequence polarizing are:

- Zero-sequence mutual coupling insensitivity.
- Normally, there is more negative-sequence current than zero-sequence current for remote ground faults with high fault resistance. This allows higher sensitivity with reasonable and secure sensitivity thresholds.
- Insensitivity to a VT's neutral shift, possibly caused by multiple grounds at a VT's neutral.

The BE1-FLEX uses constant impedance values for zero sequence and positive sequence to calculate a constant K_0. These constants are set from the Directional Control settings for Power Line Parameters.

$$K_0 = \frac{1}{3}\left(\frac{Z_0}{Z_1} - 1\right)$$

$$I_{phase\ comp} = I_{phase} + K_0 \times 3I0$$

Where,

$Z_1 = V_{phase} / I_{phase\ comp}$

Then, the BE1-FLEX uses the K_0 with residual current (3I0) and the faulted phase to determine the positive sequence impedance during a line to ground fault.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Torque Angle

A Torque Angle (or characteristic angle) represents the angle between voltage and fault current on a zero (0) ohm fault. The torque angle is used for impedance calculations. Directionality is determined by the Power Line Parameters magnitude and angle settings for Positive Sequence – Z1 and Zero Sequence – Z0. See Circuit *Directional Control*.

Tilt Angle

The tilt angle setting is used to correct the angle of the ground reactance element reach to compensate for source impedance 'inhomogeneity.'

Direction

A neutral distance element can be configured to operate in the forward or reverse direction.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when the calculated impedance falls within the zone established by the X and R Axis Reach settings in the proper direction. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the 21N element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other fault occurrences.

Trip

The Trip output becomes true if a pickup condition exists for the duration of the element Time Delay. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Neutral distance element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The neutral distance element logic block is illustrated in Figure 16-1. Logic inputs and outputs are summarized in Table 16-1.

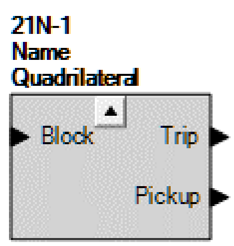


Figure 16-1. Neutral Distance Element Logic Block

Table 16-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 21N function when true
Trip	Output	True when the 21N element is in a trip condition
Pickup	Output	True when the 21N element is in a pickup condition

Operational Settings

Neutral distance element operational settings are configured on the Neutral Distance (21N) settings screen (Figure 16-2) in BESTCOMS*Plus*.

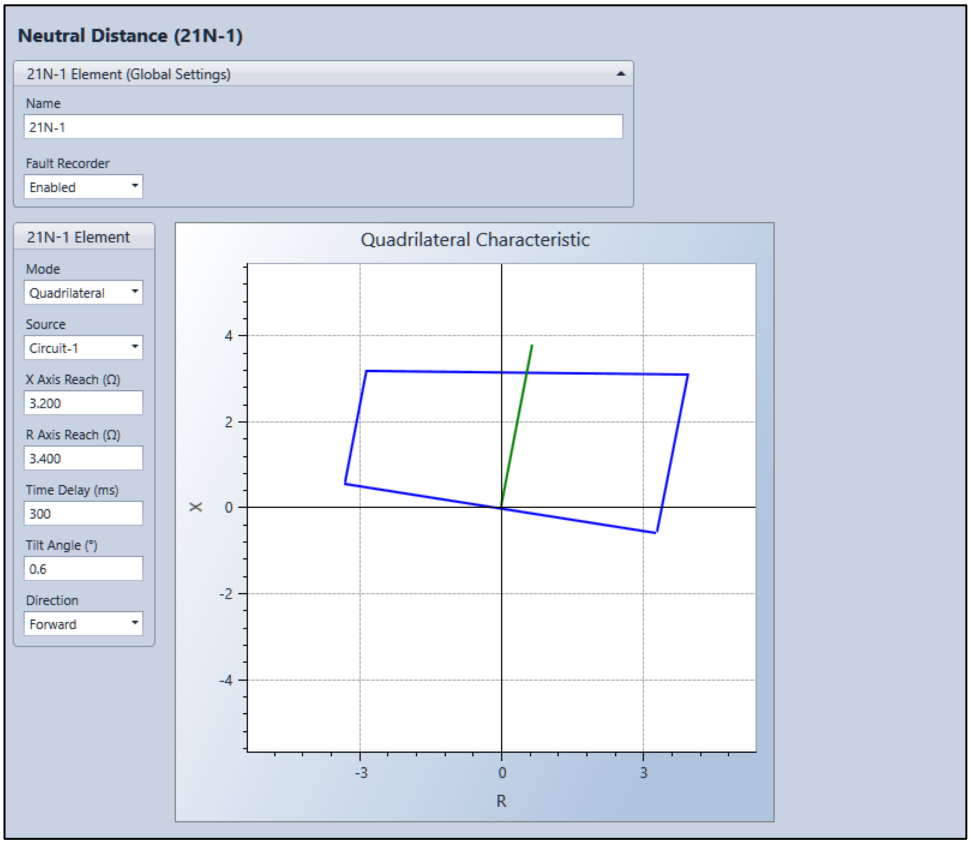


Figure 16-2. Neutral Distance Settings Screen

17 • Overexcitation (24)

The Overexcitation (24) elements monitor the volts per hertz ratio and are typically used to protect transformers and generators from the adverse effects of excessive heating resulting from overexcitation. Overexcitation exists whenever the per unit volts per hertz exceeds the equipment design limitations.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Overexcitation settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Voltage, Overexcitation (24)

Element Operation

Overexcitation occurs when a magnetic core becomes saturated. When this happens, stray flux is induced in non-laminated components, causing overheating. The BE1-FLEX detects overexcitation conditions with volts per hertz elements that consist of one alarm setting, one inverse time characteristic with selectable exponents, and two definite-time characteristics. This allows the user to select an individual inverse-time characteristic, a composite characteristic with inverse time, and one or two definite-time elements, or a dual-level, definite-time element.

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

The overexcitation element responds to the magnitude of voltage versus frequency where the measured voltage is phase to phase and includes the phase with the frequency measurement element.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Sensing Configuration

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

In the equations below, nominal voltage is defined as a phase-to-neutral quantity. Nominal V/Hz depends on the voltage VT connection setting, nominal voltage, and nominal frequency settings. Nominal V/Hz is calculated as the nominal voltage divided by nominal frequency. For VT connections equal to 3W, 4W, AB, BC, CA, the nominal voltage (phase-neutral value) must be converted to a phase-phase value by multiplying by the square root of 3. No additional conversion is required for VT connections equal to AN, BN, or CN.

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

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

Equation 17-1. V/Hz Measured (3W, 4W, AB, BC, or CA)

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

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

Equation 17-2. V/Hz Measured (AN, BN, or CN)

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Timing Mode

Definite or inverse timings can be used. Element operate times do not include logic or output operate times.

Trip and Reset Equations

Equation 17-3 and Equation 17-4 represent the trip time and reset time for a constant V/Hz level. Normally, the V/Hz pickup is set to a value greater than the V/Hz nominal. This ensures that V/Hz measured divided by V/Hz nominal is always greater than 1.000 throughout the pickup range. If the pickup is set less than nominal, then measured values above pickup and below nominal will result in the maximum time delay. The maximum time delay is determined by Equation 17-3 with (V/Hz measured / V/Hz nominal) set equal to 1.001. The overall inverse time delay range is limited to 1,000 seconds maximum and 0.2 seconds minimum.

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

Equation 17-3. Time to Trip

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

Equation 17-4. Time to Reset

where:

T_T = Time to trip

T_R = Time to reset

D_T = Time dial, trip

D_R = Time dial, reset

E_T = Elapsed time

n = Curve exponent (0.5, 1, 2)

FST = Full scale trip time (T_T)

E_T/FST = Fraction of total travel toward trip that integration had progressed to. (After a trip, this value will be equal to one.)

Pickup and Trip

Pickup

The Pickup output becomes true when the measured V/Hz increases above the V/Hz threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates an inverse or definite timer that begins timing to a trip. The duration of the timer is established by the Time Dial (inverse time) or Time Delay (definite time) setting. A Time Delay or Time Dial setting of zero (0) makes the 24 element instantaneous with no intentional time delay.

If the monitored V/Hz is above both the calculated inverse time and definite time delay thresholds, the definite time delay has priority over the inverse time characteristic.

If the pickup condition subsides before the element delay or calculated inverse time expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of overexcitation. If inverse reset is chosen, the inverse trip timer will ramp down towards reset at a linear rate based on the Reset Dial setting. A Reset Dial setting of zero (0) makes the reset instantaneous with no intentional delay. See the *Timing Characteristics* chapter for details on each of the available time curves.

Trip

The Trip output becomes true if an overexcitation pickup condition exists for the duration of the element Time Delay (definite time) or calculated inverse time. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled by the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Programmable Alarm

A 24 Volts per Hertz alarm occurs during overexcitation so that corrective action can be taken before the 24 function trips. The alarm can be set to appear on the front-panel display, web page interface, and on the Alarms metering screen in BESTCOMS*Plus*. Refer to the *Alarms* chapter for information about programming alarms.

When the Alarm Pickup setting is exceeded, a timer is initiated and begins timing toward a trip. The duration of the timer is established by the alarm Time Delay setting. An alarm Time Delay setting of zero (0) makes the alarm instantaneous with no intentional time delay.

If the alarm pickup condition persists for the duration of the alarm Time Delay setting, the 24 Volts per Hertz alarm becomes true. If the alarm pickup condition subsides before the alarm time delay expires, the timer is reset and no corrective action is taken.

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Overexcitation (24) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Overexcitation (24) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by the 60FL function should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Overexcitation element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The overexcitation element logic block is illustrated in Figure 17-1. Logic inputs and outputs are summarized in Table 17-1.

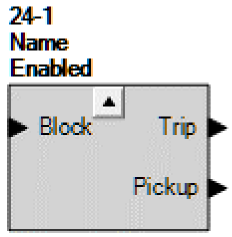


Figure 17-1. Overexcitation Element Logic Block

Table 17-1. Logic Inputs and Outputs

Name	Function	Purpose
Block	Input	Disables the 24 function when true
Trip	Output	True when the 24 element is in trip condition
Pickup	Output	True when the 24 element is in pickup condition

Operational Settings

Overexcitation operational settings are configured on the Overexcitation (24) settings screen (Figure 17-2) in BESTCOMS*Plus*.

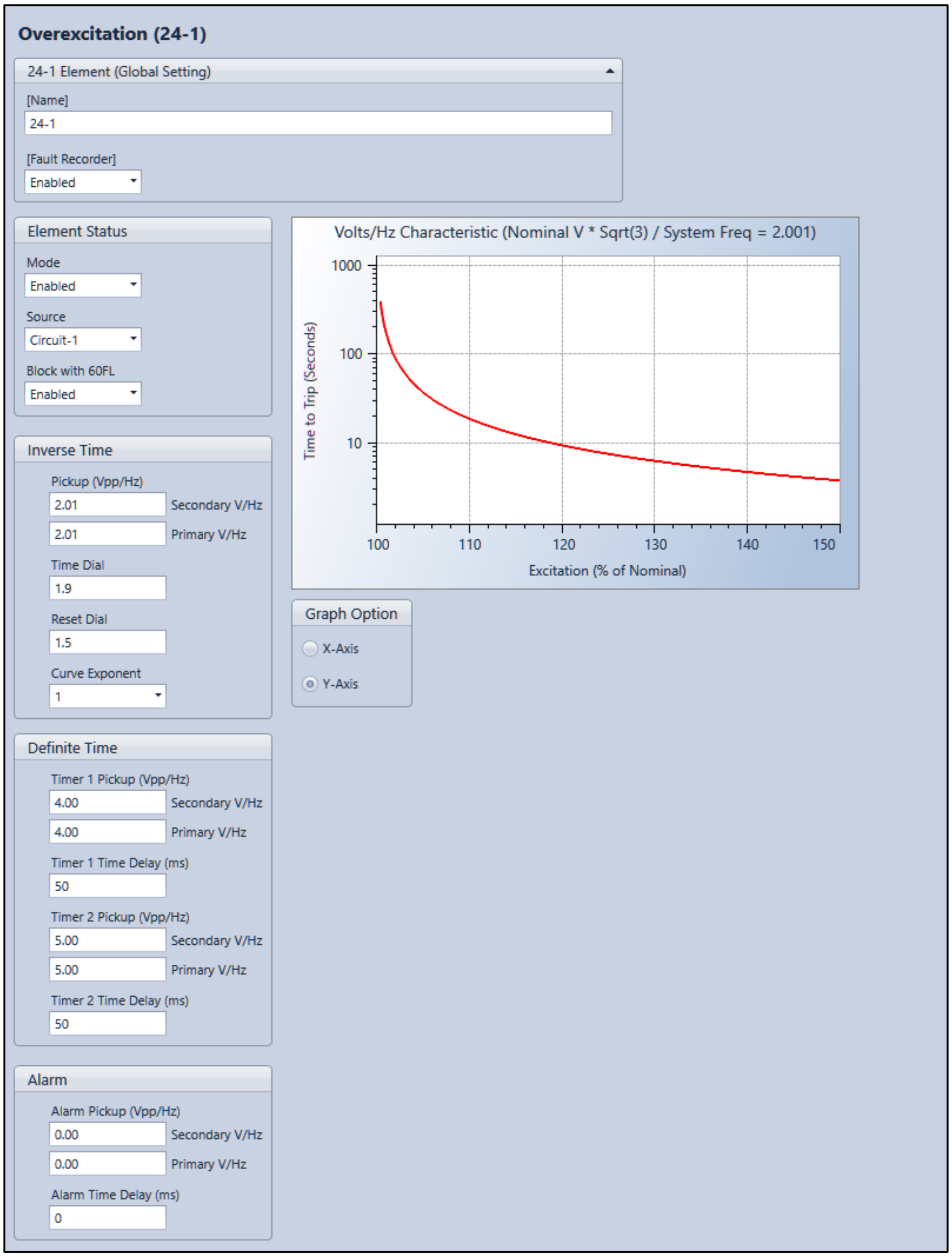


Figure 17-2. Overexcitation Settings Screen

Settings Example

The overexcitation element is typically used to de-energize a generator or transformer that is experiencing an overexcitation condition. Therefore, the manufacturer's overexcitation limit curves are required to establish optimum protection. Figure 17-3 and Figure 17-4 show examples of a transformer and generator limit curve along with the optimum composite protection characteristic.

Timing characteristics described below relate to the element itself. Total system operate time typically also includes 24 element pickup, logic scan, output operate, and breaker operate time. See the *Timing Characteristics* chapter for more information on timing.

Note

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

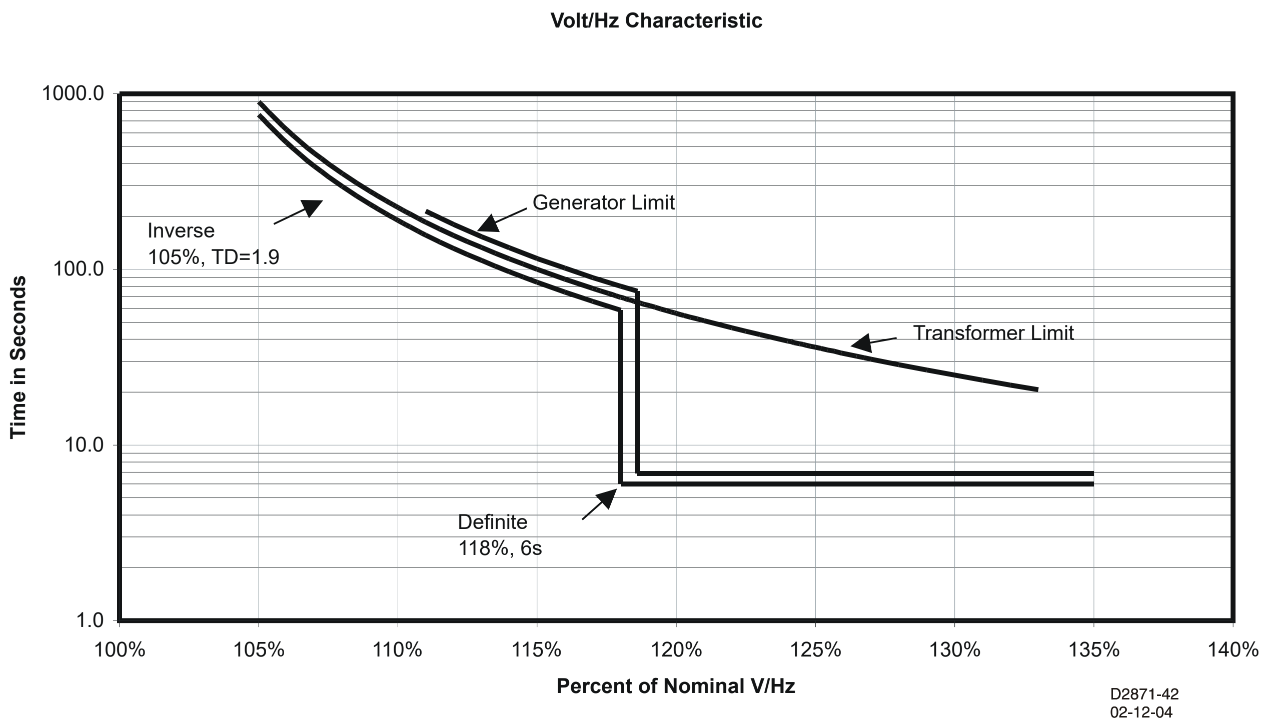


Figure 17-3. Time Shown on Vertical Axis

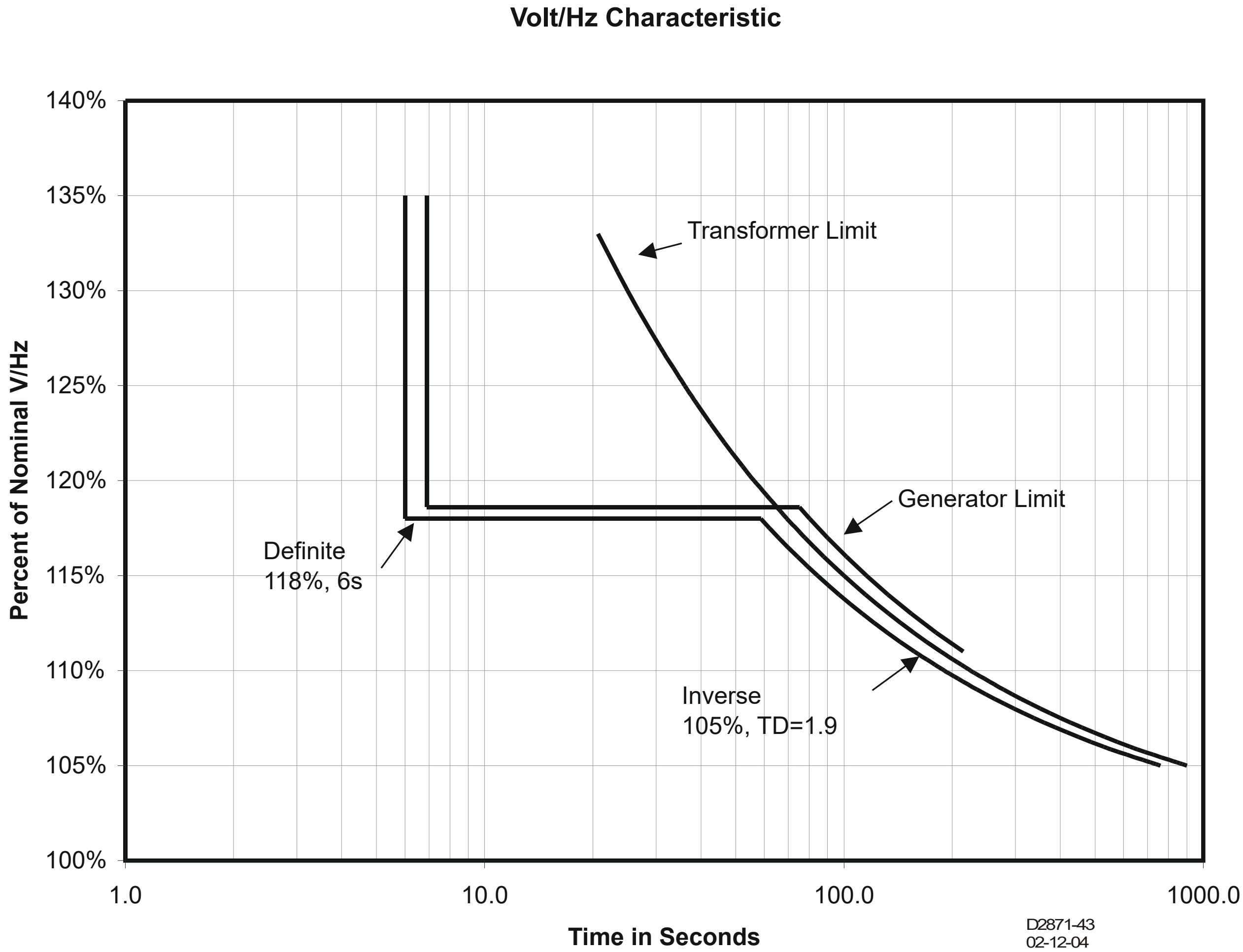


Figure 17-4. Time Shown on Horizontal Axis

Assuming a Vnom of 69.3 Vpn, 1 pu volts/hertz = (69.3 * √3) / 60 = 2.00. Using IEEE Std C37.102-2006 - *IEEE Guide for AC Generator Protection* as a guide for setting overexcitation protection, the following example demonstrates how to set the BE1-FLEX to provide a composite V/Hz characteristic for protection of a generator and a step-up transformer:

- Alarm = 105% @ 1 second time delay; V/Hz = 2 * 1.05 = 2.10
- Inverse time pickup = 105%; Time Dial = 1.9; Inverse Trip Curve = (M-1)^2; V/Hz = 2 * 1.05 = 2.10

  where $M = \frac{V/Hz_{Measured}}{V/Hz_{Nominal}}$

- Definite Time #1 = 118% @ 6 seconds time delay; V/Hz = 1.18 * 2.0 = 2.36

The reset rate is determined by the Reset Dial setting. A setting of zero (0) gives an instantaneous reset. Using the inverse squared characteristic, assume a trip time dial setting 2.0 and a pickup multiple of 1.2. The total time to element trip will be 50 seconds. If this exists for 30 seconds before being corrected (60% elapsed time), what would the total reset time be for a reset dial setting of 5? Based on the reset equation (Equation 17-5), the calculation will be:

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

Equation 17-5. Time to Reset

If the overexcitation condition returns prior to total reset (i.e., less than 300 seconds), timing resumes from that point at the inverse square rate. For example, if this condition recurs after 150 seconds or 50% of the total reset time, then trip time from the second event will start at 30% instead of 0%, therefore tripping in 70% of the original trip time or 35 seconds. Figure 17-5 illustrates the inverse time delay and reset time.

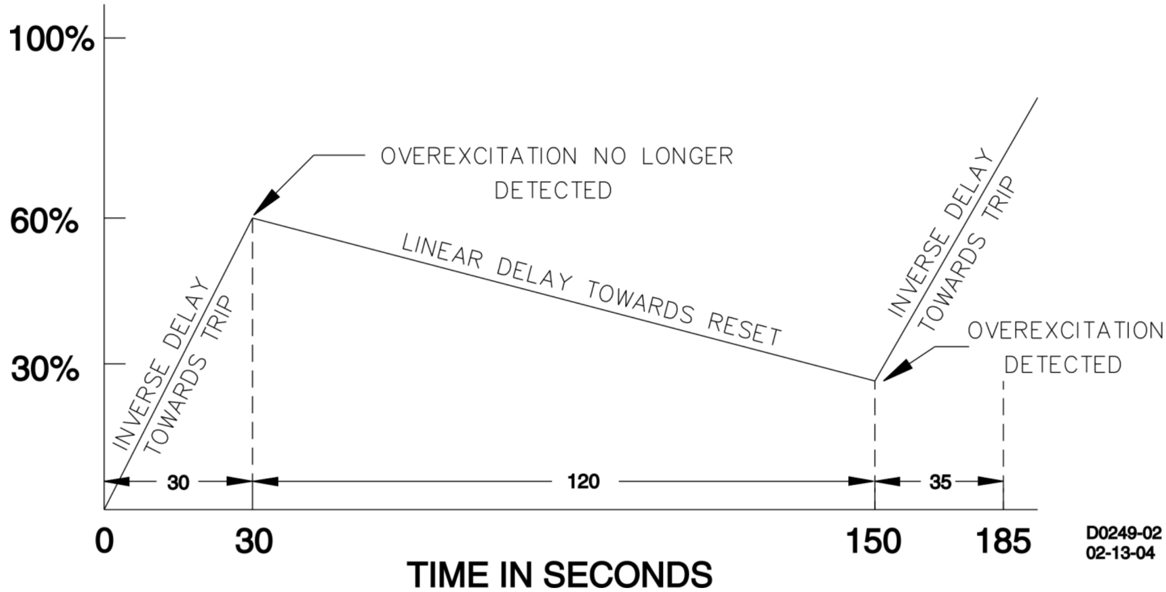


Figure 17-5. Inverse Time Delay and Reset Time

18 • Sync-Check (25)

The Sync-Check (25) elements provide breaker closing supervision by comparing the voltage magnitude, angle, and frequency of two phase voltages to determine synchronism across a breaker. Sync-check elements are commonly applied to breakers between a generator and bus source.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational setting are configured on the Sync-Check settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Voltage, Sync-Check (25)

Element Operation

The sync-check element monitors the two voltage sources of a Breaker instance. Refer to the *Power System Configuration* chapter for information on configuring breakers. When the monitored voltage between the sources meets angle, voltage, and slip criteria, the element Sync output becomes true. In BESTlogic*Plus*, the Sync output can be connected to other logic elements to annunciate the condition or control other elements in logic. The Sync logic output becomes true when all three of the following conditions are met:

1. Phase angle between sources is less than the Slip Angle setting.
2. Frequency error between sources is less than the Slip Frequency setting. (Note: When the Source 1 Frequency > Source 2 Frequency setting box is checked, only Source 1 frequency greater than Source 2 frequency is allowed. Source 1 Frequency is typically the generator 3-phase connection and Source 2 Frequency is typically the bus.)
3. Voltage magnitude between sources is less than the Voltage Difference setting. (Note: The voltage used by the BE1-FLEX for this feature is a voltage magnitude measurement, not a voltage phasor measurement.)

Voltage thresholds are entered in percent allowing the use of non-equal transformers with the sync-check function. The sync-check element Sync logic output is false when source 1 V_a/V_{nom} and source 2 V_a/V_{nom} are subtracted from each other and the magnitude exceeds the allowable percent difference. For example, the sensing for the generator is on one side of a step-down transformer and the sensing for the bus is on the other. Dead/Live values are entered as percent of the nominal voltage setting as well.

Measuring slip frequency directly allows the sync-check element to rapidly determine if systems are in synchronism and requires no timer or inherent delay (as compared to systems that check only that the phase angle is held within a window for a period of time). The moment that conditions 1, 2, and 3 (listed above) are met, the systems can be considered in synchronism, and the Sync logic output becomes true. Refer to the *Metering* chapter for more information about slip frequency measurement.

VT Connections

The sync-check element compares the Source 1 voltage to the Source 2 voltage of a Breaker instance. Proper connection of the voltage transformer inputs is vital for correct operation of the sync-check element.

For clarification on single-phase VTP connections, refer to the *Typical Connections* chapter. The single-phase parallel connections are available on VA and VX hardware input channels.

For single-phase sensing connections derived from a phase-to-neutral source into VA, VB, and VC inputs:

Terminals VA, VB, and VC are connected in parallel. The single-phase signal is connected between the parallel group and terminal VN.

For single-phase sensing connections derived from a phase-to-phase source:

Terminals VB, VC, and VN are connected in parallel. The single-phase signal is connected between terminal VA and the parallel group.

Note that the voltage monitor (described below) performs three of three testing for all connections. For 3W and 4W connections, phases A, B, and C are actually tested. For single-phase connections, the terminals are connected in parallel as described above and the single-phase is tested three times.

Voltage Monitoring

The sync-check element Sync logic output provides closing supervision for only the Live Source 1/Live Source 2 condition.

The Volt Monitor logic output is provided for conditions where either source is dead. In BESTlogic*Plus*, the Volt Monitor logic output can be connected to other logic elements to annunciate the condition or control other elements in logic. A live condition for either source is determined when the measured voltage on the respective input is equal to or above the live voltage threshold established by the Live Voltage setting. A dead condition for either source is determined when the measured voltage on the respective input is equal to or below the dead voltage threshold established by the Dead Voltage setting. The Dropout Delay setting provides hysteresis for the Volt Monitor logic output.

If the connection is three phase, 3W or 4W, all three phases are tested and must be above the live voltage threshold for a live condition to be true. Similarly, all three phases must be below the dead voltage threshold for a dead condition to be true.

The Volt Monitor logic is illustrated in Figure 18-1. Any combination of logic settings can be selected for the Voltage Monitor Logic on the Sync-Check (25) settings screen in BESTCOMS*Plus*. When a logic combination is selected, the sync-check element closes the respective switch in Figure 18-1 associated with each of the outputs.

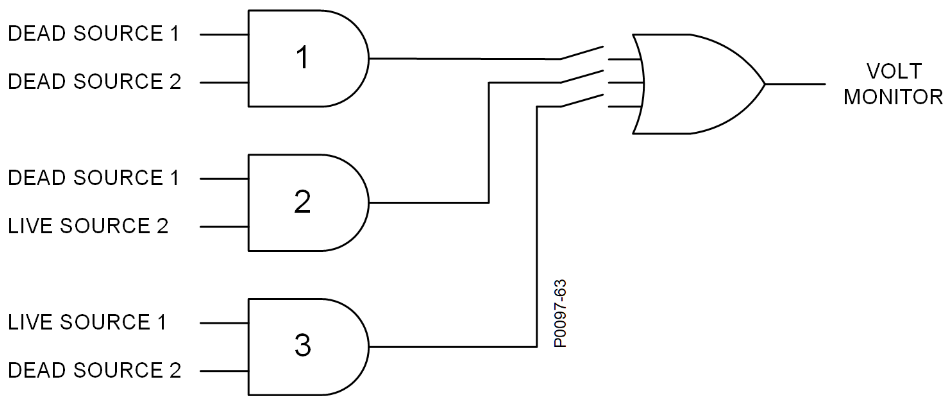


Figure 18-1. Voltage Monitor Logic

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block the Voltage Monitor (25) element when fuse loss is detected in a three-phase system. The Live Source 1/Live Source 2 condition is inherently disabled under a fuse loss condition.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Voltage Monitor (25) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to assure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the element outputs to logic 0. Connect the element Block input to the desired logic in

BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is logic 0.

Logic Connections

Sync-check element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. It is common to OR the Sync and Voltage Monitor outputs to give breaker close permission in either condition as shown in Figure 18-2. Logic inputs and outputs are summarized in Table 18-1. The Sync output is not true during Voltage Monitor conditions.

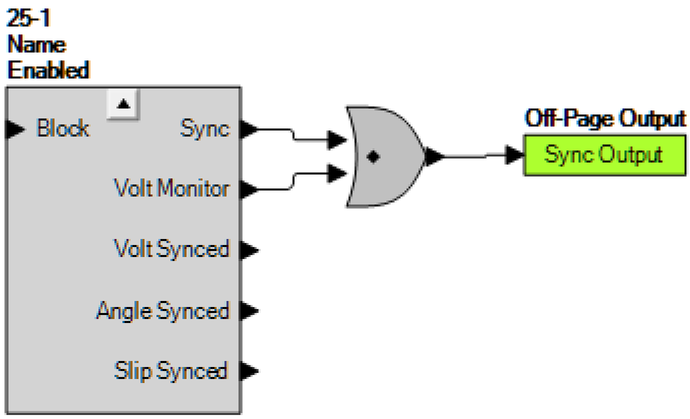


Figure 18-2. Sync-Check Element Logic Block

Table 18-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 25 function when true
Sync	Output	True when the monitored voltage between the sources meets angle, voltage, and slip criteria
Volt Monitor	Output	True when either or both sources is dead and voltage monitor condition is enabled
Volt Synced	Output	True when the voltage magnitude between sources is less than setting
Angle Synced	Output	True when the phase angle between sources is less than the Slip Angle setting
Slip Synced	Output	True when the frequency error between sources is less than the Slip Frequency setting

Operational Settings

Sync-check element operational settings are configured on the Sync-Check (25) settings screen (Figure 18-3) in BESTCOMS*Plus*.

Figure 18-3. Sync-Check Settings Screen

19 • Undervoltage (27)

The Undervoltage (27) elements monitor the phase and ground voltages applied to the BE1-FLEX. An element can be configured to protect against undervoltage by monitoring phase, zero-sequence voltage, positive-sequence voltage, negative-sequence voltage, ground fundamental voltage, or ground 3rd harmonic voltage.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Undervoltage settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Voltage, Undervoltage (27)

Element Operation

Undervoltage protection can be used to prevent equipment damage when an undervoltage condition exists. For example, an undervoltage condition could occur when a tap changing control fails. Undervoltage protection can also be used to protect equipment from damage caused by phase failure, positive/negative phase sequence, or phase unbalance.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Protection

Six modes of protection are available: Phase, 3V0, V1, V2, VG Fundamental, and VG 3rd Harmonic.

Phase

The One of Three method activates protection when one of the three phases of voltage decreases below the Pickup setting. The Two of Three method activates protection when any two phases of voltage decrease below the Pickup setting. The Three of Three method activates protection when all three phases of voltage decrease below the Pickup setting.

3V0

3V0 mode provides voltage unbalance protection in a three-phase system. The 3V0 measurement increases as the three-phase voltages become unbalanced.

V1

V1 mode provides positive phase-sequence protection in a three-phase system. The V1 measurement increases as the phase sequence is brought forward.

V2

V2 mode provides negative phase-sequence protection in a three-phase system. The V2 measurement increases as voltage becomes unbalanced and when phase sequence is reversed.

VG Fundamental

VG Fundamental mode typically provides ground offset detection on high impedance ground systems.

VG 3rd Harmonic

VG 3rd Harmonic mode typically provides internal generator short detection.

Sensing Configuration

The undervoltage element can be set to monitor VPP or VPN. This is determined by the 27/51V/59 Mode parameter of the VT setup found on the Configuration, Circuit Summary, Power System screen in

BESTCOMS*Plus*. For more information on the VT setup for PP or PN voltage response, see the *Power System Configuration* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. The Phase Voltage is monitored for modes Phase, 3V0, V1, or V2. Ground Voltage is monitored for modes VG Fundamental or VG 3rd Harmonic. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Timing Mode

The timing mode can be set for definite, inverse, or table. Element operate times do not include logic or output operate times.

Definite

When definite timing is selected, the element operate time equals the definite time delay setting.

Inverse

When inverse timing is selected, the P Curve Constants must be entered. The user can select instantaneous or integrating reset timing. When integrating reset timing is selected, the protective element uses integrated reset and emulates an electromechanical induction disk reset characteristic. The undervoltage inverse time curve with default constants is shown in the *Timing Characteristics* chapter.

Programmable Curves

The programmable curve can be used to create a custom curve by selecting constants in the inverse time characteristic equation. When inverse timing is selected, the constants used in the equation are those defined by the user. Characteristics for trip and reset programmable curves are defined by Equation 19-1 and Equation 19-2. Definitions for these equations are provided in Table 19-1.

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

Equation 19-1. Time Characteristics for Trip

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

Equation 19-2. Time Characteristics for Reset

Table 19-1. Definitions for Equation 19-1 and Equation 19-2

Parameter	Description	Explanation
T_T	Time to trip	Time that the 27 function will take to time out and trip.
D	Time dial setting	Time dial setting for the 27 function.
M	Multiple of pickup	Measured current in multiples of pickup. The timing algorithm has a dynamic range of 0 to 1 times pickup.
A	Constant specific to selected curve	Affects the effective range of the time dial.
B	Constant specific to selected curve	Affects a constant term in the timing equation. Has greatest effect on curve shape at high multiples of tap.
C	Constant specific to selected curve	Affects the multiple of PU where the curve would approach infinity if allowed to continue below pickup. Has greatest effect on curve shape near pickup.
N	Exponent specific to selected curve	Affects how inverse the characteristics are. Has greatest effect on curve shape at low to medium multiples of tap.
T_R	Time to reset	Relevant if 27 function is set for integrating reset.
R	Constant specific to selected curve	Affects the speed of reset when integrating reset is selected.

Table Curves

When table is selected, the table curve must be programmed. A minimum of 2 and maximum of 40 points can be entered for a table curve. When you are satisfied with the values chosen, select Save Curve.

The user can select instantaneous or integrating reset timing. When integrating reset timing is selected, the protective element uses integrated reset and emulates an electromechanical induction disk reset characteristic. The Curve Display setting is used to switch between the pickup and reset table curves view.

Pickup and Trip

Pickup

The Pickup output becomes true when the measured voltage decreases below the voltage threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay (definite timing) or Time Dial (inverse or table curve timing). A Time Delay or Time Dial setting of zero (0) makes the 27 element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay or calculated inverse time expires, the timer and Pickup output begin resetting according to the configured Reset mode and timing, no corrective action is taken, and the element is rearmed for any other occurrences of undervoltage.

Trip

The Trip output becomes true when an undervoltage pickup condition persists for the duration of the element Time Delay setting, or calculated inverse or table curve time. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled by the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Voltage Inhibit

The Voltage Inhibit setting impedes undervoltage element operation during undervoltage conditions that may occur during equipment startup. Voltage inhibits are typically applied to clear the trip condition after a breaker has successfully opened and cleared the fault.

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Undervoltage (27) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Undervoltage (27) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Undervoltage element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The undervoltage element logic block is illustrated in Figure 19-1. Logic inputs and outputs are summarized in Table 19-2.

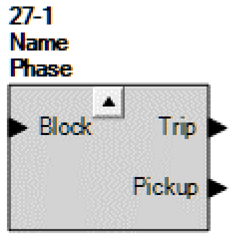


Figure 19-1. Undervoltage Element Logic Block

Table 19-2. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 27 function when true
Trip	Output	True when the 27 element is in a trip condition
Pickup	Output	True when the 27 element is in a pickup condition

Operational Settings

Undervoltage element operational settings are configured on the Undervoltage (27) settings screen (Figure 19-2) in BESTCOMS*Plus*.

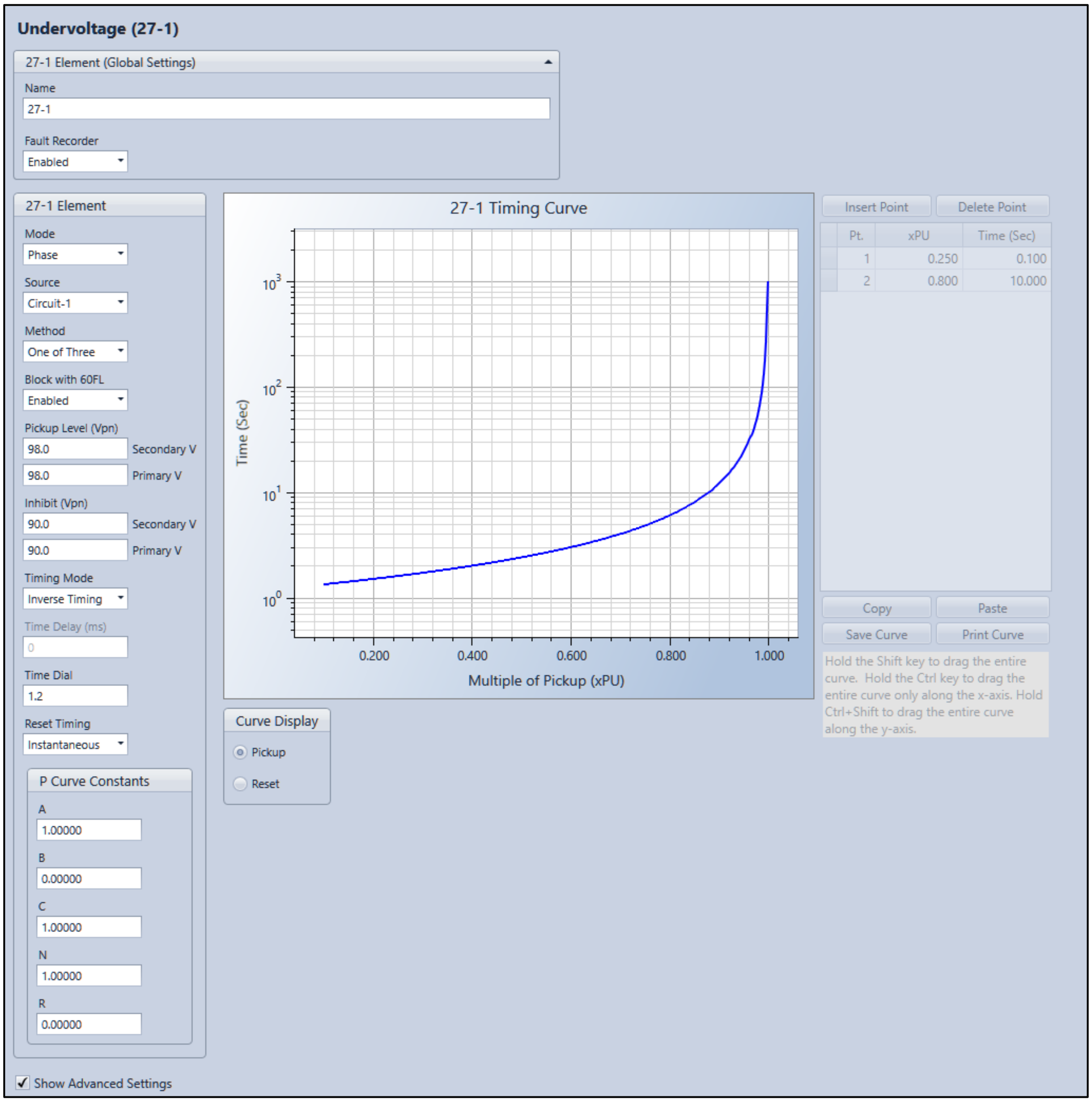


Figure 19-2. Undervoltage Settings Screen

20 • Power (32)

The Power (32) elements monitor three-phase real power (watts). An element can be configured to protect against overpower or underpower conditions in the forward or reverse direction.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Power settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Power, Power (32)

Element Operation

Power protection can be used in applications where excessive power flow in the tripping direction is undesirable. Directional power protection is desirable in applications where:

- Power flows into a generator, indicating loss of prime mover torque (motoring).
- Power flows into the secondary of a station distribution transformer, indicating an industrial or private customer is supplying power into the utility system.
- Excessive load has been connected to a system.
- Overspeed is a prime concern.
- An open breaker creates an overload on a local generation facility.
- Reduced power can indicate a loss of load on the motor.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Protection

Four modes of protection are available. One of Three mode activates protection when the power on one of the three phases exceeds the Pickup setting. Two of Three mode activates protection when the power on any two of the three phases exceeds the Pickup setting. Three of Three mode activates protection when the power on all three phases exceeds the Pickup setting. Total mode activates protection when the total power exceeds the Pickup setting. The element remains in the picked-up condition until power flow falls below the dropout ratio of 95% of the actual pickup.

To clarify the difference between Two of Three and Total modes, for example, assume that Two of Three mode has been selected and the pickup setting is 30 watts. Therefore, the BE1-FLEX picks up when two of the three phases have exceeded 30 watts. Alternately, if two phases are zero (0) watts and the third phase is 70 watts, the BE1-FLEX does not pick up because two of the phases have not exceeded the pickup threshold required for operation in Two of Three mode. Any two phases must exceed the pickup threshold for operation to occur. However, if the 32 element were set for Total mode, the same power values previously mentioned would result in a pickup condition because “Total Power” (0 + 0 + 70 watts) exceeds the three-phase pickup setting of 30 watts. For details on power calculations, refer to the *Power System Configuration* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Over/Under

This setting configures the element to pick up for overpower or underpower.

Direction of Power Flow

In addition to exceeding the power pickup threshold, direction of power flow (forward or reverse) must match the directional setting for the 32 element to operate. In the BE1-FLEX, the forward and reverse directions are defined by the polarity voltage and current connections to the BE1-FLEX as shown in Figure 20-1. Based on IEEE polarity convention, forward power is defined as bus to line and reverse power is defined as line to bus.

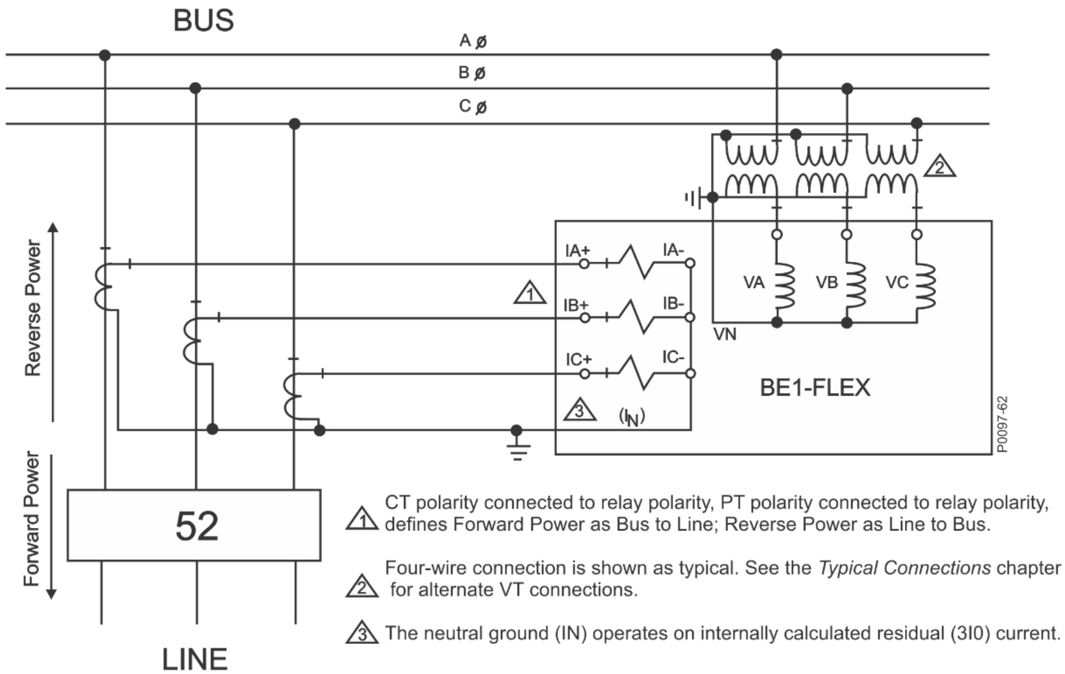


Figure 20-1. Direction of Power Flow Defined by the Polarity of Voltage and Current Connections

Establishing Forward and Reverse Pickup Values

Three-phase power pickup settings for the power elements are always positive regardless of the directional setting. However, it is useful in understanding the element response to visualize the forward direction as positive power and the reverse direction as negative power. If we think in terms of a forward and reverse scale with zero (0) in the middle as shown in Figure 20-2, positive and negative power flows relative to the forward and reverse directional setting. For example, assume an intertie application where the Area EPS (electric utility) requires the Local EPS (source of non-utility generation) to separate from the Area EPS (trip the intertie breaker) if any power flows towards the Area EPS. For illustrative purposes, assume that the BUS in Figure 20-1 is the Local EPS, 52 is the intertie breaker, and LINE is the Area EPS. Normal power flow is from the Area EPS to the Local EPS, which happens to be an industrial facility with local generation used for peak shaving.

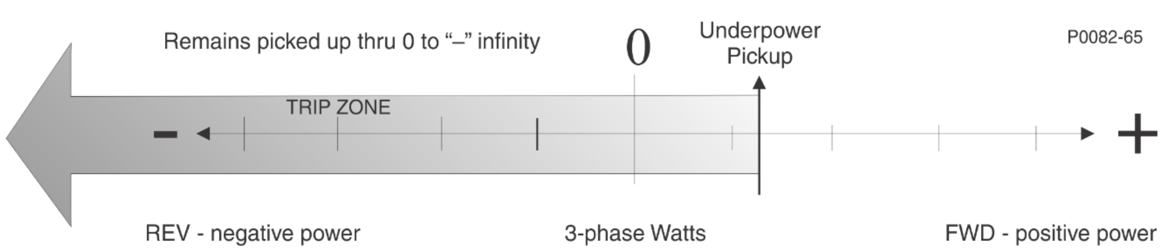


Figure 20-2. Forward and Reverse Pickup Values

Assuming polarity current and voltage connections as shown in Figure 20-1, forward power is defined as flowing into the Area EPS and reverse power is defined as flowing into the Local EPS. For this application, the 32 element should be set to trip for minimum underpower in the reverse direction (to the Local EPS). Therefore, the settings would be Reverse, Under, and 1 watt. To increase sensitivity, mode selection should be three of three, which requires each phase power to fall below one-third of the three-phase power setting or 0.33 watts. Assume that the normal power absorbed by the load is 4 kW in the reverse or negative direction on our scale. If load is suddenly lost at the industrial plant while the peak shaving generation is running, power may flow towards the area EPS depending on the load to generation ratio. What was a negative 4 kW passes through 0 watts on its way to some positive power level. However, in doing so, passes through the negative underpower trip threshold of Reverse, Under, 0.33 watts/phase, resulting in a 32 trip and opening of the intertie circuit breaker. From negative 0.33 to positive infinity, the 32 element remains in a picked up condition as shown in Figure 20-2. A trip time delay should be included to ensure that the 32 element does not operate for a transient power condition.

Pickup and Trip

Pickup

The Pickup output becomes true when the calculated real power increases above (overpower) or decreases below (underpower) the threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a definite timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the 32 element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of over/under power.

Trip

The Trip output becomes true if a power pickup condition exists for the duration of the element Time Delay. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Power (32) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Power (32) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Power element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The power element logic block is illustrated in Figure 20-3. Logic inputs and outputs are summarized in Table 20-1.

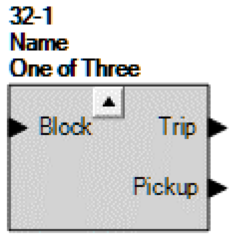


Figure 20-3. Power Element Logic Block

Table 20-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 32 function when true
Trip	Output	True when the 32 element is in a trip condition
Pickup	Output	True when the 32 element is in a pickup condition

Operational Settings

Power element operational settings are configured on the Power (32) settings screen (Figure 20-4) in BESTCOMS*Plus*.

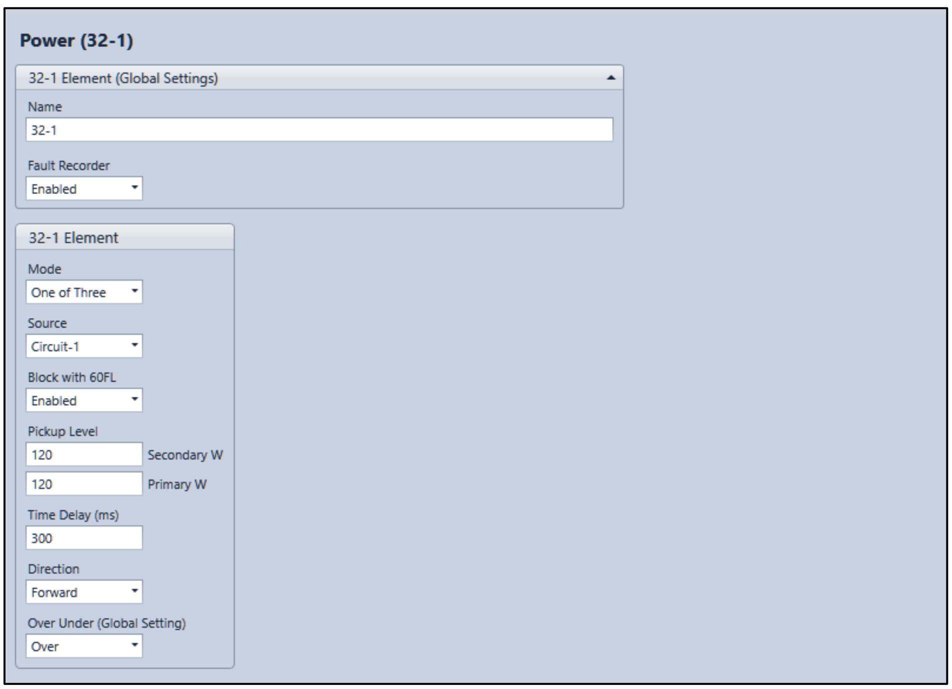


Figure 20-4. Power Settings Screen

21 • Instantaneous Undercurrent (37)

The Instantaneous Undercurrent (37) elements monitor the phase sensing current and protect against loss of load conditions, such as a breaking motor belt. This protective function will trip when a loss of load occurs.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Instantaneous Undercurrent settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, Instantaneous Undercurrent (37)

Element Operation

The instantaneous undercurrent element can be set to monitor IA, IB, IC, or all three phases. When Three-Phase mode is selected, the element monitors IA, IB, and IC and makes pickup and trip decisions from the lowest of the three phases.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when the measured current decreases below the current threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay of zero (0) makes the 37 element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of undercurrent.

Trip

The Trip output becomes true if an undercurrent condition persists for the duration of the element Time Delay. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled by the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Inhibit Level

The Inhibit Level setting prevents undesired undercurrent tripping on de-energized circuits and during motor startup. The instantaneous undercurrent element operation is disabled when the phase is below the inhibit threshold.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Instantaneous undercurrent element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The instantaneous undercurrent element logic block is illustrated in Figure 21-1. Logic inputs and outputs are summarized in Table 21-1.

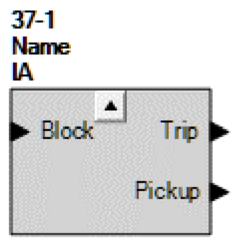


Figure 21-1. Instantaneous Undercurrent Element Logic Block

Table 21-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 37 function when true
Trip	Output	True when the 37 element is in trip condition
Pickup	Output	True when the 37 element is in pickup condition

Operational Settings

Instantaneous undercurrent element operational settings are configured on the Instantaneous Undercurrent (37) settings screen (Figure 21-2) in BESTCOMS*Plus*.

Figure 21-2. Instantaneous Undercurrent Settings Screen

22 • Loss of Excitation - Var Based (40Q)

The Loss of Excitation - Var Based (40Q) elements monitor total reactive power (vars). The 40Q elements are typically used for generator protection to detect when current leads the voltage. Current lagging voltage conditions such as in a synchronous motor application are not picked up by the 40Q when typical motor wiring is utilized.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Loss of Excitation - Var Based settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Power, Loss of Excitation - Var Based (40Q)

Element Operation

When a generator loses its excitation power, it acts as a large inductor. The generator begins to absorb large quantities of vars. The 40Q element acts on the principal that if a generator begins to absorb vars outside of its steady-state capability curve, it has likely lost its normal excitation supply. The element is always calibrated to the equivalent three-phase power even if the connection is single-phase. For more information on the calibration and power calculations, refer to the *Power System Configuration* chapter.

The 40Q element compares the reactive power to a map of the allowed reactive power as defined by the Pickup setting. The 40Q remains in a pickup condition until power flow falls below the dropout ratio of 95% of the actual pickup. A time delay is recommended for tripping. For settings well outside the generator capability curve, adding a 0.5 second time delay helps prevent transient fault conditions. However, recovery from power system swings after a major fault may take several seconds. Therefore, if the unit is to pick up near the steady-state capability curve of the generator, longer time delays are recommended. See Figure 22-1 for details.

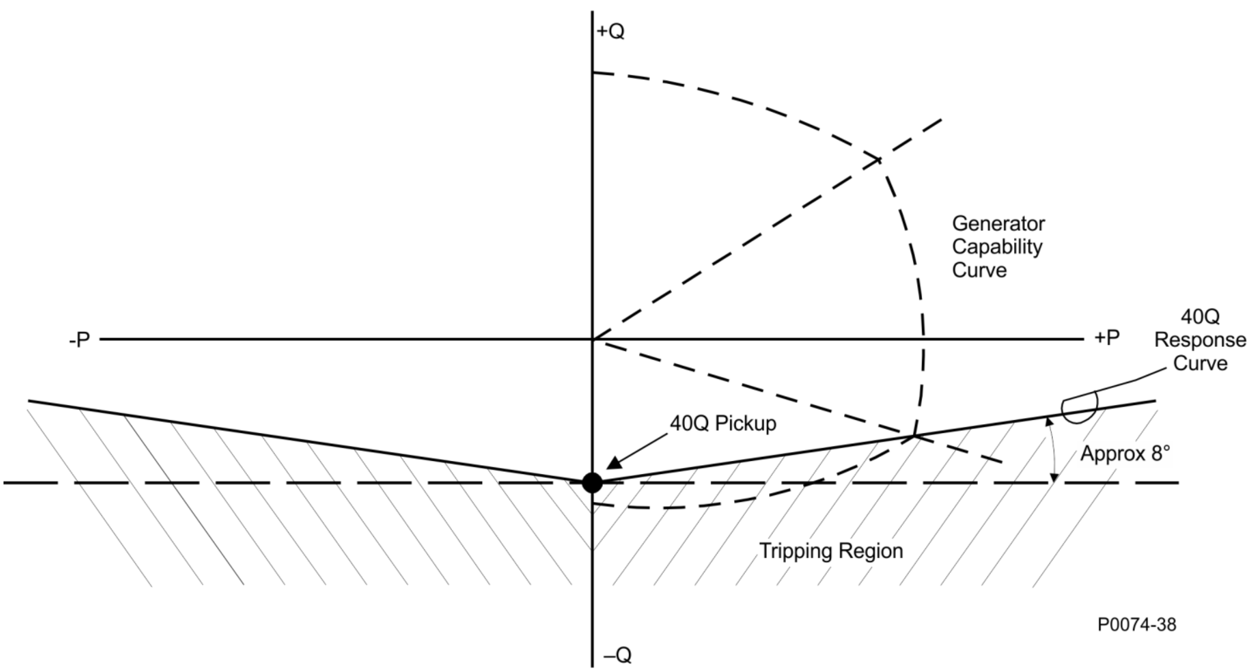


Figure 22-1. Generator Capability Curve vs. 40Q Response

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Protection

Two modes of protection are available. Eight Degree, as shown in Figure 22-1, is the typical angle used to coordinate with the Positive P, Negative Q quadrant of the generator capability curve. Zero degree mode is more common in synchronous motor applications.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when the calculated reactive power increases above or decreases below the threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the 40Q element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of loss of excitation.

Trip

The Trip output becomes true if a loss of excitation pickup condition exists for the duration of the element Time Delay. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

The 40Q element can be blocked by the fuse loss (60FL) element and the 40Q element's Block logic input.

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Loss of Excitation - Var Based (40Q) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Loss of Excitation - Var Based (40Q) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Loss of excitation - var based element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The loss of excitation - var based element logic block is illustrated in Figure 22-2. Logic inputs and outputs are summarized in Table 22-1.

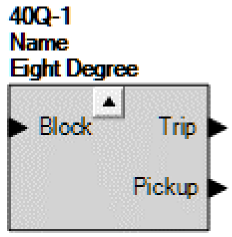


Figure 22-2. Loss of Excitation - Var Based Element Logic Block

Table 22-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 40Q function when true
Trip	Output	True when the 40Q element is in a trip condition
Pickup	Output	True when the 40Q element is in a pickup condition

Operational Settings

The 40Q element operational settings are configured on the Loss of Excitation - Var Based (40Q) settings screen (Figure 22-3) in BESTCOMS*Plus*.

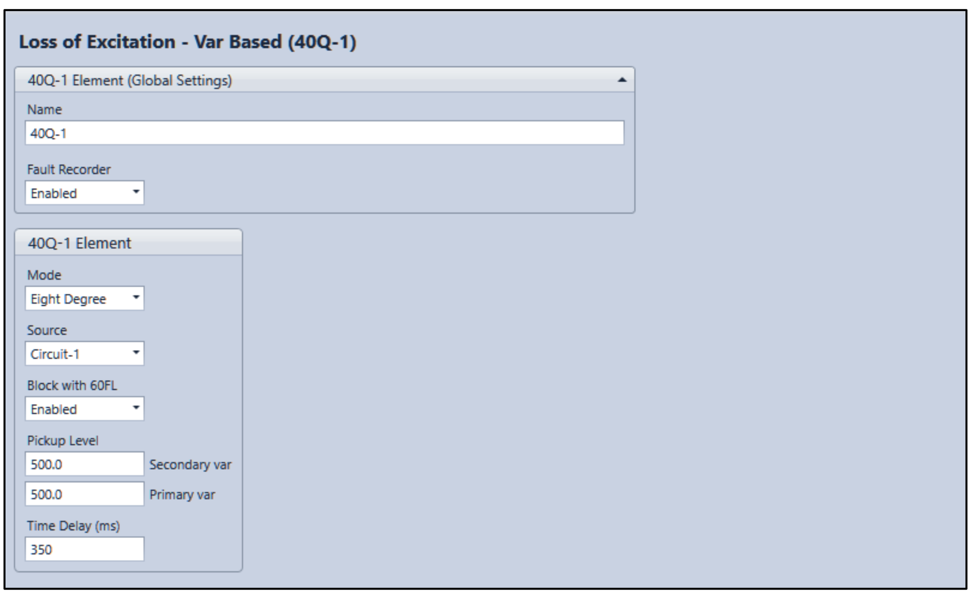


Figure 22-3. Loss of Excitation - Var Based Settings Screen

23 • Loss of Excitation - Impedance Based (40Z)

The Loss of Excitation - Impedance Based (40Z) elements implement a two zone offset mho characteristic to protect against varying load conditions. The small inner zone (Z1) protects for loss of field conditions while the large outer zone (Z2) provides protection at or near no-load conditions. The 40Z characteristic is illustrated in Figure 23-3.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Loss of Excitation - Impedance Based (40Z) settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Impedance, Loss of Excitation - Impedance Based (40Z)

Element Operation

The 40Z element monitors three-phase positive-sequence voltage (V1) and positive-sequence current (I1) and determines the impedance (V1/I1) as viewed from the BE1-FLEX terminals outward towards the power system.

The 40Z element has two mho characteristics offset below the R axis by a settable amount, and centered on the X axis. The offset of each mho circle is defined as the most negative point where the circle crosses the R axis. The size of the mho circles is defined by their diameter.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Protection

Three modes of protection are available: Non-Voltage Control, Voltage Control, or Both. Details are outlined later in this chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Directional Supervision

The Directional Supervision Angle setting modifies the effective tripping area of the mho circles. Directional supervision is disabled when the angle is set to zero (0). When the directional supervision angle is used, tripping is blocked when the measured impedance is above the directional supervision angle, and enabled when below.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when calculated impedance enters the zone defined by the mho circles. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the 40Z element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of loss of excitation.

Trip

The Trip output becomes true if a loss of excitation pickup condition exists for the duration of the element Time Delay. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Voltage Control

Voltage control provides faster tripping when low voltage results from loss of excitation. Each mho circle has a setting for Voltage Pickup and Voltage Time Delay when Voltage Control mode is enabled.

When the voltage decreases below the threshold established by the Voltage Pickup setting and the calculated impedance exists within the mho circles, the element VC Pickup output becomes true. In BESTlogic*Plus*, the VC Pickup output can be connected to other logic elements to annunciate the condition or control other elements in logic.

Assertion of the VC Pickup output initiates a timer, which begins timing toward a trip. The duration of the timer is established by the Voltage Delay. A Voltage Delay setting of zero (0) makes voltage control instantaneous with no intentional time delay.

If a voltage pickup condition exists for the duration of the element Voltage Delay, the element VC Trip output becomes true. In BESTlogic*Plus*, the VC Trip output can be connected to other logic elements or a physical relay output to annunciate the condition and initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the VC Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

If the voltage pickup condition subsides before the element time delay expires, the timer and VC Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of loss of excitation.

Element Blocking

The 40Z element can be blocked by the fuse loss (60FL) element and the 40Z element's Block logic input.

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Loss of Excitation - Impedance Based (40Z) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Loss of Excitation - Impedance Based (40Z) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Loss of excitation - impedance based element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The loss of excitation - impedance based element logic block is illustrated in Figure 23-1. Logic inputs and outputs are summarized in Table 23-1.

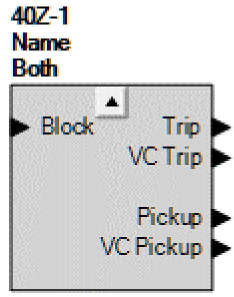


Figure 23-1. Loss of Excitation - Impedance Based Element Logic Block

Table 23-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 40Z function when true
Trip	Output	True when the 40Z element is in a trip condition
VC Trip	Output	Voltage Control pickup
Pickup	Output	True when the 40Z element is in a pickup condition
VC Pickup	Output	Voltage Control trip

Operational Settings

The 40Z element operational settings are configured on the Loss of Excitation - Impedance Based (40Z) settings screen (Figure 23-2) in BESTCOMS*Plus*.

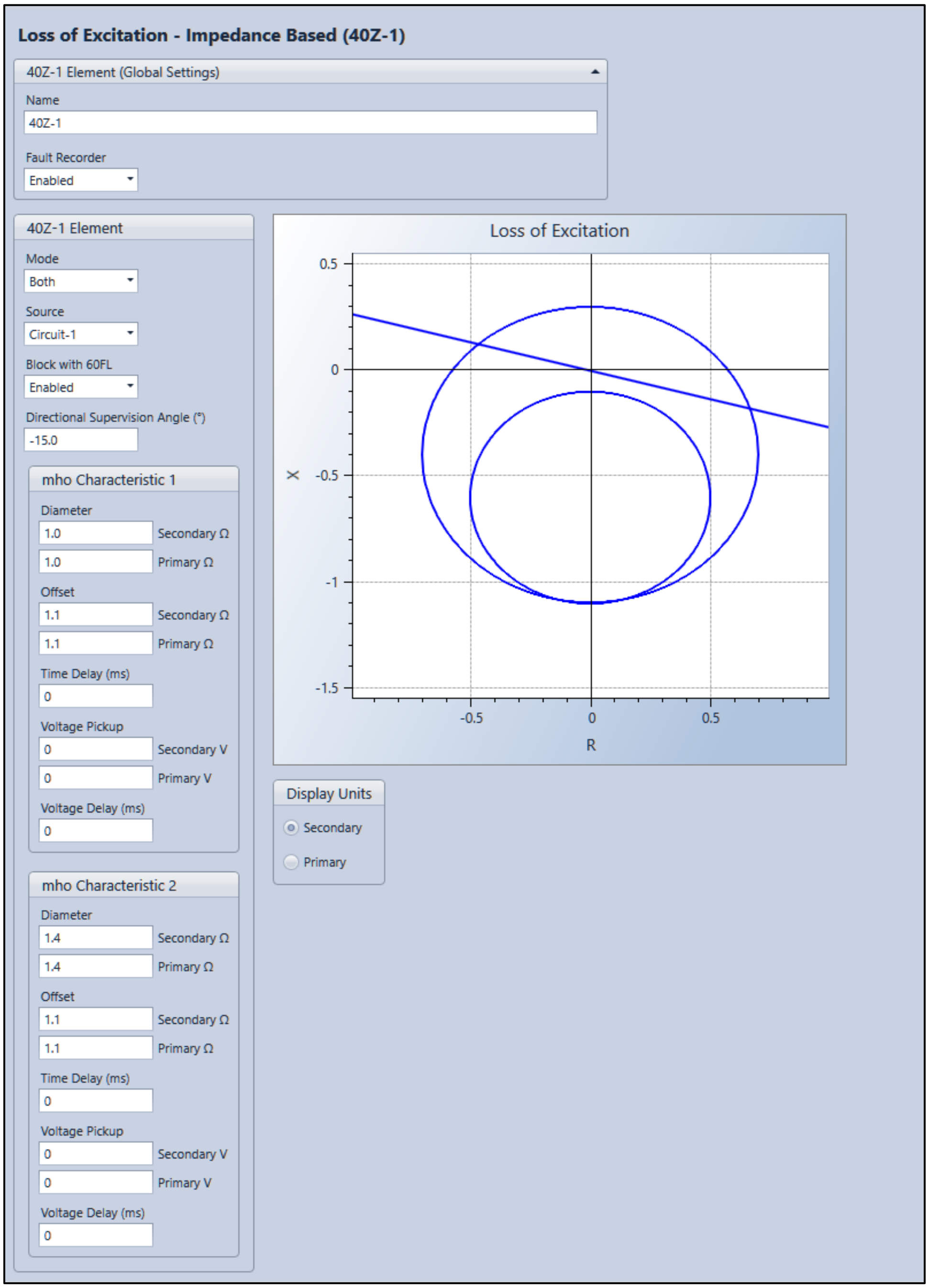


Figure 23-2. Loss of Excitation - Impedance Based Settings Screen

Typical Application

Settings and measurements are used to determine if the measured system impedance is within the tripping criteria to indicate loss of excitation.

This consists of two mho circles with the lower edge offset from the R axis by an equal distance typically set to 1.1*Xd. The diameter of the smaller circle (Z1) is typically set so that the upper edge is located at X'd/2 below the R axis. The larger circle (Z2) and the directional blocking are both set to coordinate with the steady-state stability limit of the generator. The larger circle has a time delay to prevent nuisance tripping. Refer to Figure 23-3.

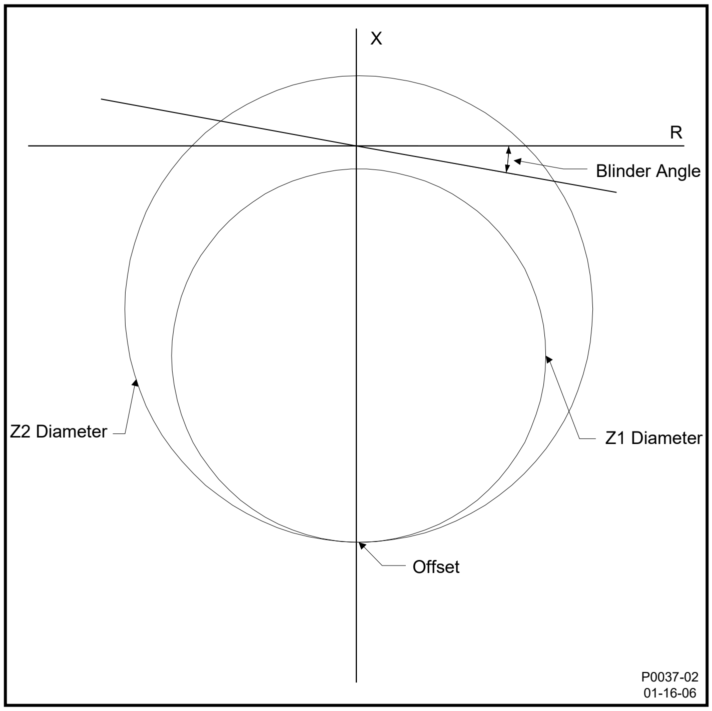


Figure 23-3. Typical Application

24 • Negative-Sequence Overcurrent (46)

Negative-sequence overcurrent protection is included as a mode of the 50 (Instantaneous Overcurrent) and the 51 (Inverse Overcurrent) elements. Refer to the chapters on *Instantaneous Overcurrent (50)* and *Inverse Overcurrent (51)* for information on how to set up and program the I2 (negative-sequence overcurrent) mode of the 50 and the 51 elements.

For years, protection engineers have enjoyed increased sensitivity to phase-to-ground unbalances with the application of ground relays. Ground relays can be set more sensitively than phase relays because a balanced load has no ground (3I0) current component. When using negative-sequence mode, the 50 and 51 elements can provide similar increased sensitivity to phase-to-phase faults because a balanced load has no negative-sequence (I2) current component.

Pickup Settings

A typical setting when using negative-sequence mode for the 50 or 51 elements might be one-half the phase pickup setting in order to achieve equal sensitivity to phase-to-phase faults as three-phase faults. This number comes from the fact that the magnitude of the current for a phase-to-phase fault is √3/2 (87%) of the three-phase fault at the same location. This is illustrated in Figure 24-1.

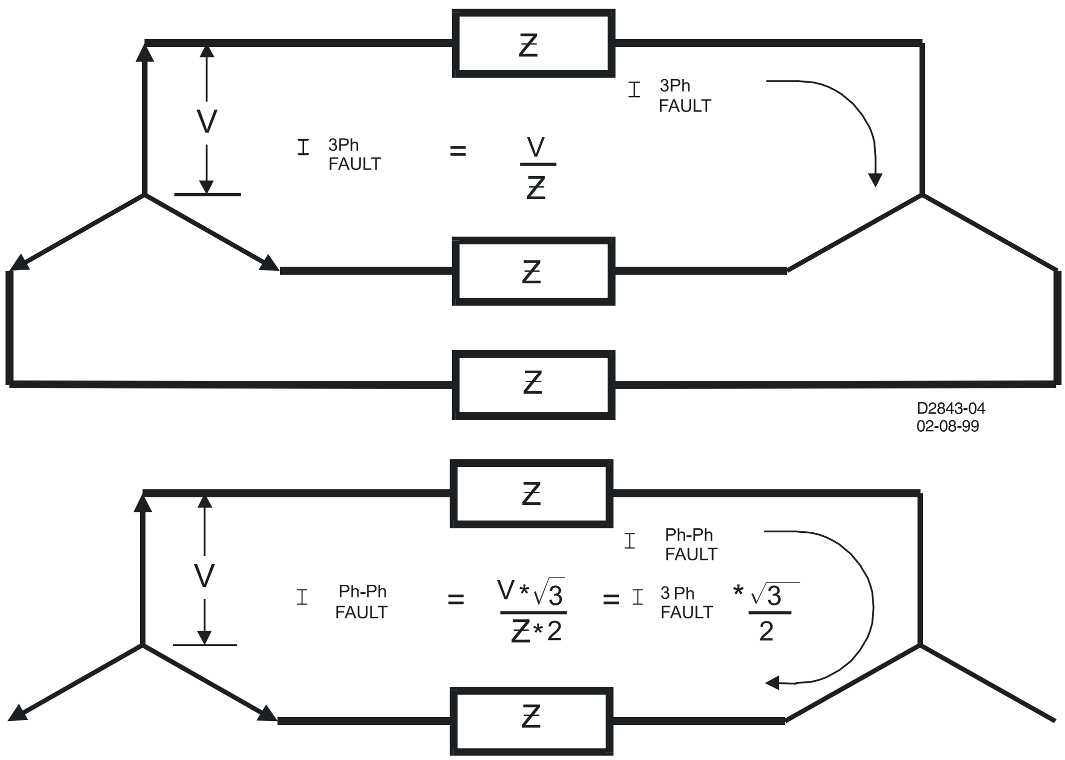


Figure 24-1. Phase-to-Phase Fault Magnitude

The phase-to-phase fault is made up of both positive and negative-sequence components as shown in Figure 24-2 For a phase-to-phase fault, the magnitude of the negative-sequence component is 1/√3 (58%) of the magnitude of the total phase current. When these two factors (√3/2 and 1/√3) are combined, the √3 factors cancel which leaves the one-half factor.

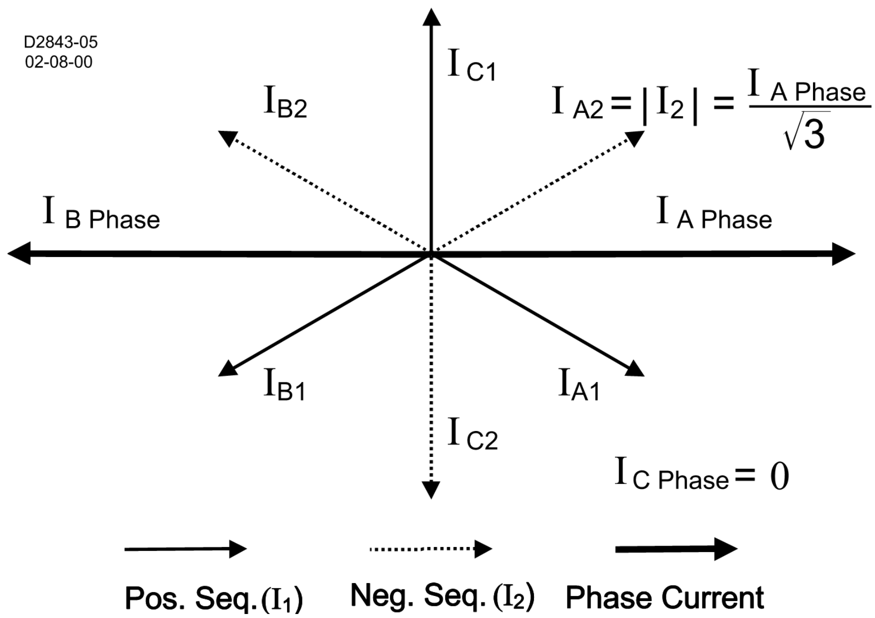


Figure 24-2. Sequence Components for an A-B Fault

Coordination Settings

The 51 negative-sequence settings should be checked for coordination with phase-only sensing devices such as downstream fuses and reclosers and/or ground relays. To plot the negative-sequence time current characteristics on the same plot for the phase devices, you need to multiply the negative-sequence element pickup value by the correct multiplier. The multiplier is the ratio of phase current to negative-sequence current for the fault type for which you are interested. To plot the negative-sequence time current characteristics on the same plot for the ground devices, you need to multiply the pickup value by the multiplier for phase-to-ground faults (see Table 24-1).

Table 24-1. Fault Type Multipliers

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

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

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

25 • Negative-Sequence Voltage (47)

Negative-sequence voltage protection is included as a mode of the 27 (Undervoltage) and 59 (Overvoltage) elements. Refer to the *Undervoltage (27)* and *Overvoltage (59)* chapters for information on how to set up and program the V2 (negative-sequence voltage) mode of the 27 and 59 elements.

Negative-sequence voltage protection is typically used to sense power-system imbalance. This situation occurs when a large single-phase load is switched onto the system, or when transformer-input fuses blow in only one or two phases. Negative-sequence voltage protection is good for detecting improper phasing when an oncoming generator is paralleled to the power system. All motor loads should be protected from the heating caused by unbalanced voltage (either on the bus or on each motor feeder). Industry standards state that the existence of unbalanced voltage feed may result in 4 to 10 times the current imbalance. For a typical motor feeder, the negative-sequence voltage unbalances should not exceed 5 percent to avoid overheating and damage.

26 • Resistance Temperature Detector (49RTD)

Resistance Temperature Detector (49RTD) elements provide over/undertemperature protection. 49RTD protection is typically applied to motors, generators, and transformers. Each element can be set to monitor any number of physical RTD sensors as defined by the RTD groups. Refer to the *Power System Configuration* chapter for information on RTD input configuration and grouping.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Resistance Temperature Detector settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Thermal, Resistance Temperature Detector (49RTD)

Element Operation

Each 49RTD element can be configured to protect against high, low, or both temperature conditions.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Protection

Three modes of protection are available: Over, Under, and Over/Under.

In Over mode, if the temperature of any RTDs in the group is above the Over Pickup setting, the element will pick up.

In Under mode, if the temperature of any of the RTDs in the group is below the Under Pickup setting, the element will pick up.

In Over/Under mode, if the temperature of any of the RTDs in the group is above the Over Pickup setting or below the Under Pickup setting, the element will pick up. The element will remain in the picked-up condition and continue timing towards a trip unless the temperature falls below the Over Pickup setting or rises above the Under Pickup setting. See Voting for the number of RTDs required for pickup.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Source

The Source setting selects which RTD group to monitor.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when the RTD group value increases above (Over mode) or decreases below (Under mode) the pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset and no corrective action is taken.

Trip

The Trip output becomes true if a pickup condition persists for the duration of the element Time Delay. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Voting

The Voting parameter defines the number of RTDs in the group that must exceed the pickup setting to cause a pickup condition. For example, if the 49RTD-1 Voting setting is 3, then at least three RTDs in the selected group must exceed the pickup setting to cause a trip.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Additionally, individual RTD inputs with an active Out of Range Alarm will be blocked from operating a 49RTD Trip. RTD's in the group that are not Out of Range will remain active.

Logic Connections

The 49RTD element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The 49RTD element logic block is illustrated in Figure 26-1. Logic inputs and outputs are summarized in Table 26-1.

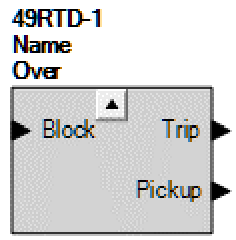


Figure 26-1. Resistance Temperature Detector Element Logic Block

Table 26-1. Logic Inputs and Outputs

Name	Function	Purpose
Block	Input	Disables the 49RTD function when true
Trip	Output	True when the 49RTD element is in trip condition
Pickup	Output	True when the 49RTD element is in pickup condition

Operational Settings

The 49RTD element operational settings are configured on the Resistance Temperature Detector settings screen (Figure 26-2) in BESTCOMS*Plus*.

Figure 26-2. Resistance Temperature Detector Settings Screen

Remote RTD Metering

RTD metering values are obtained through BESTCOMS*Plus* by using the Metering Explorer to open the Analog Metering, RTD Inputs tree branch. BESTCOMS*Plus* must be online with the BE1-FLEX to view RTD metering. Alternately, values can be obtained through the front-panel display by navigating to the Metering, RTD Meter screen.

27 • Instantaneous Overcurrent (50)

The Instantaneous Overcurrent (50) elements monitor the current applied to the BE1-FLEX. An element can be configured to protect against single- or three-phase current, neutral current, positive-sequence current, negative-sequence current, ground current, or unbalanced current.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Instantaneous Overcurrent settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, Instantaneous Overcurrent (50)

Element Operation

Instantaneous overcurrent protection can be used to protect equipment from damage caused by phase failure, forward/reverse phase sequence, or phase unbalance.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Protection

Ten modes of protection are available: IA, IB, IC, 3 Phase, 3I0, I1, I2, IG, I2/I1, and (Max-Min)/Avg.

IA, IB, or IC

Protection is activated when the selected phase current increases above the pickup setting.

3 Phase

The instantaneous overcurrent protection elements include three independent comparators, one for each phase. Protection is activated when any of the three phases increases above the Pickup setting.

3I0

3I0 mode provides calculated zero sequence neutral overcurrent protection in a three-phase system.

I1

I1 mode provides positive-sequence overcurrent protection in a three-phase system.

I2

I2 mode provides negative-sequence overcurrent protection in a three-phase system. Refer to the *Negative-Sequence Overcurrent (46)* chapter for more information.

IG

IG mode provides measured ground fault protection from the Ground connection of a circuit.

I2/I1

I2/I1 mode provides unbalanced current protection based on the negative-sequence phase current divided by the positive-sequence phase current. The unbalance annunciation is blocked if the average current of all three phases is below 25% of the nominal secondary phase current in the power system settings.

$$I_{Unbalance} = \frac{I_2}{I_1} \times \mathrm{MIN}$$

where:

$$\mathrm{MIN} = \frac{I_{Average}}{I_{Rated}} \text{ or } 1, \text{whichever is less}$$

(Max-Min)/Avg

(Max-Min)/Avg mode provides unbalanced current protection based on the average current. The unbalance annunciation is blocked if the average current of all three phases is below 25% of the nominal phase current in the power system settings.

$$I_{Unbalance} = \frac{(\mathrm{MAXp} - \mathrm{I}_{Average}) \text{ or } (\mathrm{I}_{Average} - \mathrm{MINp}), \text{whichever is greater}}{\mathrm{I}_{Average}} \times \mathrm{MIN}$$

where:

$$\mathrm{MIN} = \frac{I_{Average}}{I_{Rated}} \text{ or } 1, \text{whichever is less}$$

$$\mathrm{MAXp} = \text{maximum of all three phases}$$

$$\mathrm{MINp} = \text{minimum of all three phases}$$

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Method

Two calculation methods are used to detect the pickup value: fundamental and peak detect.

When set to Fundamental, the magnitude of current is calculated by using the first harmonic (fundamental) of current from the Discrete Fourier Transform (DFT).

When set to Peak Detect, the magnitude of current is calculated by determining the fundamental equivalent of the highest sample value. Peak Detect is not available with circuits created from Ethernet input sources.

Direction

An instantaneous overcurrent element can be configured for forward, reverse, or non-directional tripping. Refer to the *Power System Configuration* chapter for more information.

Fail Safe Direction

When the Direction setting is Forward or Reverse, and insufficient polarization signal is present, the overcurrent element will operate based upon the failsafe directional setting.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when the measured current increases above the current threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay of zero (0) makes the 50 element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the Pickup output is reset and a reset timer is initiated. The duration of the reset timer is established by the Reset Delay setting. A Reset Time Delay of zero (0) makes the reset instantaneous with no intentional reset delay. If there is no pickup for the duration of the element Reset Delay setting, the timer is reset to zero (0), no corrective action is taken, and the element is rearmed for any other occurrences of overcurrent. If the 50 element picks up again before the Reset Delay expires, the Time Delay timer will continue timing to a trip.

Trip

The Trip output becomes true if an overcurrent condition persists for the duration of the element Time Delay setting. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Second and Fifth Harmonic Inhibits

Second and fifth harmonic inhibits detect the same transformer inrush and overexcitation conditions that is commonly used on a Transformer Differential (87T) element. With harmonic inhibits, feeders near a transformer inrush condition can be set more sensitively when it can be blocked during this non-fault event.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Instantaneous overcurrent element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The instantaneous overcurrent element logic block is illustrated in Figure 27-1. Logic inputs and outputs are summarized in Table 27-1.

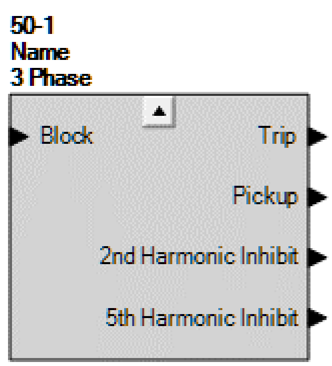


Figure 27-1. Instantaneous Overcurrent Element Logic Block

Table 27-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 50 function when true
Trip	Output	True when the 50 element is in a trip condition
Pickup	Output	True when the 50 element is in a pickup condition
2nd Harmonic Inhibit	Output	True when the 50 is inhibited by 2nd harmonic ratio
5th Harmonic Inhibit	Output	True when the 50 is inhibited by 5th harmonic ratio

Operational Settings

Instantaneous overcurrent element operational settings are configured on the Instantaneous Overcurrent (50) settings screen (Figure 27-2) in BESTCOMS*Plus*.

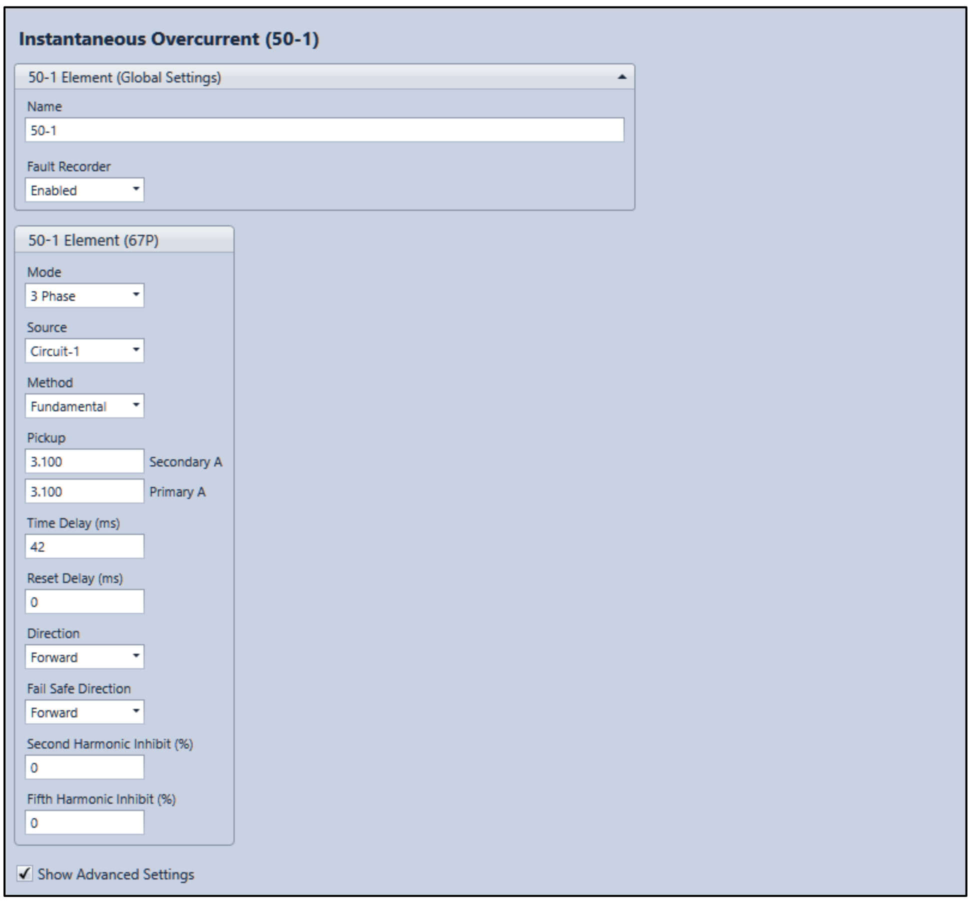


Figure 27-2. Instantaneous Overcurrent Settings Screen

28 • Breaker Failure (50BF)

The Breaker Failure (50BF) elements provide protection and security for the power system against the monitored breakers failing to open.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Breaker Fail (50BF) settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, Breaker Fail (50BF)

Element Operation

The 50BF element uses two simultaneous methods to determine if the breaker has failed to open. The first method uses the breaker status (52a or 52b input) to determine if the breaker has successfully opened. The second method uses the monitored current to detect if the breaker has successfully opened.

In the first method, the 50BF element determines that the breaker is closed when the Breaker Status (BRK) logic element input is true. See Figure 28-1. The 52BFI logic input of the Breaker Failure logic block is used to signal that the breaker has been instructed to open. When the BRK logic element and the 52BFI logic input are true, a delay timer is initiated to allow time for the breaker to transition. If the time delay expires and the BRK logic element and the 52BFI logic input are still true, the Trip output becomes true, signaling that the breaker has failed to trip.

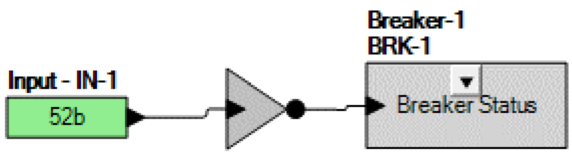


Figure 28-1. Breaker Status Logic Element

In the second method, monitored current is used to determine if the breaker has failed to open. The 50BFI logic input of the Breaker Failure logic block is used to signal that the breaker has been instructed to open. When current is present and the 50BFI logic input is true, a timer is initiated to allow time for the fault to clear. If the time delay expires and current is still present, the Trip output becomes true, signaling that the breaker has failed to open. A control timer specifies the duration the breaker can remain closed before a Breaker Fail alarm will occur.

In both methods above, a Breaker Fail Retrip (ReTrip) will be true while the delay timer is actively running. A breaker fail trip indicates a failed breaker. The Trip signal can be used to trip surrounding breakers to isolate the fault, typically the next set of breakers upstream in the power system. Breaker failure protection may be applied to any portion of the power system where failure of a circuit breaker to operate properly could result in severe system damage or instability.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Breaker Failure Trip output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Contact Sensing

Before any relay output can occur, there must first be an initiating signal to the Breaker Failure logic element. There are two possible initiating signals. The 52 Breaker Fail Initiate (52BFI) signal is the initiation signal when breaker status is used to determine a breaker failure. The 50 Breaker Fail Initiate (50BFI) is the initiation signal when current is used to determine a breaker failure. These initiate inputs can be driven by other relays into the BE1-FLEX inputs. Alternately, they can come from trip signals from other protective elements within the BE1-FLEX. Breaker status input is provided by the BRK logic element.

Information on setting up the breaker status logic can be found in the *Power System Configuration* chapter.

Control Timer

The Control Timer provides a window of opportunity for a breaker failure Trip output when the 50BFI logic input is used to signal the breaker to open. It improves dependability by sealing in the initiate request to prevent stopping of a breaker failure timing if the tripping relay drops out prematurely. The control timer is initiated by a 50BFI signal. Upon sensing the 50BFI transition from a 0 to 1 state, the control timer seals in the 50BFI signal for the duration of the Control Timer setting. The Control Timer output is true at time of initiate and returns to false after the control timer expires. If the control timer expires and the 50BFI signal is still present, an alarm signal occurs. A control timer setting of zero (0) disables the control timer seal-in function allowing the control timer to follow the 50BFI input. When not set to zero, the control timer must be longer than the delay timer.

ReTrip and Trip

The adjustable Delay Timer goes true when the 50BFI (Initiate) input is held true for the duration of the timer setting and allows time for current to clear or the breaker status to transition after signaling the breaker to trip. The delay timer is initiated when either the 52BFI input or the 50BFI input becomes true.

ReTrip

The ReTrip output is true when the delay timer is actively timing. The delay timer can be stopped by several methods depending on the timer initiate source. When initiated by a 50BFI signal, the timer is stopped when current decreases below the pickup setting, when the fast current dropout detector detects that current has dropped out, or when the control timer expires. When initiated by a 52BFI signal, the timer is stopped when the BRK logic element indicates that the breaker is open. Regardless of initiate method, asserting the Breaker Failure's Block logic input also stops the timer. In BESTlogic*Plus*, the ReTrip output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Trip

The Trip output becomes true when the delay timer expires. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Fast Current Detector

The fast current detector directly determines when the current in the poles of the breaker has been interrupted without having to wait for the fault current samples to clear the one-cycle filter time used by fundamental current measurement function. Dropout time is dependent upon sampled frequency and is less than 3/4 of a cycle. At 60 Hz, the dropout time is 8.3 ms or less.

The fast current detector logic is true if the current has been interrupted and is used to stop the breaker failure timer. The I=0 algorithm looks at the sample data directly and does not rely upon the 1 cycle phasor estimation calculation. It rejects dc tail-off by looking for the characteristic exponential decay. Current is deemed to be interrupted when the current in all three phases is below approximately 100 mA or if the current is decaying exponentially. Only the three phase currents are monitored by this method.

Circuit and Breaker Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit and Breaker Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Programmable Alarm

A Breaker Failure alarm is provided to indicate an alarm condition when the 50BF element trips. The alarm can be programmed to appear on the front-panel display, web page interface, and on the Alarms metering screen in BESTCOMS*Plus*. Refer to the *Alarms* chapter for information on how to program alarms.

Element Blocking

The Block input provides logic-supervision control of the element. Element blocking is a useful feature to prevent inadvertent backup tripping during testing.

When true, the Block input disables the element by forcing the Trip and ReTrip outputs to logic 0 and resetting the element timers. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Breaker failure element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The breaker failure element logic block is illustrated in Figure 28-2. Logic inputs and outputs are summarized in Table 28-1.

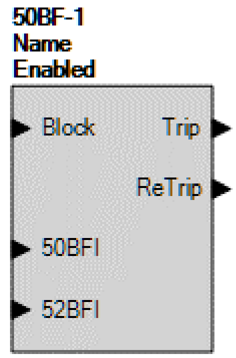


Figure 28-2. Breaker Failure Element Logic Block

Table 28-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 50BF function when true
50BFI	Input	Starts the 50BF control timer when true
52BFI	Input	Starts the 50BF control timer when true
Trip	Output	True after the 50BF Delay Timer expires
ReTrip	Output	True when the 50BF Delay Timer is actively timing

Operational Settings

Breaker failure element operational settings are configured on the Breaker Fail (50BF) settings screen (Figure 28-3) in BESTCOMS*Plus*.

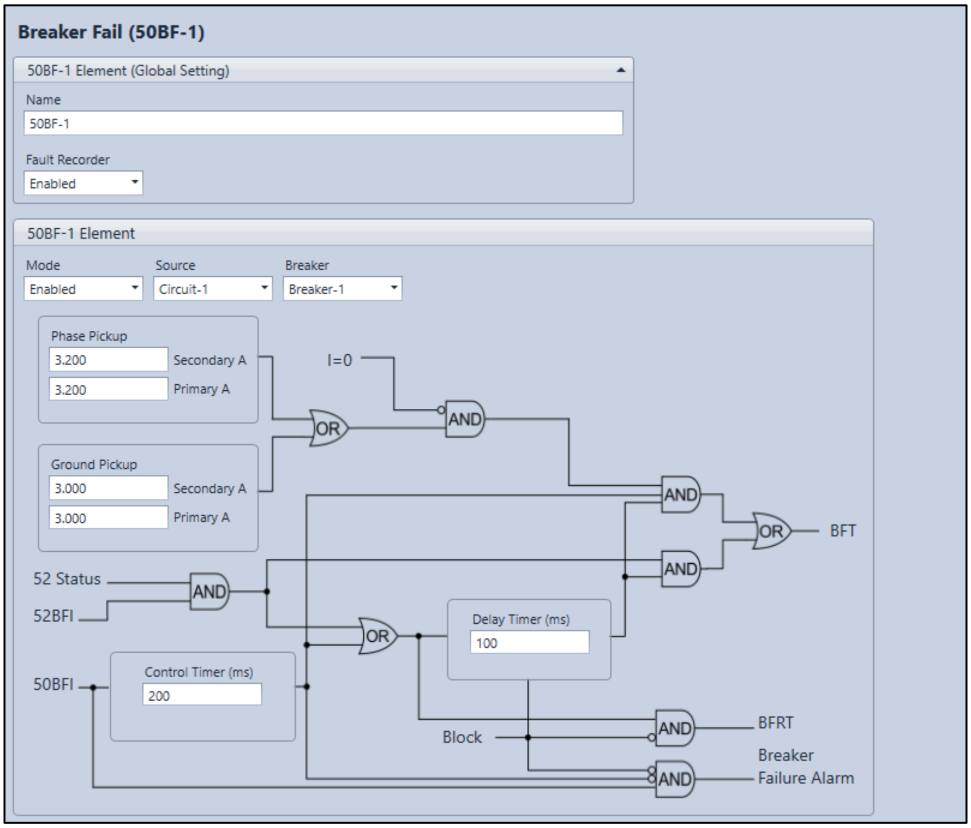


Figure 28-3. Breaker Fail Settings Screen

29 • Inverse Overcurrent (51)

The Inverse Overcurrent (51) elements monitor the current applied to the BE1-FLEX. An element can be configured to protect against overcurrent by monitoring a single- or three-phase system, neutral current, positive-sequence current, negative-sequence current, ground current, or unbalanced current.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Inverse Overcurrent settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, Inverse Overcurrent (51)

Element Operation

Inverse overcurrent protection can be used to protect equipment from damage caused by phase failure, forward/reverse phase sequence, or phase unbalance.

Modes of Protection

Ten modes of protection are available: IA, IB, IC, 3 Phase, 3I0, I1, I2, IG, I2/I1, and (Max-Min)/Avg.

IA, IB, or IC

Protection is activated when the selected phase current increases above the pickup setting.

3 Phase

The inverse overcurrent protection elements include three independent comparators, one for each phase. Protection is activated when any of the three phases increases above the Pickup setting.

3I0 Mode

3I0 mode provides zero sequence neutral overcurrent protection in a three-phase system.

I1 Mode

I1 mode provides positive-sequence overcurrent protection in a three-phase system.

I2 Mode

I2 mode provides negative-sequence overcurrent protection in a three-phase system. Refer to the *Negative-Sequence Overcurrent (46)* chapter for more information.

IG Mode

IG mode provides measured ground fault protection from the Ground connection (IG) of a circuit.

I2/I1

I2/I1 mode provides unbalanced current protection based on the negative-sequence phase current divided by the positive-sequence phase current. The unbalance is blocked if the average current of all three phases is below 25% of the nominal secondary phase current in the power system settings.

$$I_{Unbalance} = \frac{I_2}{I_1} \times \text{MIN}$$

where:

$$\text{MIN} = \frac{I_{Average}}{I_{Rated}} \text{ or } 1, \text{whichever is less}$$

(Max-Min)/Avg

(Max-Min)/Avg mode provides unbalanced current protection based on the average current. The unbalance is blocked if the average current of all three phases is below 25% of the nominal phase current in the power system settings.

$$I_{Unbalance} = \frac{(\mathrm{MAXp} - \mathrm{I}_{Average}) \text{ or } (\mathrm{I}_{Average} - \mathrm{MINp}), \text{whichever is greater}}{\mathrm{I}_{Average}} \times \mathrm{MIN}$$

where:

$$\mathrm{MIN} = \frac{I_{Average}}{I_{Rated}} \text{ or } 1, \text{whichever is less}$$

$$\mathrm{MAXp} = \text{maximum of all three phases}$$

$$\mathrm{MINp} = \text{minimum of all three phases}$$

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Direction

An inverse overcurrent element can be configured for forward, reverse, or non-directional tripping. Refer to the *Power System Configuration* chapter for more information on forward and reverse directional modes.

Fail Safe Direction

When the Direction setting is Forward or Reverse, and insufficient polarization signal is present, the overcurrent element will operate based upon the failsafe directional setting.

Timings

The element operate time is calculated as described below. Element operate times do not include logic or output operate times.

Each inverse overcurrent element has a Curve setting. The following paragraphs describe the available timing curves. The user can select integrating reset timing to make the protective element use integrated reset and emulate an electromechanical induction disk reset characteristic.

Standard Curves

There are 22 standard curves available including standard inverse, short inverse, moderately inverse, long inverse, very inverse, and extremely inverse. Refer to the *Timing Characteristics* chapter for specific information on each curve.

Programmable Curves

An available programmable curve can be used to create a custom curve by selecting coefficients in the inverse time characteristic equation. When inverse time overcurrent characteristic curve P is selected, the coefficients used in the equation are those defined by the user. Inverse overcurrent characteristics for trip and reset programmable curves are defined by Equation 29-1 and Equation 29-2. These equations comply with IEEE Std C37.112-2018 - *IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays*. Definitions for these equations are provided in Table 29-1. The curve-specific coefficients are defined for the standard curves as listed in the *Timing Characteristics* chapter.

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

Equation 29-1. Time OC Characteristics for Trip

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

Equation 29-2. Time OC Characteristics for Reset

Table 29-1. Definitions for Equation 29-1 and Equation 29-2

Parameter	Description	Explanation
T_T	Time to trip	Time that the 51 function will take to time out and trip.
D	Time dial setting	Time dial setting for the 51 function.
M	Multiple of pickup	Measured current in multiples of pickup. The timing algorithm has a dynamic range of 1 to 40 times pickup and definite time above 40.
A	Coefficient specific to selected curve	Affects the effective range of the time dial.
B	Coefficient specific to selected curve	Affects a constant term in the timing equation. Has greatest effect on curve shape at high multiples of tap.
C	Coefficient specific to selected curve	Affects the multiple of PU where the curve would approach infinity if allowed to continue below pickup. Has greatest effect on curve shape near pickup.
N	Exponent specific to selected curve	Affects how inverse the characteristics are. Has greatest effect on curve shape at low to medium multiples of tap.
K	Constant	Characteristic minimum delay term.
T_R	Time to reset	Relevant if 51-x function is set for integrating reset.
R	Coefficient specific to selected curve	Affects the speed of reset when integrating reset is selected.

Curve coefficients are entered on the Inverse Overcurrent (51) settings screen in BESTCOMS*Plus*. Programmable curve coefficients can be entered only when the P curve is chosen for the protection element from the Curve drop-down menu.

Table Curves

BESTCOMS*Plus* is used to set the 51 element Table Curve. A minimum of 2 and maximum of 40 points can be entered graphically, numerically, or pasted from an external source for any Table curve. When you are satisfied with the values chosen, select Save Curve.

46 Curve

The 46 curve is a special curve designed to emulate the I_2t withstand ratings of generators using what is frequently referred to as the generator's K factor. Do not confuse the 46 curve with the I2 mode. The 46 curve was designed for use with the I2 mode. However, in actuality, the 46 curve can be selected for use with any mode of the inverse overcurrent element as well.

To use the 46 curve, the user should determine the K factor of the generator and the continuous $(I_2)^2t$ rating of the generator (supplied by the manufacturer) and use this to set the time dial and pickup for the 46 curve by the process described in the *Timing Characteristics* chapter. The K factor is the time the generator can withstand 1 per unit I_2 where 1 pu is the BE1-FLEX setting for nominal current.

Pickup and Trip

Pickup

The Pickup output becomes true when the measured current increases above the current threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Dial and Curve settings. A Time Dial setting of zero (0) makes the 51 element instantaneous with no intentional time delay.

If the pickup condition subsides before the calculated inverse time expires, the timer and Pickup outputs are reset per the Timing Reset setting, no corrective action is taken, and the element is rearmed for any other occurrences of overcurrent.

Trip

The Trip output becomes true if an overcurrent pickup condition persists for the duration of the calculated inverse time. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Voltage Restraint (51/27R)

When a 51 element is set for 3 Phase, IA, IB, or IC mode, the 51 element can be used for voltage control or voltage restraint mode of operation. This feature is used to allow increased phase overcurrent sensitivity while providing security from operation due to load current. This feature is also often used for generator protection to ensure delayed tripping during a short-circuit where the fault current contribution from the generator falls to a value close to the full-load rating of the generator.

A Voltage Restraint threshold of zero (0) disables voltage restraint/control and the 51 element operates without voltage bias.

Control Mode

When set for Control mode of operation, the 51 element is disabled until the measured voltage drops below the Voltage Restraint threshold. Thus, as long as the voltage on the appropriate phase is above the Voltage Restraint threshold, the 51 element will be blocked. When set for this mode of operation, the 51 Pickup setting is typically set near or below load current levels.

Restraint Mode

When set for Restraint mode of operation, the pickup of the 51 element is adjusted based upon the magnitude of the measured phase voltage. Figure 29-1 shows how the 51 Pickup setting is adjusted in response to the measured voltage level. Equation 29-3 determines the pickup level for the 51 element when the measured voltage is between 25% and 100% of the Voltage Restraint threshold. Below 25%, the pickup level stays at 25%. Above 100%, the pickup level stays at 100%. For example, if the Voltage Restraint threshold is set for 120 V and the measured voltage on the appropriate phase is 100 V (83% of the Voltage Restraint threshold), the phase overcurrent pickup level will be reduced to 83% of its setting. When set for this mode of operation, the 51 element Pickup setting is typically set above worst case, load current levels.

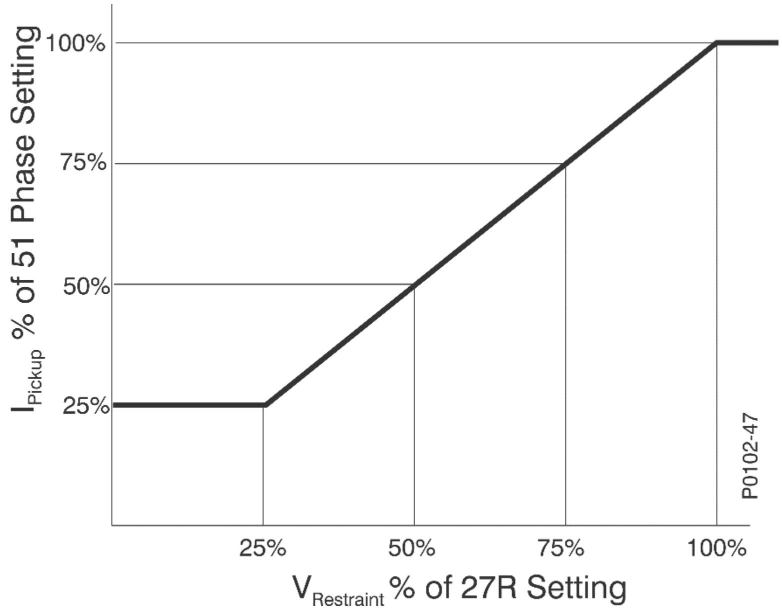


Figure 29-1. 51 Phase Pickup Level Compensation

$$Pickup = \frac{Sensing\ Phase\ Voltage}{Restraint\ Pickup\ Setting} \times 51\ Phase\ Pickup\ Setting$$

Equation 29-3. Restraint Pickup Level

Phase VT Configuration

The 51/27R function can be set to monitor either Vpp or Vpn depending upon the Phase VT Connection settings. See the *Configuration* chapter for details on how to set the phase VT connections. Table 29-2 shows which voltage measurements are used by the 51 element for each possible phase VT connection and 51/27 voltage monitoring mode setting.

Table 29-2. Phase VT Connection Cross Reference

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

* Calculated value. See the *Power System Configuration* chapter for more information.

Fuse Loss

The fuse loss element (60FL) can be set to supervise the 51/27R function. It is possible to set the 60FL element to prevent misoperation on loss of sensing voltage. When the 51/27R function is set for control and a 60FL condition is detected, the 51/27R element will be disabled. When the 51/27R function is set for restraint and a 60FL condition is detected, the 51/27R element will remain enabled but the pickup will not be adjusted from 100% of its setting. See the *Fuse Loss (60FL)* chapter for more information.

Protective elements blocked by 60FL should be set so that trip times are 60 milliseconds or greater to ensure proper coordination of blocking.

Logic Connections

Inverse overcurrent element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The inverse overcurrent element logic block is illustrated in Figure 29-2. Logic inputs and outputs are summarized in Table 29-3.

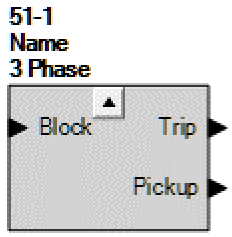


Figure 29-2. Inverse Overcurrent Element Logic Block

Table 29-3. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 51 function when true
Trip	Output	True when the 51 element is in a trip condition
Pickup	Output	True when the 51 element is in a pickup condition

Operational Settings

Inverse overcurrent element operational settings are configured on the Inverse Overcurrent (51) settings screen (Figure 29-3) in BESTCOMS*Plus*.

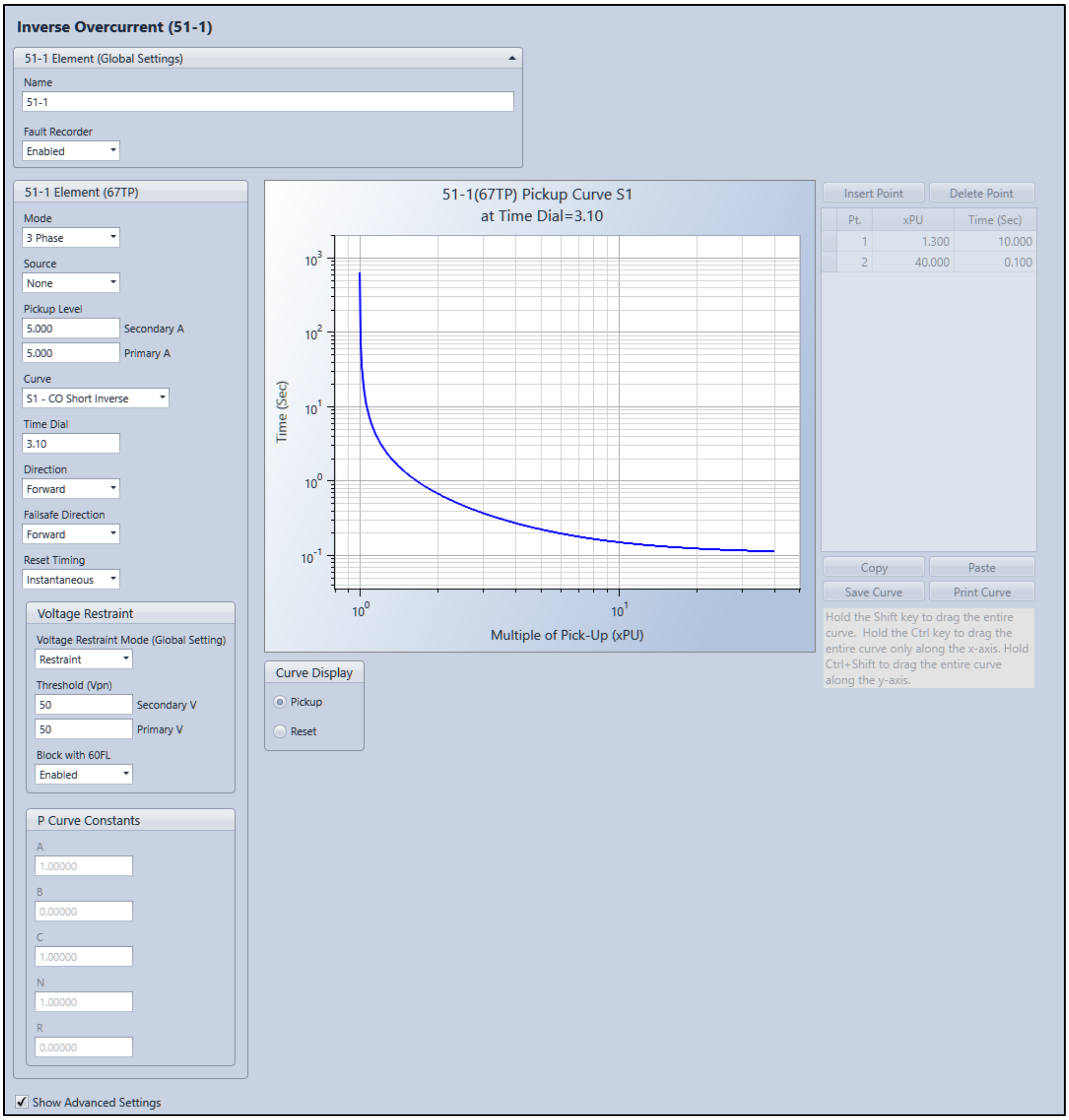


Figure 29-3. Inverse Overcurrent Settings Screen

30 • Overcurrent Through-Fault Counter (51TF)

The Overcurrent Through-Fault Counter (51TF) elements implement a through-fault counter, which allows the user to schedule wear-based maintenance instead of time-based maintenance.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Overcurrent Through-Fault Counter settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, Overcurrent Through-Fault Counter (51TF)

Element Operation

The 51TF element uses time characteristic curves to monitor the pickup count and report the through-faults of a transformer.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Time Curve

The time current characteristic curve is the combination of up to three time curves each with their own operating threshold and own curve constants. The curve being used is determined by current Threshold Setting 1, Threshold Setting 2, and Threshold Setting 3. When the current is above Threshold Setting 1, timing will be determined by TF_1. If current increases above Threshold Setting 2 or 3, timing will be determined by TF_2 or TF_3 respectively. Threshold Setting 3 has priority over Threshold Setting 2. Threshold Setting 2 has priority over Threshold Setting 1.

$$TF_1 = \frac{K1}{(M-1)^{N1}} \qquad TF_2 = \frac{K2}{(M-1)^{N2}} \qquad TF_3 = \frac{K3}{(M-1)^{N3}}$$

TF_X = Time to Trip when M ≥ Threshold Setting x

M = Multiple of Transformer Base Current Setting

K, N = Constants for the particular curve

Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

When the measured current increases above the lowest of three threshold settings established by the curve Threshold settings, the element Pickup output becomes true and the pickup counts are incremented. When picked up, the element is timing towards the increment of the through-fault counter. In BESTlogic*Plus,* the Pickup output can be connected to other logic elements to annunciate the condition or control other elements in logic.

Trip

The through-fault counter will increment when the timing characteristic curve has been exceeded and the Trip output will become true. In BESTlogic*Plus,* the Trip output can be connected to other logic elements or a physical relay output to annunciate the condition and initiate corrective action.

Alarm

A 51TF Through-Fault alarm indicates an alarm condition when the 51TF element trips the number of times set as Alarm Count. The alarm can be set to appear on the front-panel display, web page interface, and on the Alarms metering screen in BESTCOMS*Plus*. Refer to the *Alarms* chapter for information on how to program alarms.

The alarm count can be preset and reset through the front-panel interface or BESTCOMS*Plus*.

Element Blocking

The Block logic input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element trip-hold time. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

The 51TF element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The 51TF element logic block is illustrated in Figure 30-1. Logic inputs and outputs are summarized in Table 30-1.

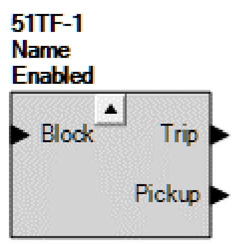


Figure 30-1. Overcurrent Through-Fault Element Logic Block

Table 30-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 51TF function when true
Trip	Output	True when the 51TF is in a trip condition
Pickup	Output	True when the 51TF is in a pickup condition

Operational Settings

The 51TF element operational settings are configured on the Overcurrent Through-Fault Counter (51TF) settings screen (Figure 30-2) in BESTCOMS*Plus*.

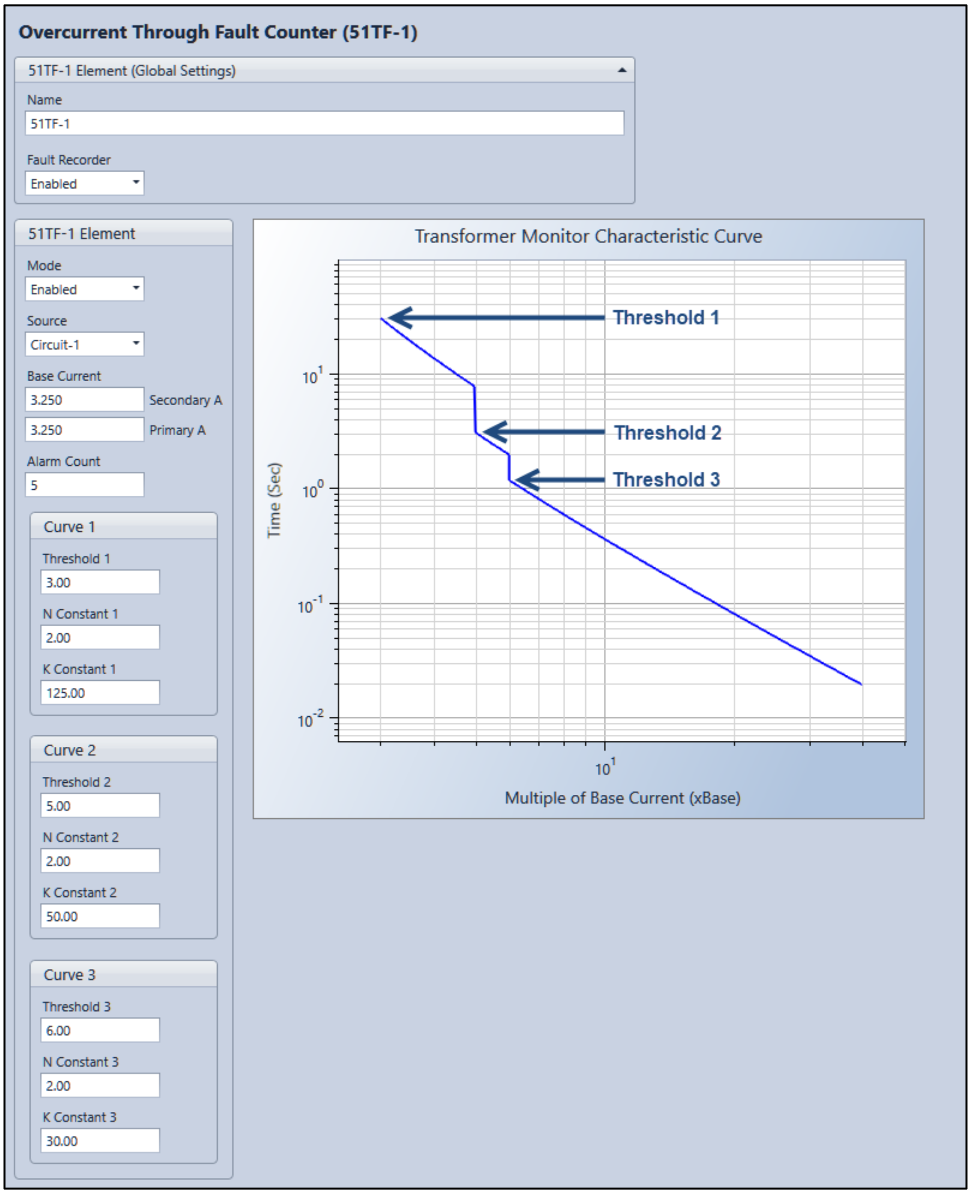


Figure 30-2. Overcurrent Through-Fault Counter (51TF) Screen

Transformer Damage Report

Navigation Path: Metering, Reports, Transformer Damage

Transformer damage report values can be read at the front-panel display or through BESTCOMS*Plus*. Write access to reports is required to edit transformer damage report values. Use the Metering Explorer to open the Transformer Damage Report screen shown in Figure 30-3.

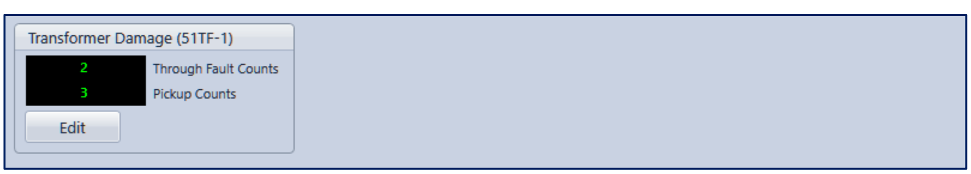


Figure 30-3. Transformer Damage Report Screen

31 • Power Factor (55)

The Power Factor (55) elements typically provide synchronous motor pullout or loss of synchronism protection. Loss of synchronism can occur when there is an increase in load with no increase in field excitation. Continuing to operate a synchronous motor after a loss of synchronism will result in increased line current and additional heating in the motor.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Power Factor settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Power, Power Factor (55)

Element Operation

The power factor element monitors the power factor and protects a synchronous motor from consuming excessive reactive power (vars) from the power system. The power factor element can also prevent a synchronous condenser from exporting excessive vars to the power system. A mode setting enables the power factor element.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when the measured power factor decreases below the lagging or leading threshold established by the Leading Pickup or Lagging Pickup setting. A specific trip region can be disabled by setting its Pickup setting to zero (0). In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition (act as an alarm) and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the 55 element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset and the element is rearmed for any other fault occurrences.

Trip

The Trip output becomes true if a leading or lagging pickup condition exists for the duration of the element Time Delay. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition (act as an alarm) and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Power Factor (55) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Power Factor (55) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. In a typical application, the power factor element will be blocked during motor start-up and until reaching synchronous speed.

When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Power factor element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The power factor element logic block is illustrated in Figure 31-1. Logic inputs and outputs are summarized in Table 31-1.

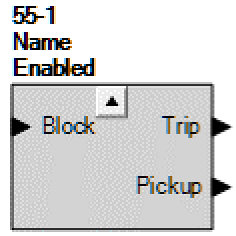


Figure 31-1. Power Factor Element Logic Block

Table 31-1. Logic Inputs and Outputs

Name	Function	Purpose
Block	Input	Disables the 55 function when true
Trip	Output	True when the 55 element is in trip condition
Pickup	Output	True when the 55 element is in pickup condition

Operational Settings

Power factor operational settings are configured on the Power Factor (55) settings screen in BESTCOMS*Plus*.

Figure 31-2 shows typical settings for a motor with sensing connected typical for motor or generator with sensing typical for generator.

Figure 31-3 shows typical settings for a part time motor (pump/storage). Power factor settings may be needed for motor/generator with sensing connected in a typical generator arrangement. The 55 can be set as positive or negative leading or lagging to reach any of the four quadrants. When using this configuration, either AND the outputs or block/unblock individual 55 elements based on motor or generator operation.

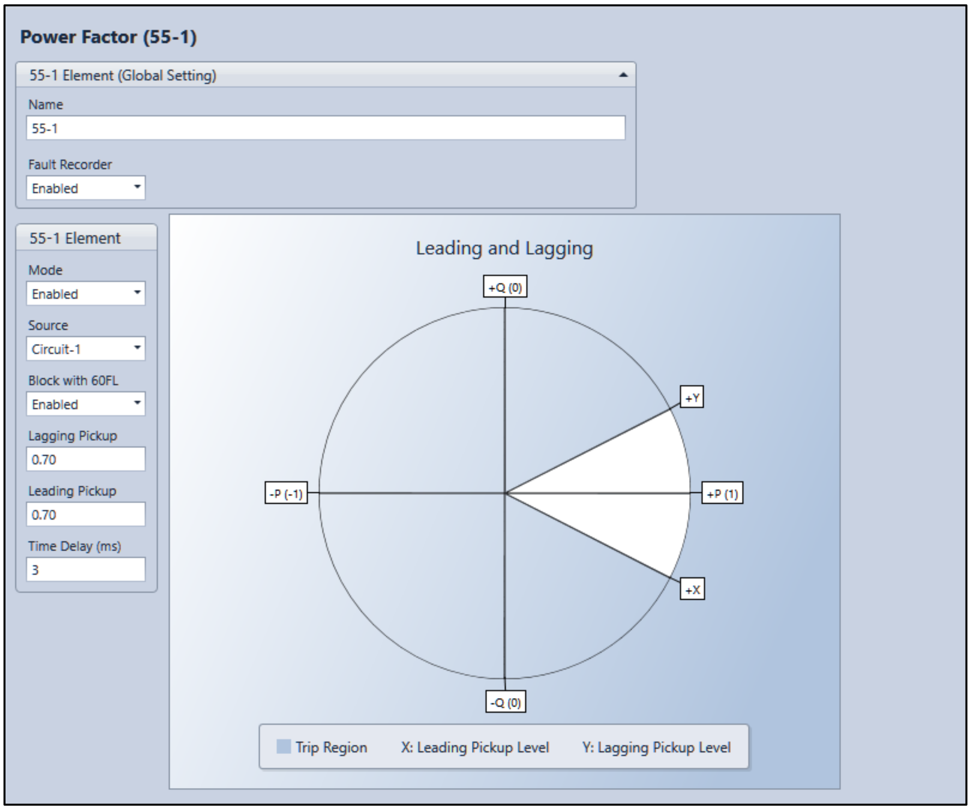


Figure 31-2. Power Factor Settings Screen (Typical Motor/Generator Settings)

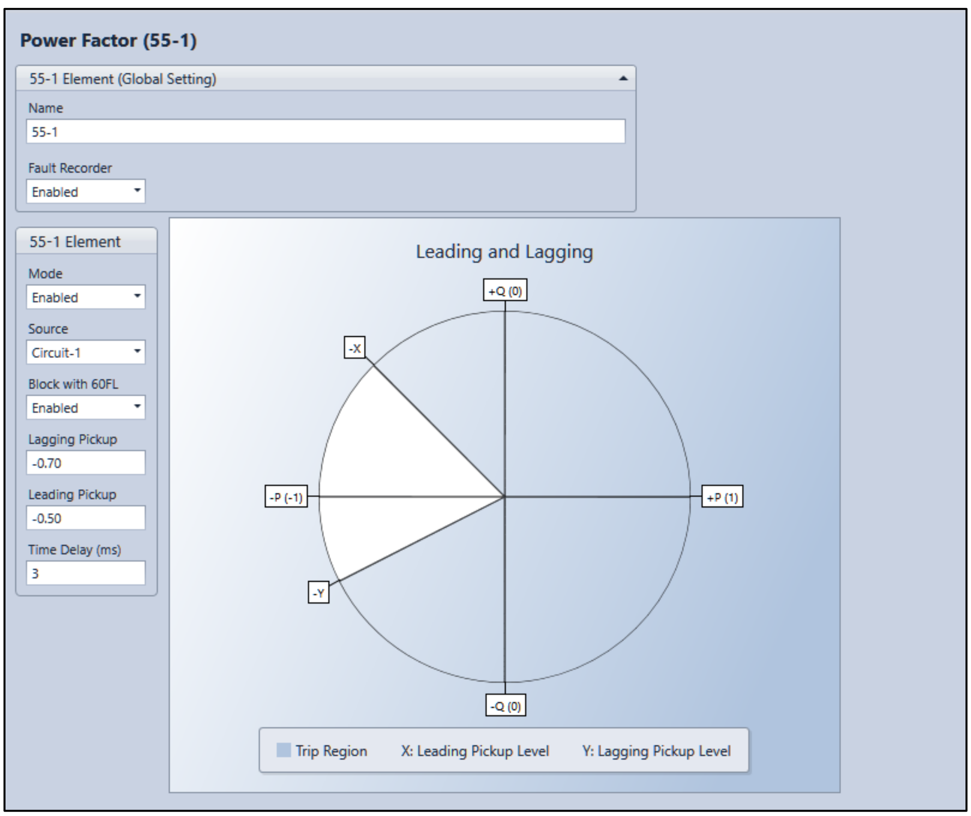


Figure 31-3. Power Factor Settings Screen (Typical Part-Time Motor Settings)

32 • Overvoltage (59)

The Overvoltage (59) elements monitor the phase and ground voltages applied to the BE1-FLEX. An element can be configured to protect against overvoltage by monitoring phase, zero-sequence voltage, positive-sequence voltage, negative-sequence voltage, ground fundamental voltage, or ground 3rd harmonic voltage.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Overvoltage settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Voltage, Overvoltage (59)

Element Operation

Overvoltage protection can be used to prevent equipment damage when an overvoltage condition exists. For example, an overvoltage condition could occur when the tap changing control fails. Overvoltage protection can also be used to protect equipment from damage caused by phase failure, positive/negative phase sequence, or phase unbalance.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Protection

Six modes of protection are available: Phase, 3V0, V1, V2, VG Fundamental, and VG 3rd Harmonic.

Phase

The One of Three method activates protection when one of the three phases of voltage increases above the Pickup setting. The Two of Three method activates protection when any two phases of voltage increase above the Pickup setting. The Three of Three method activates protection when all three phases of voltage increases above the Pickup setting.

3V0

3V0 mode provides voltage unbalance protection in a three-phase system. The 3V0 measurement increases as the three-phase voltages become unbalanced.

V1

V1 mode provides positive phase-sequence protection in a three-phase system. The V1 measurement increases as the phase sequence is brought forward.

V2

V2 mode provides negative phase-sequence protection in a three-phase system. The V2 measurement increases as voltage becomes unbalanced and when phase sequence is reversed.

VG Fundamental

VG Fundamental mode typically provides ground offset detection on high impedance ground systems.

VG 3rd Harmonic

VG 3rd Harmonic mode typically provides internal generator short detection.

Sensing Configuration

The overvoltage element can be set to monitor VPP or VPN. This is determined by the 27/51V/59 Mode parameter of the VT setup found on the Configuration, Circuit Summary, Power System screen in

BESTCOMS*Plus*. For more information on the VT setup for PP or PN voltage response, see the *Power System Configuration* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. The Phase Voltage is monitored for modes Phase, 3V0, V1, or V2. Ground Voltage is monitored for modes VG Fundamental or VG 3rd Harmonic. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Timing Mode

The timing mode can be set for definite, inverse, or table. Element operate times do not include logic or output operate times.

Definite

When definite timing is selected, the element operate time equals the definite time delay setting.

Inverse

When inverse timing is selected, the P Curve Constants must be entered. The user can select instantaneous or integrating reset timing. When integrating reset timing is selected, the protective element uses integrated reset and emulates an electromechanical induction disk reset characteristic. The overvoltage inverse time curve with default constants is shown in the *Timing Characteristics* chapter.

Programmable Curve

The programmable curve can be used to create a custom curve by selecting constants in the inverse time characteristic equation. When inverse timing is selected, the constants used in the equation are those defined by the user. Characteristics for trip and reset programmable curves are defined by Equation 32-1 and Equation 32-2. Definitions for these equations are provided in Table 32-1.

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

Equation 32-1. Time Characteristics for Trip

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

Equation 32-2. Time Characteristics for Reset

Table 32-1. Definitions for Equation 32-1 and Equation 32-2

Parameter	Description	Explanation
T_T	Time to trip	Time that the 59 function will take to time out and trip.
D	Time dial setting	Time dial setting for the 59 function.
M	Multiple of pickup	Measured current in multiples of pickup. The timing algorithm has a dynamic range of 1 to 3 times pickup.
A	Constant specific to selected curve	Affects the effective range of the time dial.
B	Constant specific to selected curve	Affects a constant term in the timing equation. Has greatest effect on curve shape at high multiples of tap.
C	Constant specific to selected curve	Affects the multiple of PU where the curve would approach infinity if allowed to continue below pickup. Has greatest effect on curve shape near pickup.
N	Exponent specific to selected curve	Affects how inverse the characteristics are. Has greatest effect on curve shape at low to medium multiples of tap.
T_R	Time to reset	Relevant if 59 function is set for integrating reset.
R	Constant specific to selected curve	Affects the speed of reset when integrating reset is selected.

Table Curve

When table is selected, the table curve must be programmed. A minimum of 2 and maximum of 40 points can be entered for a table curve. When you are satisfied with the values chosen, select Save Curve.

The user can select instantaneous or integrating reset timing. When integrating reset timing is selected, the protective element uses integrated reset and emulates an electromechanical induction disk reset characteristic. The Curve Display setting is used to switch between the pickup and reset table curves view.

Pickup and Trip

Pickup

The Pickup output becomes true when the measured voltage increases above the voltage threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay (definite timing) or Time Dial (inverse or table curve timing). A Time Delay or Time Dial setting of zero (0) makes the 59 element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay or calculated inverse time expires, the timer and Pickup output begin resetting according to the configured Reset mode and timing, no corrective action is taken, and the element is rearmed for any other occurrences of overvoltage.

Trip

The Trip output becomes true if an overvoltage pickup condition persists for the duration of the element Time Delay setting, or calculated inverse or table curve time. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled by the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Overvoltage (59) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Overvoltage (59) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Overvoltage element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The overvoltage element logic block is illustrated in Figure 32-1. Logic inputs and outputs are summarized in Table 32-2.

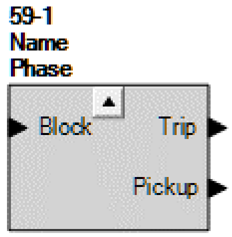


Figure 32-1. Overvoltage Element Logic Block

Table 32-2. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 59 function when true
Trip	Output	True when the 59 element is in a trip condition
Pickup	Output	True when the 59 element is in a pickup condition

Operational Settings

Overvoltage element operational settings are configured on the Overvoltage (59) settings screen (Figure 32-2) in BESTCOMS*Plus*.

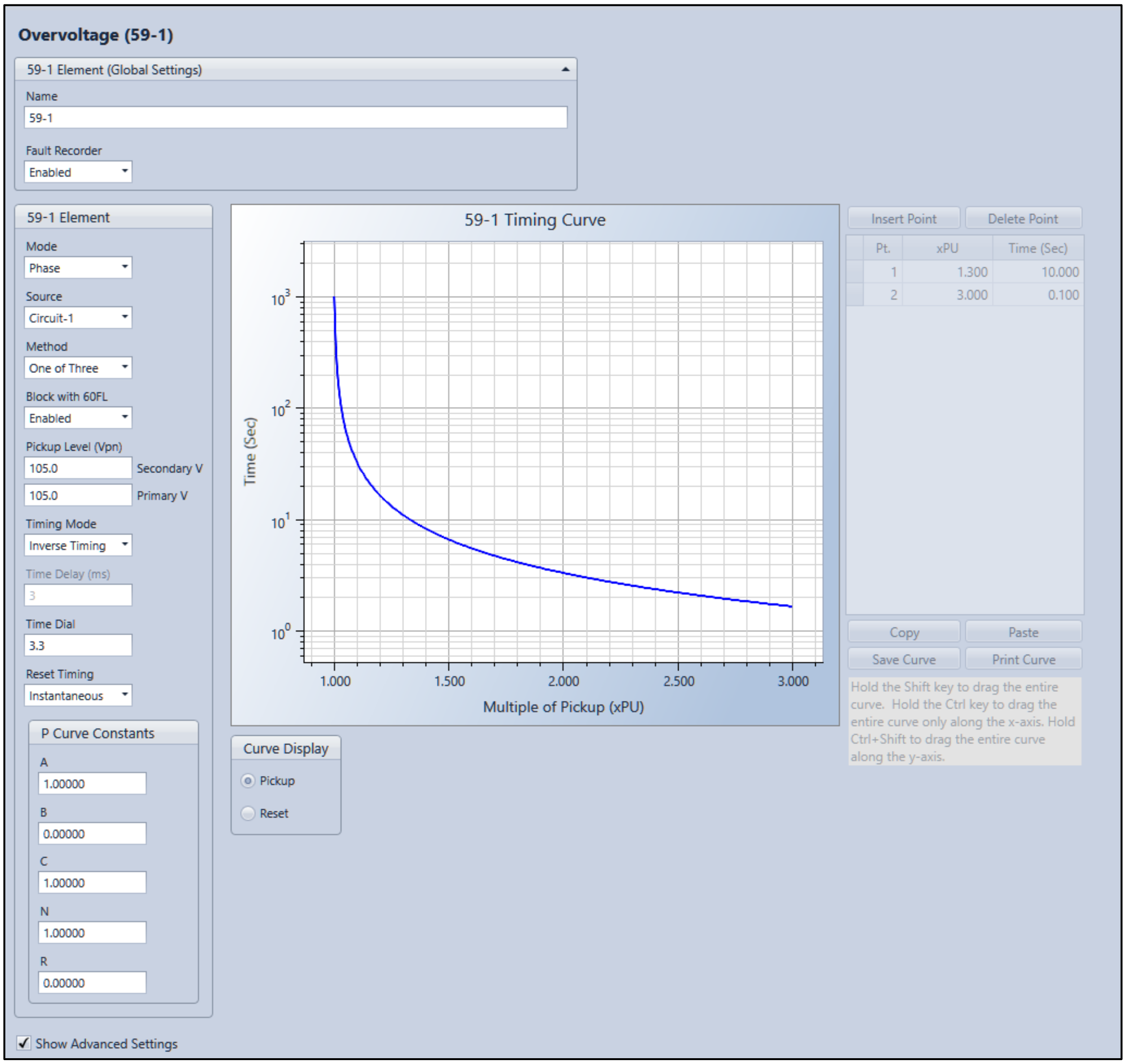


Figure 32-2. Overvoltage Settings Screen

33 • Stator Ground (64G)

The BE1-FLEX provides ground protection for 100% of the stator winding on high-impedance, grounded generators. This protection is implemented by using the 27 element in VG Third Harmonic mode and the 59 element in VG Fundamental mode. The 59 element detects winding ground faults in approximately 85% of the winding. Faults closer to the generator neutral do not result in high neutral voltage but are detected by the 27 element using third harmonic voltages. The combination of these two measuring methods provides ground fault protection for the full winding.

Refer to the *Undervoltage (27)* and *Overvoltage (59)* chapters for information on how to configure the VG Third Harmonic undervoltage and VG Fundamental overvoltage modes of the 27 and 59 elements.

34 • DC Overcurrent (76)

The DC Overcurrent (76) elements provide instantaneous and inverse overcurrent protection for DC circuits. The 76 element utilizes 50 or 100 mV analog inputs.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the DC Overcurrent settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, DC Overcurrent (76)

Element Operation

DC overcurrent protection can be used to protect almost any DC power system regardless of nominal voltage. Aside from DC power Transmission of Distribution, DC overcurrent protection is also commonly applied to Synchronous machine excitation field protection.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Shunt Input Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Timing Mode

The timing mode can be set for definite, inverse, or table. Element operate times do not include logic or output operate times.

Definite

When definite timing is selected, the element operate time equals the definite time delay setting.

Inverse

When inverse timing is selected, the P Curve Constants must be entered. The user can select instantaneous or integrating reset timing. When integrating reset timing is selected, the protective element uses integrated reset and emulates an electromechanical induction disk reset characteristic. The DC overcurrent inverse time curve with default constants is shown in the *Timing Characteristics* chapter.

Programmable Curves

The programmable curve can be used to create a custom curve by selecting constants in the inverse time characteristic equation. When inverse timing is selected, the constants used in the equation are those defined by the user. Characteristics for trip and reset programmable curves are defined by Equation 34-1 and Equation 34-2. Definitions for these equations are provided in Table 34-1.

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

Equation 34-1. Time Characteristics for Trip

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

Equation 34-2. Time Characteristics for Reset

Table 34-1. Definitions for Equation 34-1 and Equation 34-2

Parameter	Description	Explanation
T_T	Time to trip	Time that the 76 function will take to time out and trip.
D	Time dial setting	Time dial setting for the 76 function.

Parameter	Description	Explanation
M	Multiple of pickup	Measured current in multiples of pickup. The timing algorithm has a dynamic range of 0 to 40 times pickup and definite time above 40.
A	Constant specific to selected curve	Affects the effective range of the time dial.
B	Constant specific to selected curve	Affects a constant term in the timing equation. Has greatest effect on curve shape at high multiples of tap.
C	Constant specific to selected curve	Affects the multiple of PU where the curve would approach infinity if allowed to continue below pickup. Has greatest effect on curve shape near pickup.
N	Exponent specific to selected curve	Affects how inverse the characteristics are. Has greatest effect on curve shape at low to medium multiples of tap.
T_R	Time to reset	Relevant if 76 function is set for integrating reset.
R	Constant specific to selected curve	Affects the speed of reset when integrating reset is selected.

Table Curves

When table is selected, the table curve must be programmed. A minimum of 2 and maximum of 40 points can be entered graphically, numerically, or pasted from an external source for a Table curve. When you are satisfied with the values chosen, select Save Curve.

The user can select instantaneous or integrating reset timing. When integrating reset timing is selected, the protective element uses integrated reset and emulates an electromechanical induction disk reset characteristic. The Curve Display setting is used to switch between the pickup and reset table curves view.

Pickup and Trip

Pickup

The Pickup output becomes true when the measured shunt voltage increases above the shunt voltage threshold established by the Pickup setting. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay (definite timing) or Time Dial (inverse or table curve timing). A Time Delay or Time Dial setting of zero (0) makes the 76 element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay or calculated inverse time expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of DC overcurrent.

Trip

The Trip output becomes true when a DC overcurrent pickup condition persists for the duration of the element Time Delay setting, or calculated inverse or table curve time. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled by the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

DC overcurrent element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The DC overcurrent element logic block is illustrated in Figure 34-1. Logic inputs and outputs are summarized in Table 34-2.

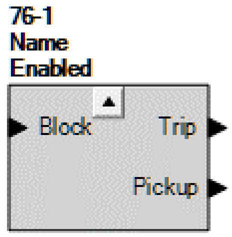


Figure 34-1. DC Overcurrent Element Logic Block

Table 34-2. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 76 function when true
Trip	Output	True when the 76 element is in a trip condition
Pickup	Output	True when the 76 element is in a pickup condition

Operational Settings

Inverse overcurrent element operational settings are configured on the DC Overcurrent (76) settings screen (Figure 34-2) in BESTCOMS*Plus*.

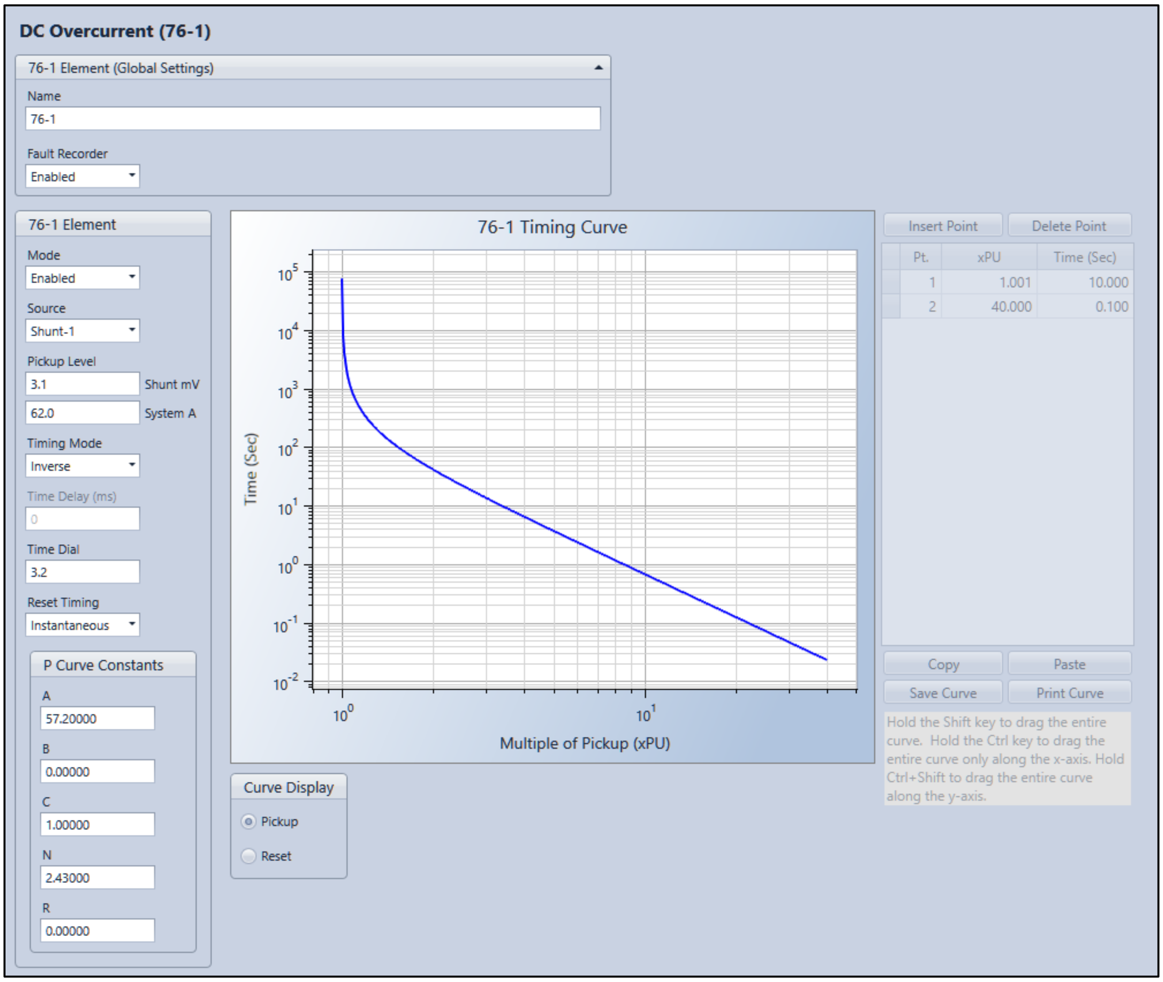


Figure 34-2. DC Overcurrent Settings Screen

35 • Out of Step (78OOS)

The Out of Step (78OOS) elements detect out-of-step conditions by monitoring the rate of impedance change as viewed at the generator terminals.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Out of Step settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Impedance, Out of Step (78OOS)

Element Operation

When a fault occurs on the power system, a synchronous generator can begin to accelerate due to differences in the mechanical power into the generator and the electrical power at the generator terminals. If the power system fault is not cleared quickly enough, this acceleration will result in the generator rotor voltage advancing beyond 90 degrees with respect to the generator terminal voltage. At this point, power will flow into the generator and the rotor angle will continue to advance until it is aligned with the next pole. This condition is known as slipping a pole or loss of synchronism.

The out of step element uses a single blinder scheme as shown in Figure 35-1 to detect an out-of-step condition and protect against pole slip. The blinder units allow the BE1-FLEX to trip for a region of impedances that are supervised or enabled by a mho unit, which is set to permit tripping only for impedance swings appearing in the generator or unit transformer and a limited portion of the system.

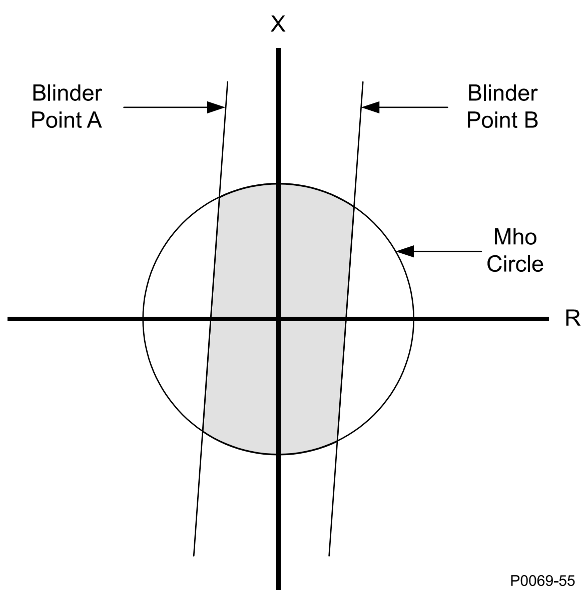


Figure 35-1. Single Blinder Scheme

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Trip Timer

The element operate time equals the trip timer setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

When a typical OOS event occurs, the calculated impedance will enter the mho circle from the right, moving to the left past Blinder B and eventually crossing Blinder A.

The Mho Pickup output becomes true when the calculated impedance moves inside the mho circle. The Blinder A Pickup output becomes true when the calculated impedance is both to the right of Blinder A and within the mho circle.

The Blinder B Pickup output becomes true when the calculated impedance moves to the left of Blinder B while inside the mho circle. Assertion of the Blinder B Pickup output initiates a timer. The duration of the timer is established by the Blinder Traverse Time Delay setting.

The Pickup output becomes true if the calculated impedance moves to the left of Blinder A, while inside the mho circle and after the Blinder Traverse Time Delay expires. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Trip Timer setting. A Trip Timer setting of zero (0) makes the 78OOS element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other out-of-step conditions.

Trip

The Trip output becomes true if an out-of-step condition persists for the duration of the element Trip Timer setting. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block Out of Step (78OOS) protection when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Out of Step (78OOS) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Out of step element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The out of step element logic block is illustrated in Figure 35-2. Logic inputs and outputs are summarized in Table 35-1.

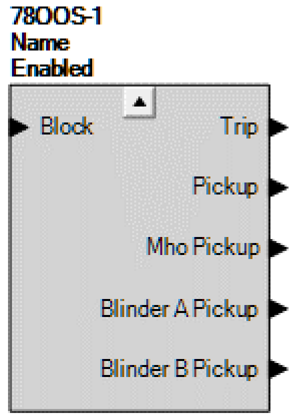


Figure 35-2. Out of Step Element Logic Block

Table 35-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 78OOS function when true
Trip	Output	True when the 78OOS element is in a trip condition
Pickup	Output	True when the 78OOS element is in a pickup condition
Mho Pickup	Output	Z1 impedance is inside mho circle
Blinder A Pickup	Output	Z1 impedance is to the right of blinder B_A and inside mho circle
Blinder B Pickup	Output	Z1 impedance is to the left of blinder B_B and inside mho circle

Operational Settings

Out of Step protection element operational settings are configured on the Out of Step (78OOS) settings screen (Figure 35-3) in BESTCOMS*Plus*.

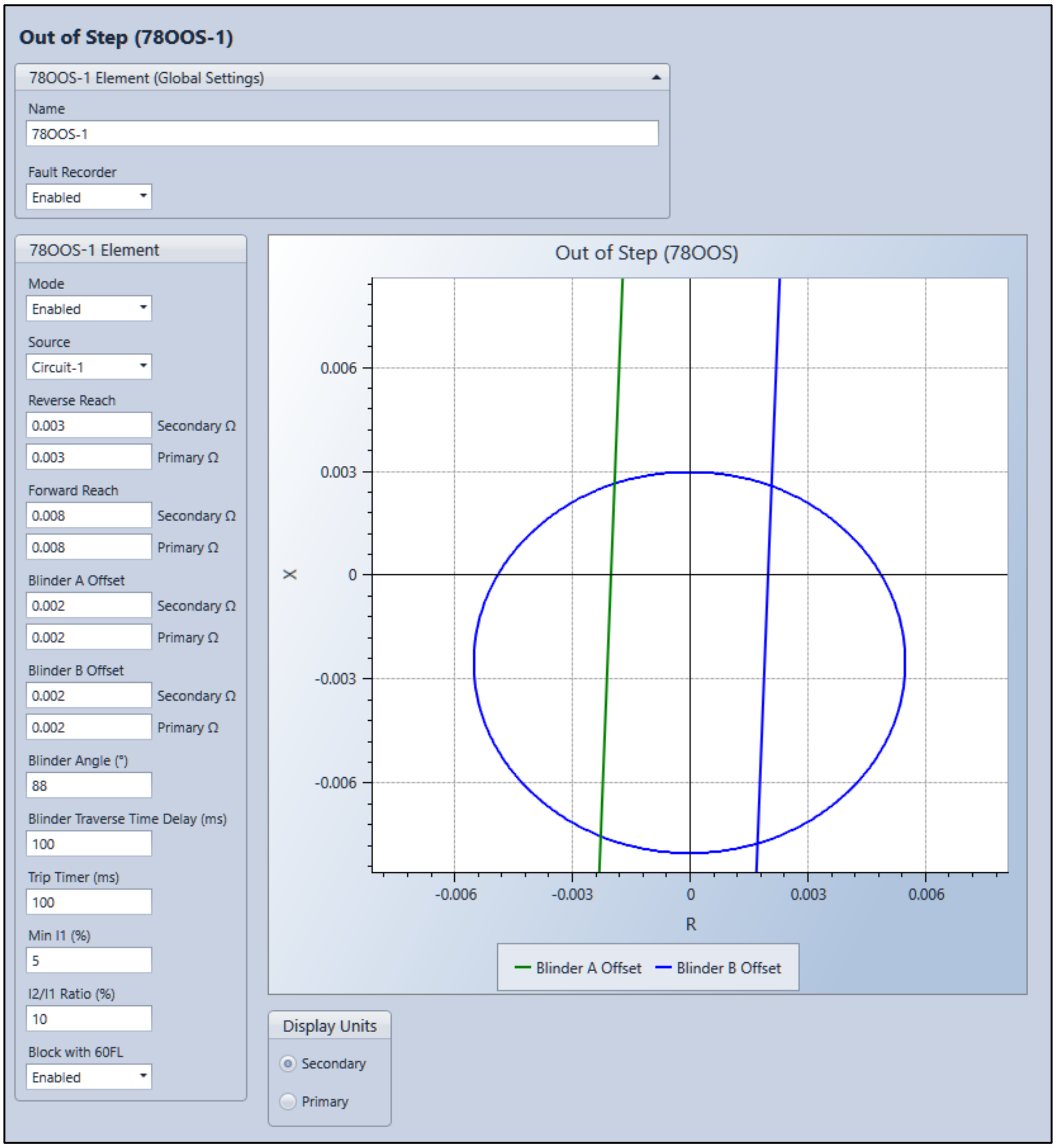


Figure 35-3. Out of Step Settings Screen

36 • Vector Jump (78V)

The Vector Jump (78V), also called Vector Shift, elements are typically applied in distributed generation applications. The 78V elements protect the generator by disconnecting it from the grid when a loss of mains or mains failure occurs. This prevents the generator from remaining tied to the mains if the mains returns due to an external reclose device. The 78V elements are also typically used in anti-islanding protection applications.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Vector Jump settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Voltage, Vector Jump (78V)

Element Operation

When a loss of mains occurs, it is likely that the generator load will shift abruptly since the generator is driving everything between the distributed generation source output and the utility breaker that removed mains power. Such a load shift is likely to cause a speed shift, which may result in the distributed generator system being out of phase with the mains when a reclose occurs. If the distributed generation source is out of phase and connection with the mains is established, damage could occur.

The vector jump element trips when it detects a phase shift in the measured voltage. A sudden change in phase angle often occurs when the grid is lost. This change of phase angle results in an earlier zero crossing of the generator voltage if the generator load decreases. It results in a later zero crossing if the generator load increases. This shift of the zero crossing (vector jump) is expressed in degrees. Figure 36-1 shows a typical measured waveform result during a vector jump event.

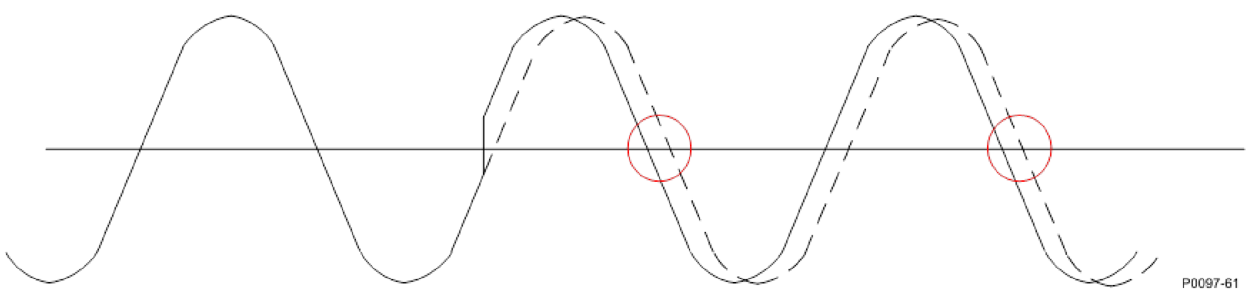


Figure 36-1. Typical Measured Waveform Result

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Trip

The Trip output becomes true when the vector shift increases above the threshold established by the Pickup Level setting. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled by the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

A 78V power system condition is momentary. Because of this, it is often necessary to use the Hold Output setting to ensure the Trip output is held closed long enough for breaker operation to occur.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Vector jump element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. Unlike other protective elements, the 78V does not have a logical pickup output, as the pickup state always equals the trip state. The 78V condition is momentary, so trip delays are not part of the function or the condition would be missed. Logic timers can be implemented if trip coordination delays are desired. The vector jump element logic block is illustrated in Figure 36-2. Logic inputs and outputs are summarized in Table 36-1.

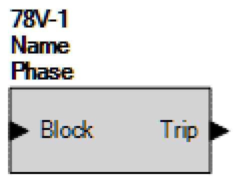


Figure 36-2. Vector Jump Element Logic Block

Table 36-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 78V function when true
Trip	Output	True when the 78V element is in trip condition

Operational Settings

Vector jump element operational settings are configured on the Vector Jump (78) settings screen (Figure 36-3) in BESTCOMS*Plus*.

Figure 36-3. Vector Jump Settings Screen

37 • Frequency (81)

Frequency (81) elements monitor the frequency of the sensing phase voltage applied to the BE1-FLEX. An element can be configured to protect against underfrequency, overfrequency, or the rate of frequency change.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Frequency settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Frequency, Frequency (81)

Element Operation

Underfrequency and overfrequency protection can be useful for detecting load shedding needs or islanding. For example, when a source of distributed generation (DG) is suddenly separated or isolated from the electric utility, the frequency will change quickly from the nominal value (except for the improbable case of a perfect load-to-generation match). This makes frequency measurement an excellent method for detecting an island condition.

When a source of distributed generation is suddenly separated from the electric utility, the rate-of-change of frequency (ROCOF, ROC, df/dt) will typically increase or decrease rapidly. ROCOF protection provides high-speed detection of an islanding situation that may not be detected by overfrequency or underfrequency protection when the frequency does not sag or swell beyond fixed over or under setpoints. A ROCOF protection element can be used for load shedding in conjunction with an underfrequency protection element to accelerate shedding during a substantial overload or inhibit shedding following a sudden, transient decrease in frequency. An 81 element can be configured to respond to positive ROCOF, negative ROCOF, or either condition.

Security of a load-shedding scheme can be enhanced by monitoring two independent voltage circuits.

Frequency Measurement

To measure frequency, the voltage sensed by the BE1-FLEX must be greater than 10 Vac. The measured frequency is the average of two cycles of voltage measurement.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Protection

Underfrequency, overfrequency, or rate-of-change protection is selected through the Mode setting.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. Frequency measurements are derived from the circuits phase voltage. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip (Underfrequency and Overfrequency)

Pickup

The Pickup output becomes true when the measured frequency decreases below (underfrequency protection) or increases above (overfrequency protection) the frequency threshold established by the Pickup (Over Under) setting for three consecutive sensing voltage cycles. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay (Over Under) setting. A Time Delay (Over Under) setting of zero (0) makes the 81 element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of underfrequency or overfrequency.

Trip

The Trip output becomes true if an underfrequency or overfrequency pickup condition persists for the duration of the element Time Delay (Over Under) setting. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Pickup and Trip (Frequency Rate-of-Change)

Pickup

When the rate of frequency change (expressed in hertz per second) exceeds the threshold established by the Pickup (Rate-of-Change) setting, the element Pickup output becomes true. Pickup detection time varies according to the value of the fault frequency. When the frequency greatly exceeds the pickup setting, pickup detection occurs very quickly. More precise and less quick pickup detection occurs when the frequency change is much closer to the Pickup (Rate-of-Change) setting. Pickup detection times are summarized as follows:

- Faults exceeding the pickup setting by 0.57 Hz/s are detected in 2 cycles
- Faults exceeding the pickup setting by 0.24 Hz/s are detected in 4 cycles
- Faults exceeding the pickup setting by 0.08 Hz/s are detected in 8 cycles
- No pickup detection time will be greater than 16 cycles

In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition or control other elements in logic.

Assertion of the Pickup output initiates a timer, which begins timing toward a trip. The duration of the timer is established by the Time Delay (Rate-of-Change) setting. A Time Delay (Rate-of-Change) setting of zero (0) makes the 81 element instantaneous (with the exception of the pickup detection time).

If the pickup condition subsides before the element time delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other occurrences of a ROCOF condition.

Trip

If an ROCOF pickup condition persists for the duration of the element Time Delay (Rate-of-Change) setting, the element Trip output becomes true. In BESTlogic*Plus*, the Trip output can be connected to other logic elements or a physical relay output to annunciate the condition and initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Inhibit Functions (Frequency Rate-of-Change)

ROCOF protection can be inhibited by the degree of underfrequency or overfrequency or the percentage of negative sequence voltage.

The Inhibit Overfrequency setting disables ROCOF protection when the sensed frequency exceeds the setting threshold. Likewise, the Inhibit Underfrequency setting disables ROCOF protection when the sensed frequency decreases below the setting threshold.

ROCOF protection can be inhibited when the percentage of negative sequence voltage exceeds the limit established by the Inhibit Negative Sequence setting. An Inhibit Negative Sequence setting of zero (0) inhibits this feature.

Inhibit Voltage

The Inhibit Voltage setting impedes frequency element operation during undervoltage conditions that may occur during equipment startup.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Frequency element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus.* The frequency element logic block is illustrated in Figure 37-1. Logic inputs and outputs are summarized in Table 37-1.

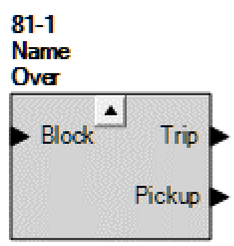


Figure 37-1. Frequency Element Logic Block

Table 37-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 81 function when true
Trip	Output	True when the 81 element is in a trip condition
Pickup	Output	True when the 81 element is in a pickup condition

Operational Settings

Frequency element operational settings are configured on the Frequency (81) settings screen (Figure 37-2) in BESTCOMS*Plus*.

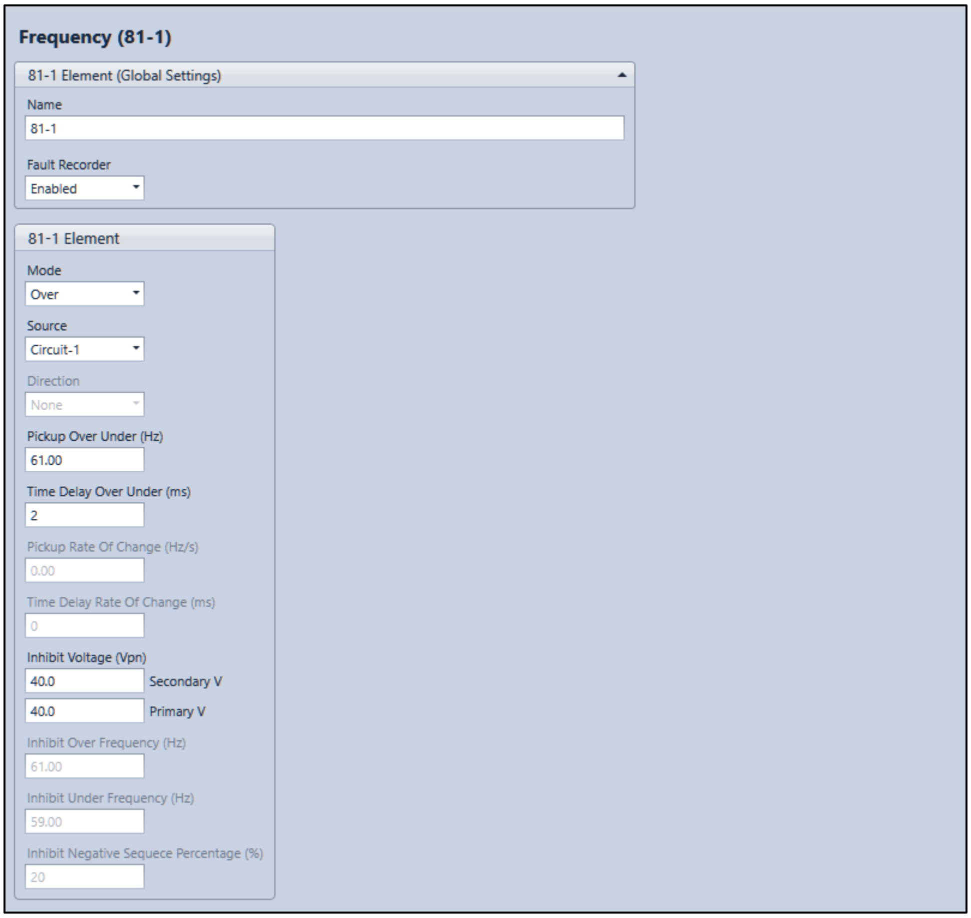


Figure 37-2. Frequency Settings Screen

38 • Phase Differential (87)

The Phase Differential (87) element monitors the differential current and provides primary protection for generators, transformers, busses, and differential zone applications.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Phase Differential (87) settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, Phase Differential (87)

Element Operation

The phase differential element compares the currents entering and leaving the zone of protection. In some applications, the zone of protection may include only a single resource such as a generator. In other applications, a power transformer may be included in the generator zone of protection. If a fault is detected, the BE1-FLEX initiates a trip signal to isolate the protected zone. This action limits equipment damage and minimizes impact on the power system.

Functional Description

Figure 38-1 shows a detailed functional diagram of one phase of the phase differential protection function. These functions and comparators are duplicated for each phase. The 87 function can be applied as single or dual phase differential by excluding phases in a Circuits configuration.

The measured currents are phase, zero-sequence, and tap compensated. The *Power System Configuration* chapter describes the setup of the BE1-FLEX for phase and zero-sequence compensation. Setup of the tap adjustment compensation is described later in this chapter. The restraint current function uses the compensated current to calculate the restraint current magnitude (in multiples of tap). Depending on the setting, it calculates the maximum or average restraint current. The Operating Current function determines the magnitude of the fundamental, second, and fifth harmonic differential current as the phasor sum of those components of the compensated currents.

Figure 38-2 shows the characteristic of the phase differential protection element. This comparator has two slope settings and a minimum pickup setting. The slope settings are the ratios of delta operating current to delta restraint current. The slope settings should be set above the maximum mismatch caused by excitation losses, tap mismatch, and load tap changers. The minimum pickup setting determines the minimum sensitivity of the restrained element.

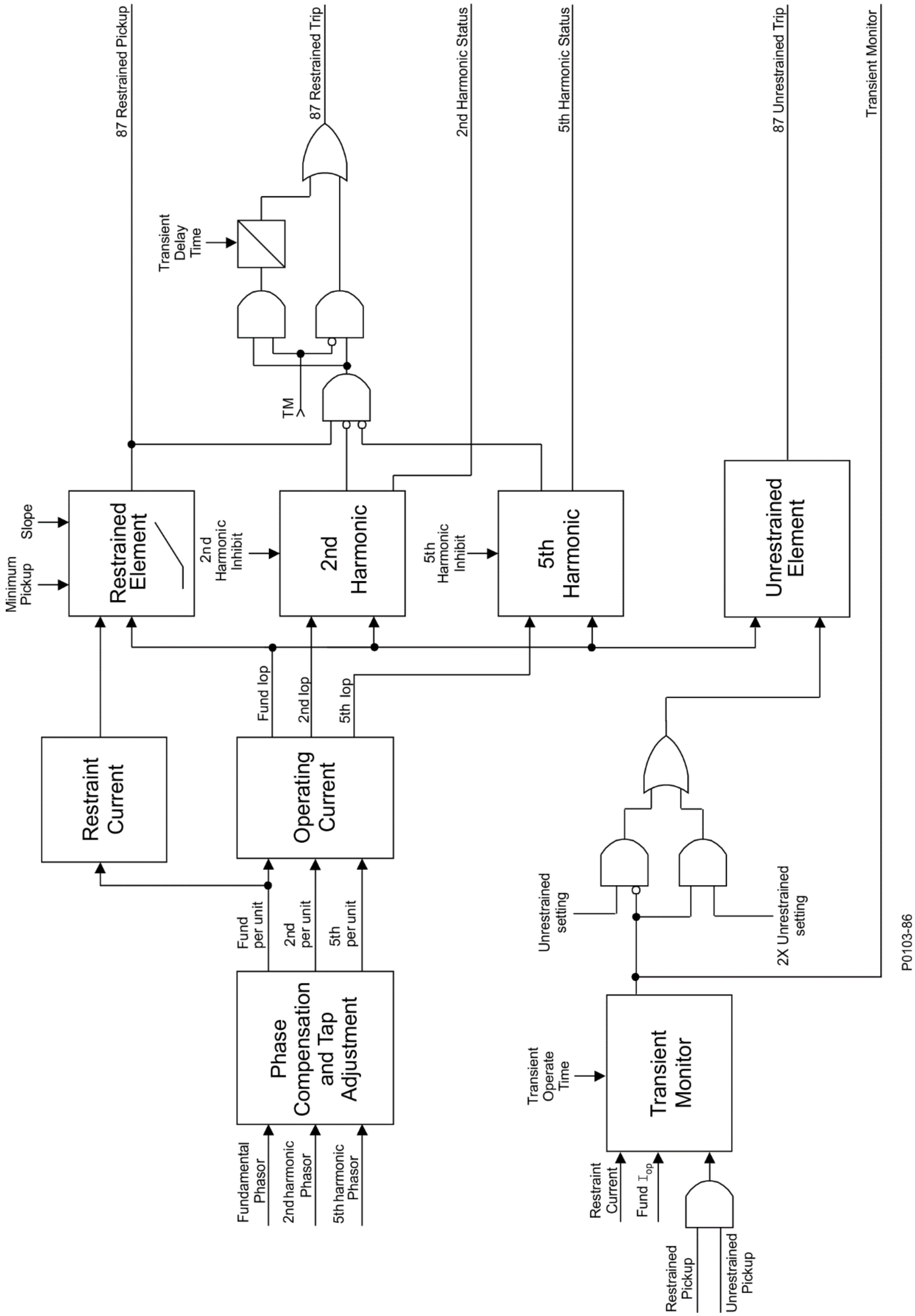


Figure 38-1. 87 Phase Differential Protection Functional Block Diagram

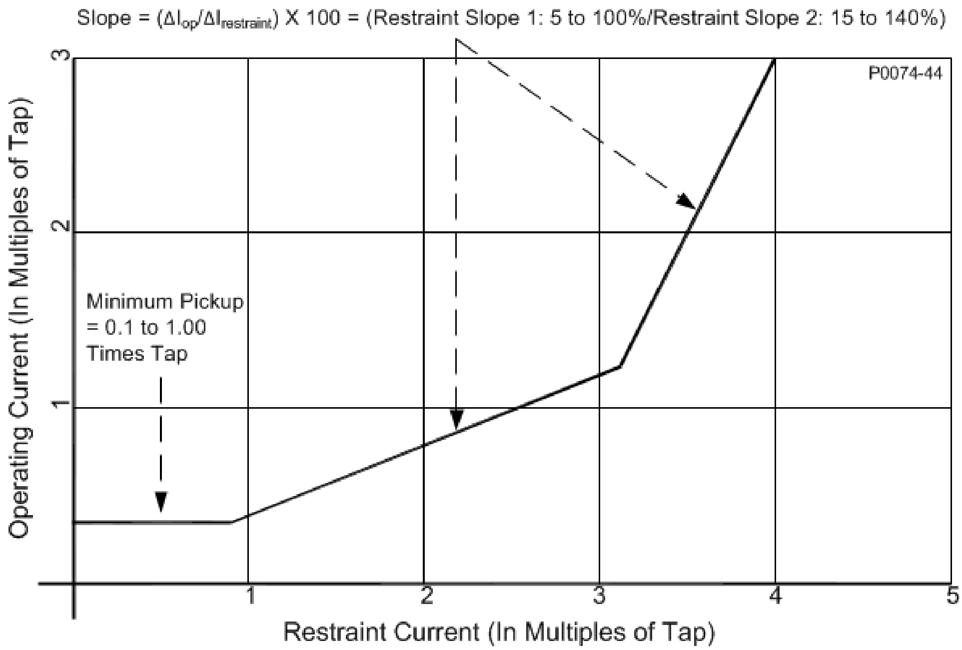


Figure 38-2. Percentage Restrained Differential Characteristic

The phase differential element provides three-phase percentage-restrained differential protection with dual slopes.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Zone Configuration

A differential Zone can be configured with both Circuits and Virtual Circuits by clicking the Zone. Each Circuit and Virtual Circuit in a zone has independent parameter and tap settings. Taps can be auto-configured and manually entered. When using Virtual Circuits, the sources in the Virtual Circuit must be included as 87 Zone Circuits. Connections are made on the rear of the BE1-FLEX and configured through Circuit and Virtual Circuit Configuration. IEC Transformer Setup provides configuration based upon IEC Vector Group designations. For an illustration of terminals, refer to the *Hardware Configuration* chapter and Circuit Configuration in the *Power System Configuration* chapter.

The Differential Zone Setup screen is shown in Figure 38-3. The IEC Transformer Setup screen is shown in Figure 38-4.

IEC Transformer Setup

This provides an alternate way to set Phase and Polarity based on IEC nomenclature if it is available on the transformer. If IEC Setup is used, BESTCOMS*Plus* will set the Polarity and Phase Relationship based on the IEC Setup configuration.

Transformer Taps

The user can set the taps for each Circuit and Virtual Circuit directly. This is often used when replacing an existing relay and wanting to use existing understood settings. When Calculate Taps is clicked, BESTCOMS*Plus* uses the MVA rating, kV rating, Transformer Connection, and CT ratios to update the tap settings below.

Add/Remove Zone Circuit and Virtual Circuit

These buttons are used to add or remove up to 28 Circuits and 2 Virtual Circuits to define the Differential Zone.

Source

The Source setting selects the Circuit to monitor.

Circuit Connection

This setting identifies which side of the protected transformer the circuit is located. For example, if the circuit is on the delta side of a Delta/wye transformer, set to DAB or DAC depending on how the delta of the transformer is constructed. Set to wye if the circuit is on the wye side of the transformer. Set to NA when there is no transformer in the protected zone, such as in a bus differential application. The circuit connection applies the phasor compensation necessary to balance the circuits. A special case exists where all CT and Circuit connections are set to wye, which applies delta compensation to remove the zero-sequence component from the calculations.

Ground Compensation

If there is a ground source within the protected zone, the user can apply a numerical, zero-sequence trap to remove the zero-sequence components from the current to prevent misoperation on external ground faults when a ground bank is in the zone of protection. This setting is optional. It is not required to enter a ground source setting of 1 to describe a grounded wye transformer connection. Even though not all grounded wye transformer connections are ground sources, the BE1-FLEX always assumes that a wye transformer connection is a ground source so that it is secure. Zero-sequence current unbalance can occur in three legged core transformers due to the phantom tertiary effect. In all cases, the BE1-FLEX chooses delta compensation for a wye transformer connection so that the zero-sequence components are blocked.

Polarity

This will typically be set to Normal. In some applications, the secondary side of the transformer may be wired 180 degrees instead of 0. If this is the case, then set to Reverse.

Phase Relationship

This will typically be A. In some cases, multiple circuits will be connected such that A on one side of the zone is in the same electrical location as B on the other side. In this situation, the second circuit phase relationship would be set to B.

kV Rating

This setting is used with CT ratios and Transformer connection to provide a correct ratio between Circuit and Virtual Circuit taps.

CT Connection

This is set on the Sensing Transformers page and displayed here for information.

Phase CT Ratio

This is set on the Sensing Transformers page and displayed here for information.

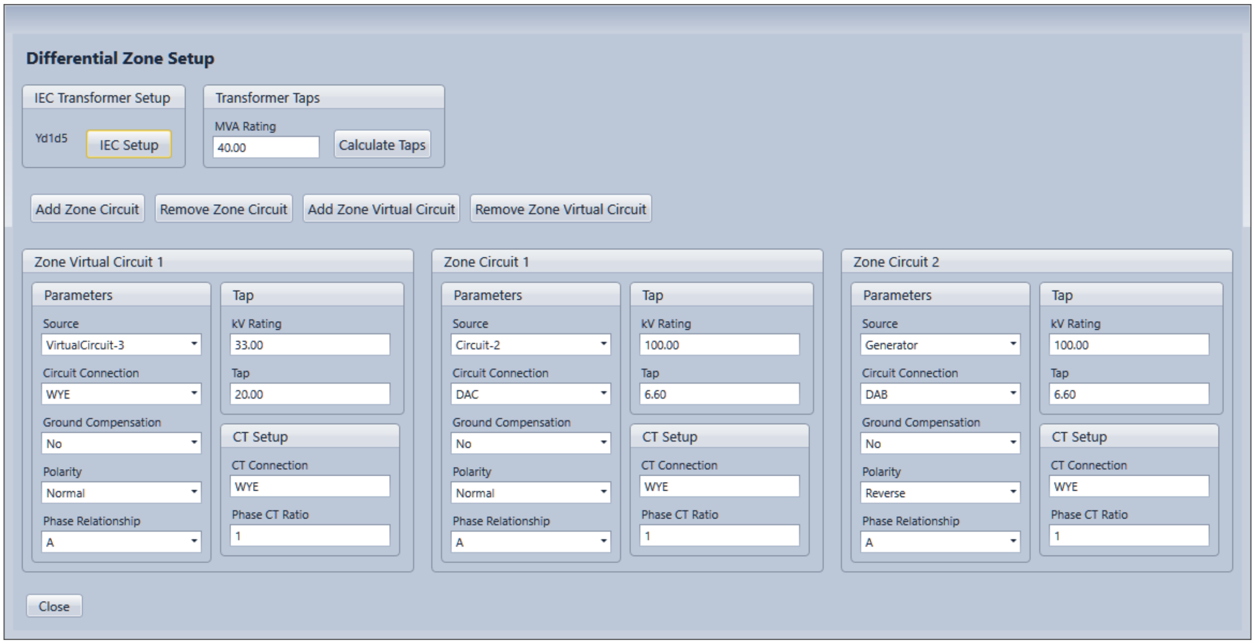


Figure 38-3. Differential Zone Setup Screen

Figure 38-4. IEC Transformer Setup Screen

Virtual restraint is designed for applications where high per unit current flows through the primary or secondary breaker current transformers without flowing though the protected transformer. The 87 element will work correctly without virtual circuits. However, differential protection is significantly enhanced by using virtual circuits when determining restraint current to calculating % slope used by the 87 element without requiring additional primary side CT's. See Figure 38-5.

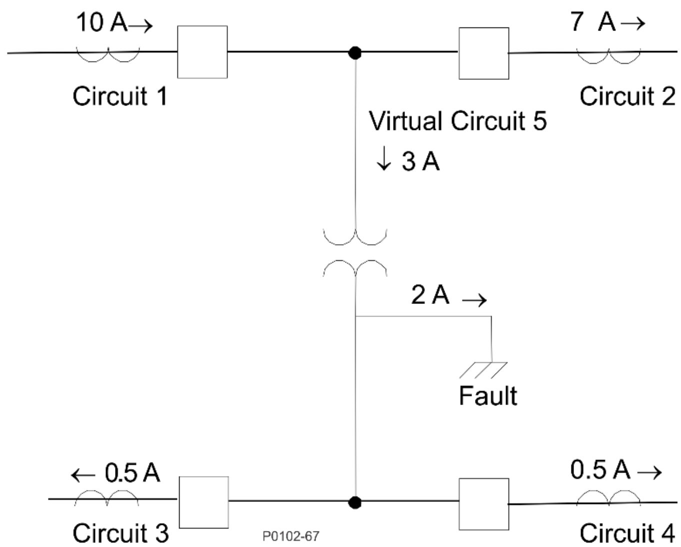


Figure 38-5. Virtual Circuit 5 Example

Using the example above, configure Virtual Circuit 5 as Circuits 1 and 2. Next, add the Virtual Circuit 5 to an 87 Differential Zone. The BE1-FLEX automatically excludes Circuits 1 and 2 from the restraint calculations.

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

Virtual Circuit 5 becomes the vector sum of Circuits 1 and 2 and is equal to 3 A. Using the maximum mode, Equation 38-1 applies:

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

Equation 38-1. Slope Calculation using Virtual Circuit 5

Using the setting of 45% slope, when an 87R operates for the fault condition that restrained. By using virtual restraint, the high current flowing thought Circuits 1 and 2 has no impact on the restraint calculations. By using virtual restraint, the restraint current is only proportional to current actually flowing through the protected transformer. This avoids the need to apply a separate CT at Virtual Circuit 5 location and maintains a good balance between sensitivity and security.

Unrestrained Tripping

The 87 element provides high-speed tripping for high-grade faults inside the zone of protection. If the operate current is above the Unrestrained Tripping threshold for any of the three phases, the Unrestrained Trip logic output becomes true. The transient monitor function also enhances security for this function by doubling the pickup threshold when CT saturation is detected. The minimum setting for the Unrestrained Tripping threshold should be the maximum inrush current with a small margin.

Harmonics

The second and fifth harmonic functions check the ratio of the second and fifth harmonic operate current to the fundamental operate current. Traditional harmonic restraint units operate on the ratio of harmonic current to total operate current versus the ratio to only the fundamental operate current used by the BE1-FLEX. For this reason, the BE1-FLEX will provide greater security for inrush and overexcitation with the same harmonic inhibit ratio settings used with traditional differential relays. When either of these two comparators is above the threshold, the percentage-restrained output is blocked from setting the Restrained Trip logic output. If the second or fifth harmonic inhibit comparators are picked up for any of the three phases, the Second Harmonic Inhibit and Fifth Harmonic Inhibit logic outputs respectively are also set.

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

Transient Monitor

A transient monitor detects the effects of CT saturation during a through fault. The 87 element monitors the change in restraint current versus the change in operate current. For an internal fault, the restraint current and operate current will experience a step increase at the same time. For an external fault, there should be no operate current. If CT saturation occurs during a through fault, the operate current will increase at some time after the restraint current increases.

The restrained or unrestrained differential must be picked up for the transient monitor to detect transient. The Transient Operation Time setting defines how long the transient remains detected after the restrained or unrestrained differential drops out. The Transient Delay Time setting affects only the restrained Trip output.

Pickup and Trip

Pickup

The Pickup output becomes true when the ratio of operating current to restraint current increases above the slope setting. The operating current is greater than the Minimum Restrained Pickup setting in any of the three phases. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Transient Time Delay setting.

If the pickup condition subsides before the element delay expires, the timer and Restrained Pickup output are reset, no corrective action is taken, and the element is rearmed for any other fault conditions.

Trip

The Trip output becomes true when a restrained pickup condition occurs and is delayed by the duration of the Transient Time Delay setting when a Transient event is detected. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If enabled for the element, the BE1-FLEX will record a target when the Trip or Unrestrained Trip outputs become true. See the *Fault Reporting* chapter for more information about target reporting.

Programmable Alarm

An 87 phase differential alarm occurs when the percentage restrained differential protection is nearing a trip condition on load as defined by the Alarm Slope. This alarm triggers a diagnostic routine that attempts to determine the source of the mismatch that is causing the differential unbalance. The alarm can be set to appear on the front-panel display, web page interface, and on the Alarms metering screen in BESTCOMS*Plus*. Refer to the *Alarms* chapter for information about programming alarms.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Phase differential element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The phase differential element logic block is illustrated in Figure 38-6. Logic inputs and outputs are summarized in Table 38-1.

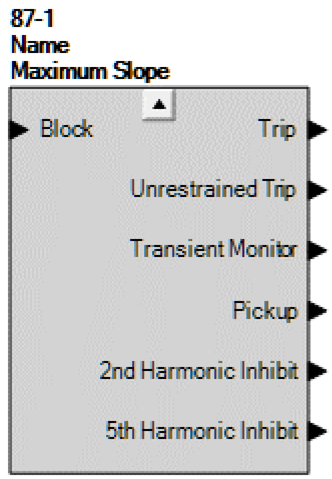


Figure 38-6. Phase Differential Element Logic Block

Table 38-1. Logic Inputs and Outputs

Name	Function	Purpose
Block	Input	Disables the 87 function when true
Trip	Output	True when the 87 element is in a trip condition
Pickup	Output	True when the 87 element is in a pickup condition
Unrestrained Trip	Output	True when the 87 element is in an unrestrained trip condition
2^{nd} Harmonic Inhibit	Output	True when the 87 is inhibited by 2^{nd} harmonic ratio
5^{th} Harmonic Inhibit	Output	True when the 87 is inhibited by 5^{th} harmonic ratio
Transient Monitor	Output	True when the Transient Monitor has detected the effects of CT saturation

Settings

Tap Compensation Settings

The measured currents must be tap adjusted to eliminate magnitude mismatch prior to being used by the Phase Differential Protection (87) element. The tap adjust factors can be manually calculated per Equation 38-2. Or, the user can enter the MVA and kV base parameters (Table 38-2) and the BE1-FLEX will calculate the tap-adjust factors using CT Ratio (CTR) and Compensation Factor (COMP) parameters from the Power System CT Setup settings. For a transformer application, the mismatch will be at a minimum if the actual transformer voltage ratings are used.

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

Equation 38-2. Calculate Tap Adjust Factors

Table 38-2. MVA and kVn Base Parameters

Parameter	Description	Explanation
Tapn	Restraint winding	Tap per Circuit/Virtual Circuit used in the zone.
MVA	MVA base	Full load MVA or top rating of the protected equipment.
kVn	kV base for Circuit/Virtual Circuit n	L-L Voltage in kV for each Circuit/Virtual Circuit.
CTRn	CT ratio for Circuit/Virtual Circuit n	Actual ratio not effective ratio.
COMPn	Phase compensation adjustment factor for Circuit/Virtual Circuit n	√3 if CTs are connected in Delta (CT connection = DAB or DAC). 1 in all other cases. See the *Power System Configuration* chapter.

The input currents can be tap adjusted up to a spread ratio of 50:1. If the ratio between the largest and smallest taps are greater than 50, it will be necessary to adjust the CT ratios to bring the tap factors closer together. When the auto-tap calculation feature is used, the BE1-FLEX will give an error message if the spread ratio is greater than 50.

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

BESTCOMS*Plus* is used to provide auto tap calculation by filling in the appropriate fields on the Transformer Setup screen and pressing the calculate button or manual tap values can be entered.

Operational Settings

The settings for restrained minimum pickup and unrestrained trip are set in multiples of tap. If the ideal taps calculated by Equation 38-2 fell within the acceptable range, the sensitivity settings will be in Per Unit on the MVA Base used in the equation. For example, a 100 MVA, 115 kV transformer has a full load (1 per unit) current of 500 amperes. A pickup setting of 10 times tap for the unrestrained output pickup element is equivalent to 5,000 primary amperes of differential current.

If the taps had to be adjusted upwards or downwards to fit within the acceptable range, the sensitivity settings for these protective elements should be adjusted as well. Equation 38-3 gives the adjustment factor. The definitions for the variables in Equation 38-3 are the same as those for Equation 38-2. For example, the ideal taps ($TAPn_I$) were calculated using Equation 38-3 and Equation 38-4 to be 1.6 and 5.0. They had to be adjusted upwards so that the actual taps ($TAPn_A$) are 2.0 and 6.25. Per Equation 38-3, X = 0.8. It is desired that the minimum pickup of the restrained element be 0.35 per unit on the circuit base. The actual setting should be 0.35 ∗ 0.8 = 0.28 to achieve the same sensitivity.

The pickup settings in Times Tap can be related to primary amps by Equation 38-4. Minpu is the minimum pickup setting in Times Tap. The definitions for the remaining variables in Equation 38-4 are the same as those for Equation 38-2.

$$X = \frac{TAPn_I}{TAPn_A} = \frac{MVA \times 1000 \times COMPn}{TAPn_A \times \sqrt{3} \times KVn \times CTRn}$$

Equation 38-3. Tab Adjustment Equation

$$Ipri = \frac{Minpu \times TAPn \times CTRn}{COMPn}$$

Equation 38-4. Calculate Primary Amps

Mode

Maximum Slope - The maximum of the compensated input currents is used. For example, the restraint current for phase A would be I_{RA} = max ($I_{AXCOMPS}$) where x = 2, 3, 4, or more based upon the number of circuits in the zone.

Average Slope - The average of the compensated input currents is used. For example, the restraint current for phase A would be given by Equation 38-5.

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

Equation 38-5. Calculate Restraint Current for Phase A, % of Average

Average Slope/2 - The sum of the compensated input currents divided by 2 is used. For example, the restraint current for phase A would be given in Equation 38-6.

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

Equation 38-6. Calculate Restraint Current for Phase A, Average Slope/2

Phase differential element operational settings are configured on the Phase Differential (87) settings screen (Figure 38-7) in BESTCOMS*Plus*.

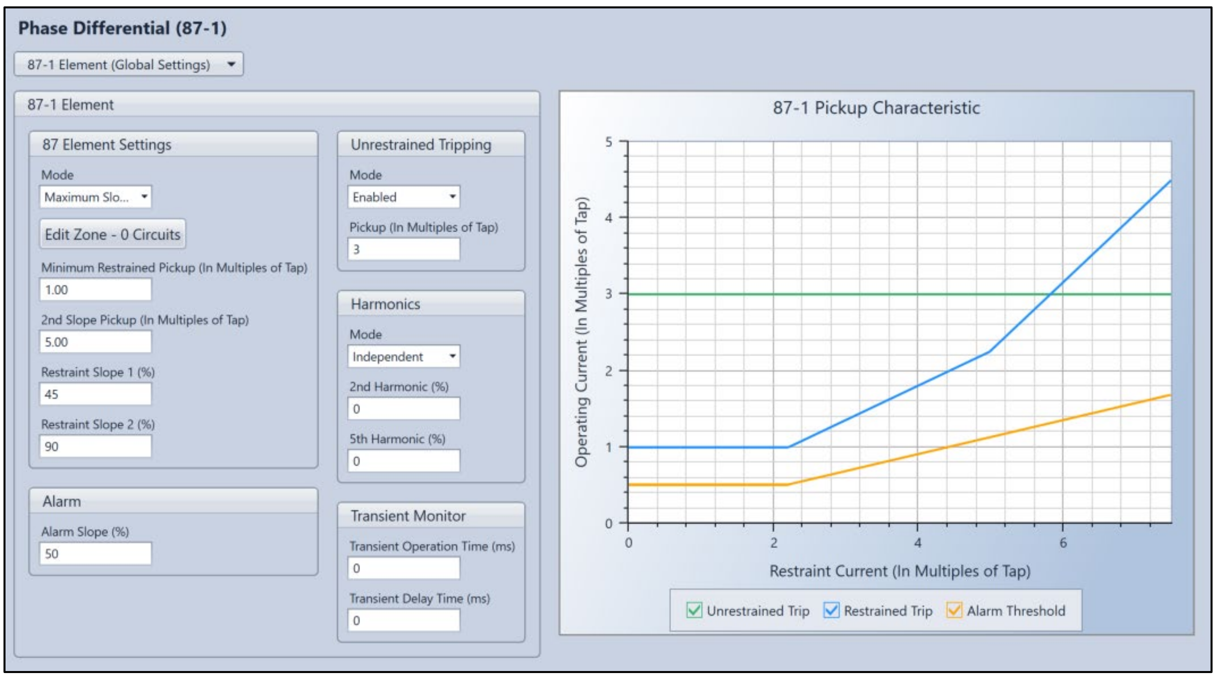


Figure 38-7. Phase Differential Settings Screen

Differential Compensation Methodology

Determining the Circuit Connection Parameters

Non-Transformer Differential Applications

Circuit connection is typically set to NA for differential applications that do not include a transformer in the zone. Phasor compensation is not typically required in these applications.

Wye and Autotransformer Windings

The transformer connection for a circuit that is connected to either a wye or autotransformer winding should be classified as a wye connection.

Delta Transformer Windings

The transformer connection for a circuit that is connected to a delta winding could be classified as one of two delta connections: Delta IA-IB (DAB) or Delta IA-IC (DAC). Figure 38-8 shows an example of a transformer with a DAB connection (left) and the same transformer with the phases reconnected to provide a DAC connection (right). If there is no wye winding to use as a reference, as is the case with a delta/delta transformer, the definition of the delta configuration is not important.

Zigzag Transformer Windings

Similar to Delta Transformer connections, select the appropriate connection type.

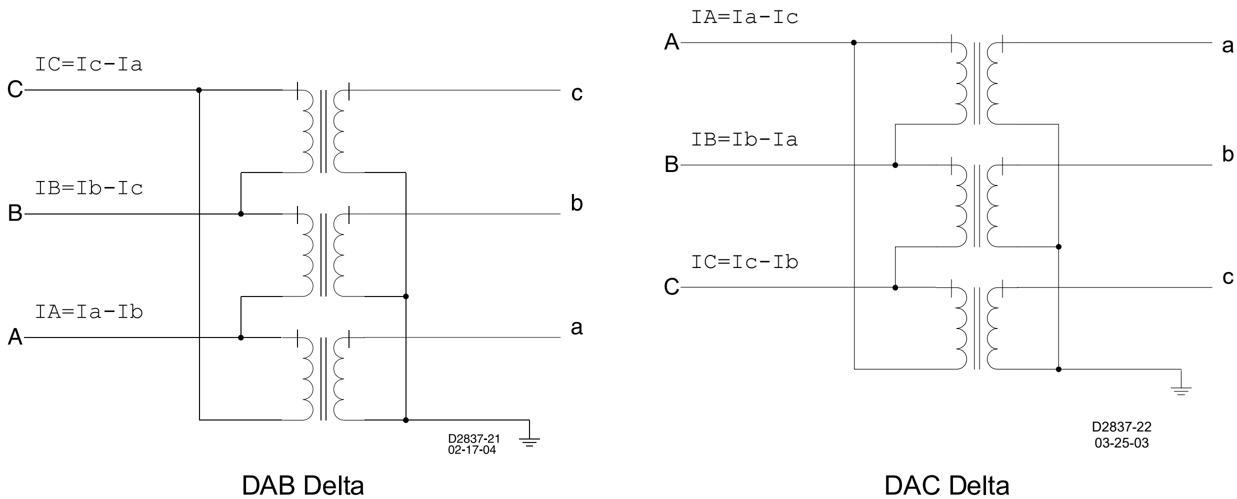


Figure 38-8. DAB/DAC Delta

With the appropriate CT and transformer connection information, the relay automatically applies the correct compensation. Normally, all circuits are compensated to obtain their equivalent delta currents. If all transformer windings and CTs are connected in wye, a special case exists and no compensation is required. For this case, wye currents on all circuits apply DAB compensation to remove the zero sequence component.

Total compensation is accomplished by summing the appropriate phasors from each of the CT inputs prior to using them in the differential function. For a wye to DAB connection, the wye CT phasors must first be phase-compensated to match the DAB circuit as shown in Figure 38-9. This is done using the DAB compensator, which provides a phasor sum of Ia + Ib to form I'a for comparison to the DAB's Ia CT current. A similar operation is used to form I'b and I'c.

Total compensation uses six phase compensation factors: DAB, DAC, REV, Rotation Factors R1 and R2, wye, and Double Delta DDAB.

Mathematically, the compensation factors provide the following equations shown in Table 38-3.

Note
A 1/√3 factor is missing from the compensation equations. See Table 38-9 for the magnitude adjustments applied.

Table 38-3. Compensation Factor Equations

Factor	$\hat{I}'a$	$\hat{I}b$	$\hat{I}'c$
DAB	$\hat{I}'a = \hat{I}a - \hat{I}b$	$\hat{I}'b = \hat{I}b - \hat{I}c$	$\hat{I}'c = \hat{I}c - \hat{I}a$
DAC	$\hat{I}'a = \hat{I}a - \hat{I}c$	$\hat{I}'b = \hat{I}b - \hat{I}a$	$\hat{I}'c = \hat{I}c - \hat{I}b$
REV	$\hat{I}'a = -\hat{I}a$	$\hat{I}'b = -\hat{I}b$	$\hat{I}'c = -\hat{I}c$
R1	$\hat{I}'a = \hat{I}c$	$\hat{I}'b = \hat{I}a$	$\hat{I}'c = \hat{I}b$
R2	$\hat{I}'a = -\hat{I}b$	$\hat{I}'b = -\hat{I}c$	$\hat{I}'c = -\hat{I}a$
DDAB	$\hat{I}''a = \hat{I}'a - \hat{I}'b$	$\hat{I}''b = \hat{I}'b - \hat{I}'c$	$\hat{I}''c = \hat{I}'c - \hat{I}'a$

The example in Figure 38-9 shows the resulting compensated angle and magnitude of DAB compensation. As the example shows, the compensated value is not necessarily a direct multiple of 30-degree compensation as the math applies to the phasor instead of applying a fixed magnitude and angle value.

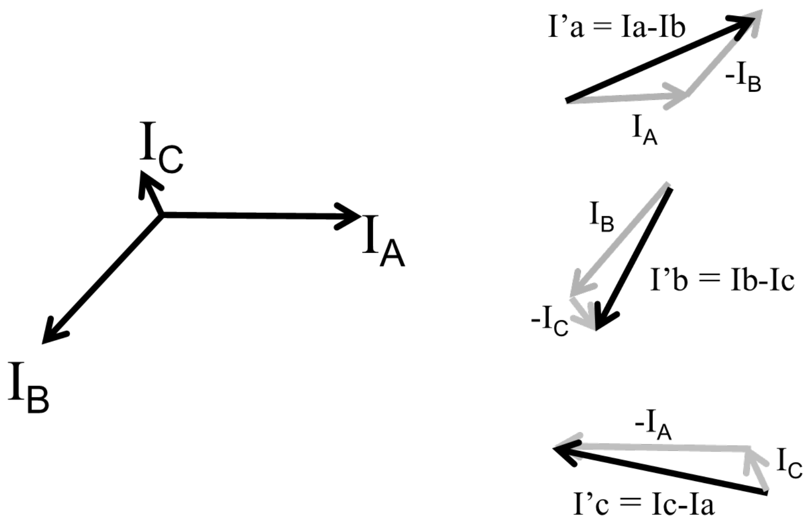


Figure 38-9. Phasor measurements with DAB compensated currents

Tables 38-4, 38-5, 38-6, and 38-7 illustrate how the various phase compensation factors are applied to different winding and CT configurations.

The BE1-FLEX can also compensate for phase “mismatch”. That is, if A phase of the incoming system is connected to the transformer primary H1 and A phase of the secondary system is connected to X2, the phases can be matched at the relay with this feature. Phase matching can be set through BESTCOMS*Plus*, under *Protection, Current, Phase Differential, Edit Zone*.

Settings for the current measurement functions are provided in Tables 38-4 through 38-7. These tables indicate the transformer circuit, CT settings, and type of phase compensation applied for various applications. The settings are indicated on a per circuit basis. Differential can be applied to single-, dual- or three-phase CT sets pending circuit configuration as any unpopulated phase will provide zero measured current. Missing phases can show operate or restraint currents pending compensation applied.

Table 38-4 indicates settings when applying the BE1-FLEX in a non-transformer application. The table also specifies the settings for a transformer case where all of the three-phase windings and all of the three-phase CTs are connected in wye.

Tables 38-5 and 38-6 are applied when a combination of delta and wye connections are present in the transformer connection and CT circuits. Table 38-5 is applied when only one type of delta connection is present in the transformer connection and CT circuits, such as DAB or DAC. This table is used for the majority of transformer protection applications. If the application requires a combination of delta circuits, such as both DAB and DAC connections being present, Table 38-6 is applied. The only exceptions are when all CT and winding connections are wye as indicated above or when one or more of the individual transformer windings are connected in delta or zigzag and has its corresponding CTs connected in delta.

Table 38-7 is applied when one or more of the individual transformer windings are connected in delta or zigzag and have its corresponding CTs connected in delta. This special connection can require up to two delta compensations for the other windings depending on the circuit's configuration.

Figure 38-8 shows how the currents will be magnitude-adjusted for each set of current inputs used by the phase differential protection function. The calculation is dependent upon the phase compensation chosen as shown in Tables 38-4, 38-5, and 38-6 and the ground source setting.

Table 38-4. Compensation applied when all Transformer Connections are WYE or N/A

Transformer Connection	CT Input Connection	BE1-FLEX Settings		Compensation Applied	
		TX	CT	Phase	Rotation
N/A	WYE	NA	WYE	WYE	NONE
	DAB	NA	DAB	WYE	NONE
	DAC	NA	DAC	WYE	NONE
	GND	NA	GND	WYE	N/A
All WYE ∗	All WYE ∗	WYE	WYE	DAB	NONE

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

Table 38-5. Compensation applied with only one Delta or Zigzag Connection is in the Zone

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

Table 38-6. Compensation applied when more than one Delta or Zigzag Connection is in the Zone

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

Table 38-7. Compensation applied when an Individual Circuit in the Zone is Delta or Zigzag and the CT's are Delta

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

See *Settings, Tap Calculation Settings,* above for more information on the auto-tap calculation function.

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

Table 38-8. Internal Compensation Chart

Compensation	Ground Source	A Phase	B Phase	C Phase
WYE (none)	0 = No	IA	IB	IC
WYE (none)	1 = Yes	IA - I0	IB - I0	IC - I0
DAB	0 = No or 1 = Yes	(IA - IB) / √3	(IB - IC) / √3	(IC - IA) / √3
DAC	0 = No or 1 = Yes	(IA - IC) / √3	(IB - IA) / √3	(IC - IB) / √3
DDAB	0 = No or 1 = Yes	(IA - 2IB + IC) / 3	(IA + IB - 2IC) / 3	(-2IA + IB + IC) / 3

An example of a zone with four circuits and the resulting compensated phase A current values are shown in Table 38-9. Phases B and C will follow the relative math.

Table 38-9. Example of a Zone with 4 Circuits and the Resulting Compensated Phase A Current Values

	Circuit 1	**Circuit 2**	**Circuit 3**	**Circuit 4**
Transformer Connection*	WYE	DAB	DAC	ZAC
CT Connection*	DAB	WYE	WYE	WYE
Ground Compensation	No	No	Yes	No
Phase Compensation Applied	DAB	WYE	WYE	WYE
Rotation Applied	None	None	R2	R2
Compensated Ia	**(Ia - Ib) / √3**	**Ia**	**- (Ib - I0)**	**- Ib**
* Multiple connections, no delta or zigzag with delta CTs. Use Table 38-5.				

39 • Flux Balance (87FB)

The Flux Balance (87FB) element monitors the differential current and provides primary protection for small generators.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Flux Balance (87FB) settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, Flux Balance (87FB)

Element Operation

A differential element compares the currents entering and leaving the protected machine. If a fault is detected, the BE1-FLEX initiates a trip signal. This action limits damage to the machine and minimizes impact on the power system. Flux Balance differential is typically used on small machines with relatively small diameter conductors. Medium, large, and critical machines are commonly protected with an 87 Phase element instead.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. For an illustration of terminals, refer to the *Hardware Configuration* chapter. Refer to the *Typical Connections* chapter for flux balance connections.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Pickup and Trip

Pickup

The Pickup output becomes true when the measured difference current in any phase exceeds the Flux Balance Pickup level. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the 87FB element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other fault conditions.

Trip

The Trip output becomes true when a pickup condition persists for the duration of the element Time Delay setting. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If the target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Programmable Alarm

An 87FB Alarm condition is commonly set to indicate when the flux balance differential is nearing a trip condition on load.

The alarm can be set to appear on the front-panel display, web page interface, and on the Alarms metering screen in BESTCOMS*Plus*. Refer to the *Alarms* chapter for information on how to program alarms.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Flux balance element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The flux balance element logic block is illustrated in Figure 39-1. Logic inputs and outputs are summarized in Table 39-1.

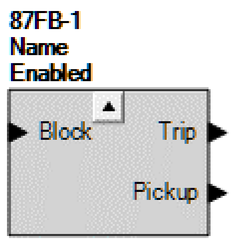


Figure 39-1. Flux Balance Element Logic Block

Table 39-1. Logic Inputs and Outputs

Name	Function	Purpose
Block	Input	Disables the 87FB function when true
Trip	Output	True when the 87FB element is in a trip condition
Pickup	Output	True when the 87FB element is in a pickup condition

Flux balance element operational settings are configured on the Flux Balance (87FB) settings screen (Figure 39-2) in BESTCOMS*Plus*.

Figure 39-2. Flux Balance Settings Screen

40 • Neutral Differential (87N)

The Neutral Differential (87N) element provides sensitive differential protection from phase-to-ground faults in the Y-connected winding. On impedance grounded systems, ground fault levels may be reduced below the sensitivity of the phase differential protection. The result is that ground faults within the protected zone have to be cleared by time delayed backup overcurrent protection if sensitive differential protection is not available.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Neutral Differential (87N) settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Current, Neutral Differential (87N)

Element Operation

The 87N element detects an imbalance between the neutral current (3I0) and ground current (IG).

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Circuit Configuration

Connections are made on the rear of the BE1-FLEX and configured through Circuit Configuration. 3I0 is derived from the Phase source. IG is measured directly from IG within a circuit. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Overcorrection Coefficient

The 87N element is directionally supervised by making a comparison of two vectors, the calculated IOP vector and the current present on IG. For Circuit Configuration, see the *Power System Configuration* chapter. First, the magnitude of the vector (IopMag) is checked by the equation IopMag = 3I0 + IG to determine if it is above the user defined pickup setting. Second, the measured IG quantity is used as the polarizing quantity to determine directionality (IopDir) by the equation IopDir = IG + (OVCR * 3I0). The overcorrection coefficient (OVCR) is used to add security to the directional element in the previous equation. For the IopDir check, OVCR is used to offset the 3I0 measurement by the quantity determined in the Overcorrection Coefficient setting, which at low levels of 3I0 and IG, will provide greater confidence that the directional criterion is met. The decision to trip will be made only when IopMag is above the user defined pickup setting and IopDir is within ±90° of the current present on IG.

CT Flip

For a CT with an auxiliary CT installed, a CT Flip might be necessary to correct the polarity of the 3I0. Setting the CT Flip to Yes will introduce a 180° phase shift internally in the 3I0 calculation.

Transient Delay

A user-defined transient delay time provides security from misoperation on false residual caused by CT saturation during a through fault. Commonly, the transient monitor function from the phase current differential (87) function detects CT saturation and is routed to the 87N Transient Delay initiate. The 87N Trip logic output is then routed through a timer when the Transient Monitor logic input is asserted. See Figure 40-1. The timer should be set longer than the normal clearing time for a fault just outside the zone of protection to allow it to ride through until the external fault is cleared.

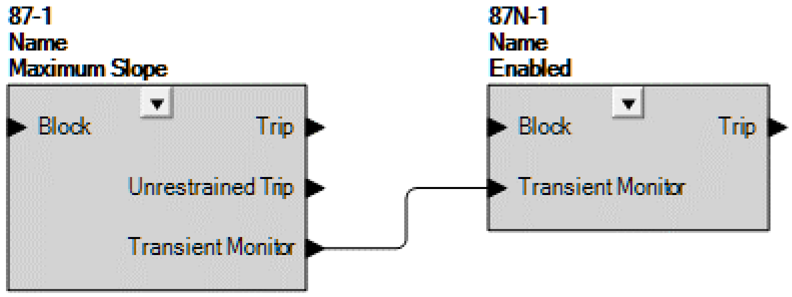


Figure 40-1. Transient Delay Logic

Pickup Calculations

The differential value is calculated as shown in Equation 40-1 and Equation 40-2 and displayed in BESTCOMS*Plus* metering and on the front-panel display.

$$\text{If CT Flip Setting} = \text{Yes, then Iop} = \text{IG}_{\text{sec}} - \left(\frac{\text{Phase CT Ratio}}{\text{Ground CT Ratio}} \times 3\text{I0}_{\text{sec}}\right)$$

Equation 40-1. Iop Calculation when CT Flip Setting = Yes

$$\text{If CT Flip Setting} = \text{No, then Iop} = \text{IG}_{\text{sec}} + \left(\frac{\text{Phase CT Ratio}}{\text{Ground CT Ratio}} \times 3\text{I0}_{\text{sec}}\right)$$

Equation 40-2. Iop Calculation when CT Flip Setting = No

Pickup and Trip

Pickup

The Pickup output becomes true when the Iop Minimum setting is exceeded. In BESTlogic*Plus*, the Pickup output can be connected to other logic elements to annunciate the condition and control other elements in logic.

Assertion of the Pickup output initiates a timer that begins timing to a trip. The duration of the timer is established by the Time Delay setting. A Time Delay setting of zero (0) makes the 87N element instantaneous with no intentional time delay.

If the pickup condition subsides before the element delay expires, the timer and Pickup output are reset, no corrective action is taken, and the element is rearmed for any other fault occurrences.

Trip

The Trip output becomes true if a fault condition persists for the duration of the element Time Delay setting. In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled for the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0 and resetting the element timer. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Current-Polarized Directional Scheme

Figure 40-2 shows the correct CT polarity to ensure proper Iop magnitude (50) and directionality (67) validation within the 87N with a CT Flip setting of “Yes”. With the assumed positive current direction, 3I0 and IG are in phase for an internal fault and are out of phase for an external fault.

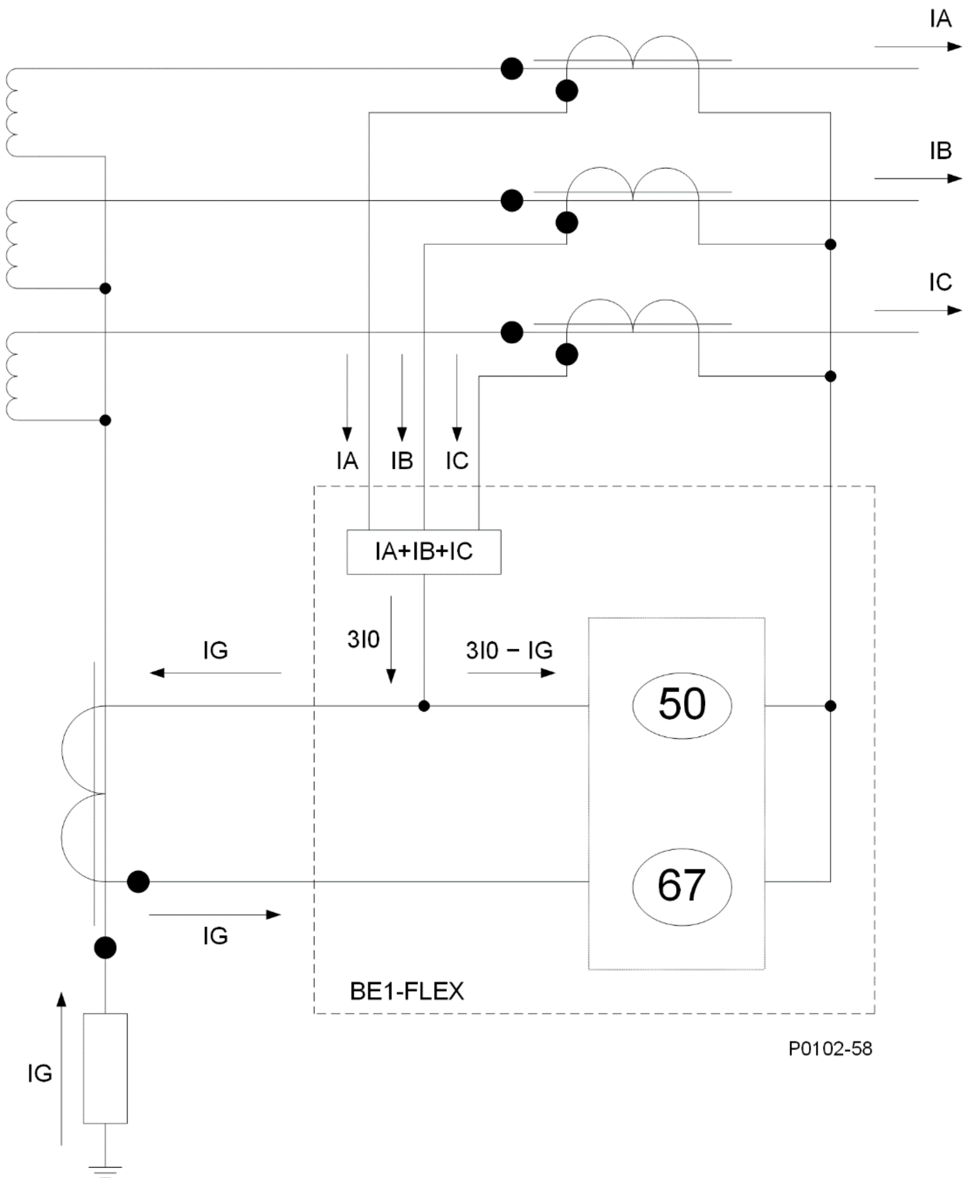


Figure 40-2. Current-Polarized Directional Scheme for BE1-FLEX CT Connection

Logic Connections

Neutral current differential element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The neutral current differential element logic block is illustrated in Figure 40-3. Logic inputs and outputs are summarized in Table 40-1.

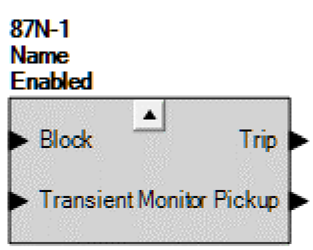


Figure 40-3. Neutral Current Differential Element Logic Block

Table 40-1. Logic Inputs and Outputs

Name	Function	Purpose
Block	Input	Disables the 87N function when true
Transient Monitor	Input	Enables the transient delay when true
Trip	Output	True when the 87N element is in trip condition
Pickup	Output	True when the 87N element is in pickup condition

Operational Settings

Neutral current differential element operational settings are configured on the Neutral Current Differential (87N) settings screen (Figure 40-4) in BESTCOMS*Plus*.

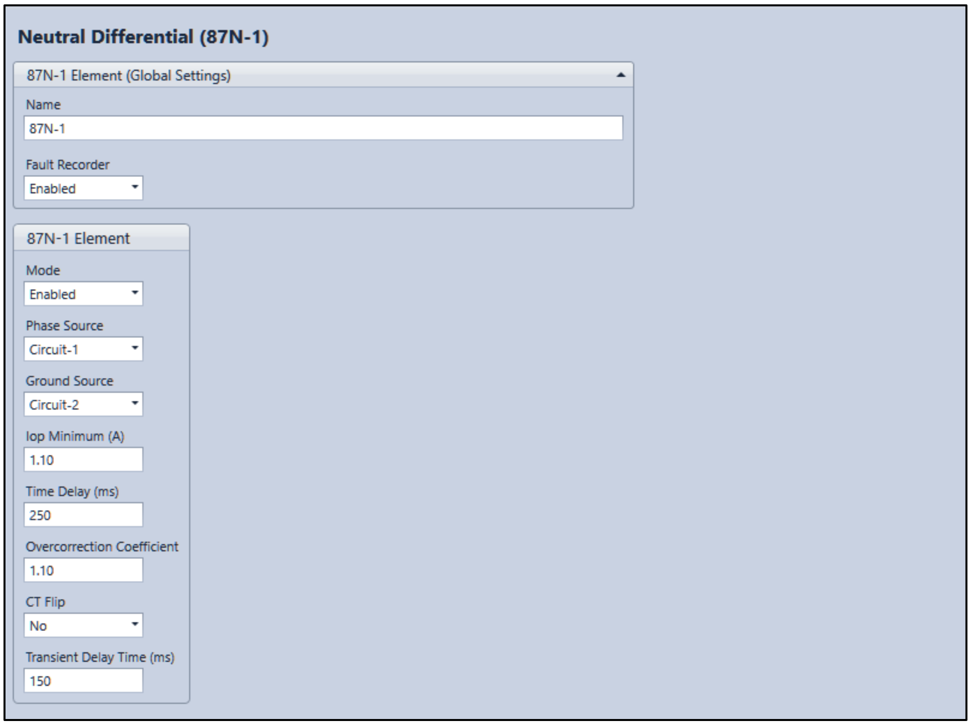


Figure 40-4. Neutral Current Differential Settings Screen

41 • Configurable Protection

Configurable protection can be used when standard protection functions do not meet the needs of the application. Nearly all measured and calculated parameters are available. Configurable protection also includes math operators between two values for even further flexibility. Configurable protection operates at standard protective function scan rates.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Configurable Protection settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Configurable Protection

Element Operation

Name

In order to make identification of the items easier, each of the items can be given a user-assigned name. The label is an alphanumeric string with a maximum of 64 characters.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Operator

Operators Plus, Minus, Multiply, and Divide are used in the mathematical equation from Parameter 1 to Parameter 2. For example, a Divide operator results in Parameter 1 divided by Parameter 2. If None is selected, no mathematical equation is performed and Parameter 2 is ignored.

Parameter 1 and 2

Two parameters may be selected for use in simple mathematical equations. The result of the equation is compared to the configurable protection thresholds. Scale factors and offsets are also provided for each parameter.

Source

Nearly all measured and calculated analog values in the BE1-FLEX can be utilized by Configurable Protection. Parameters are utilized as magnitude only. Units are ignored, but can be referenced in the User Programmable Name field if desired. For an illustration of terminals and configuration, refer to the *Hardware Configuration* chapter.

Parameter Selection

Available functions include the following:

- Breaker
- Breaker Monitor
- Circuit
- Control Power Monitor
- Demands
- Energy
- Logic Timer (62)
- Neutral Differential (87N)
- Overcurrent Through Fault Counter (51TF)
- Phase Differential (87)
- Power Quality

- Recloser (79)
- Setting Group

Scale Factor

The scale factor allows parameters to be normalized relative to each other such as per unit.

Offset

The offset shifts the magnitude of a parameter up or down. Similar to scale factor, offset is commonly used to normalize multiple parameters to each other. An example of both scale factor and offset is to normalize 4-20 mA auxiliary analog to a 0-10 V auxiliary analog input. Scale the 0-10 by 10 to provide necessary resolution. In addition, scale the 4-20 to 10/16*10 for a full range of 25-125 and offset by –25 to normalize these parameters.

Thresholds

There are two programmable thresholds for each configurable protection element. Each threshold has a mode setting, pickup setting, time delay setting, and a hysteresis setting.

Mode

The mode can be set for Over or Under for either Threshold. If Over mode is selected, the Trip output becomes true when the metered parameter increases above the Pickup setting for the duration of the Time Delay. If Under mode is selected, the Trip output becomes true when the metered parameter decreases below the Pickup setting for the duration of the Time Delay.

Pickup

When the selected parameter rises above or falls below this setting, depending on the Mode setting, the time delay begins and the Pickup output becomes true.

Time Delay

After the threshold has been exceeded for the duration of the time delay, the Trip output becomes true. If the threshold detection drops out before the time delay expires, the timer is reset.

In BESTlogic*Plus*, the Trip output can be connected to other logic elements and to a physical relay output to annunciate the condition and to initiate corrective action. If a target is enabled by the element, the BE1-FLEX will record a target when the Trip output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Hysteresis

This setting provides a level of hysteresis between a threshold detection tripping and dropping out. For instance, if the hysteresis is set for 5% and the mode is set as Over, once the threshold detection picks up, the measured parameter must drop to 95% of the threshold before the threshold detection drops out. This hysteresis helps prevent rapid or repeated transitions between trip and dropout in cases where the measured parameter is nearly equal to the threshold.

If the mode is set as Under with 5% hysteresis, once the threshold detection trips, the measured value must rise to 105% of the threshold before the threshold detection will drop out.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the Trip and Pickup outputs to logic 0. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Measurements, such as Auxiliary Inputs, with active Out of Range Alarms will not automatically block a configurable protection function, but can be set to block in logic if desired.

Logic Connections

Configurable protection element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The configurable protection element logic block is illustrated in Figure 41-1. Logic inputs and outputs are summarized in Table 41-1.

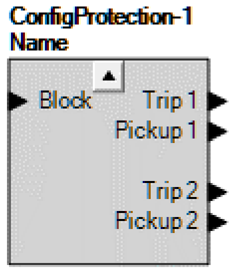


Figure 41-1. Configurable Protection Element Logic Block

Table 41-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the Configurable Protection element when true
Trip 1	Output	True when the Configurable Protection element's Threshold 1 is in a Trip condition
Pickup 1	Output	True when the Configurable Protection element's Threshold 1 is in a Pickup condition
Trip 2	Output	True when the Configurable Protection element's Threshold 2 is in a Trip condition
Pickup 2	Output	True when the Configurable Protection element's Threshold 2 is in a Pickup condition

Operational Settings

Configurable protection element operational settings are configured on the Configurable Protection settings screen (Figure 41-2) in BESTCOMS*Plus*.

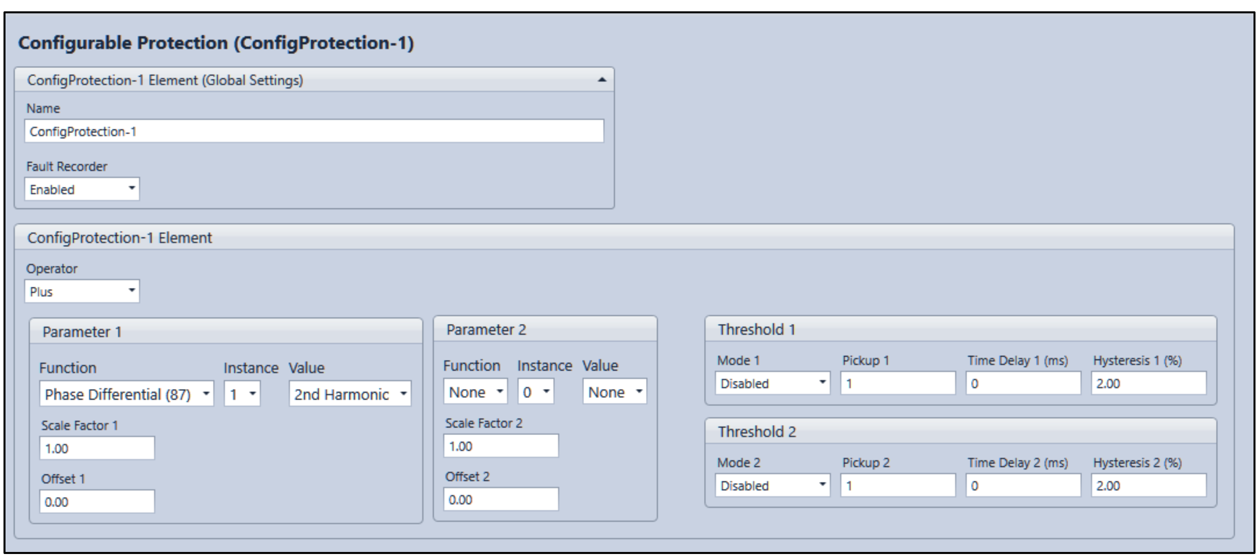


Figure 41-2. Configurable Protection Settings Screen

42 • Control Power Monitor

The Control Power Monitor element monitors positive, negative, and ground DC voltage of the power supply board.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Control Power Monitor settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Protection, Control Power Monitor

Element Operation

Alarm thresholds for High Voltage and Low Voltage can be set. Ground detect will operate if either the positive or negative voltage is 10% from Ground. Trip times (ms) can be set for High Voltage, Low Voltage, and Ground conditions. Alarms are available in logic and annunciation for each threshold.

Control Power Monitor only applies to DC voltage. If an application calls for AC control power monitoring, wire it into one of the standard Voltage inputs such as VX and use the 27 and 59 elements.

Hardware Configuration

The Control Power Monitor measures voltages across the Power Supply input terminals. The Power Supply Input Type setting in Hardware Configuration enables the Control Power Monitor function when set to DC. It also varies the sampling method based upon the voltage type. For an illustration of terminals, refer to the *Hardware Configuration* chapter.

Time Delay

The element operate time equals the time delay setting. Element operate times do not include logic or output operate times.

Undervoltage and Overvoltage Alarms

Alarm thresholds and trip times for undervoltage and overvoltage can be set.

Ground Detect

Ground detect operates if either the positive or negative voltage is 10% from Ground.

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element.

Logic Connections

Control Power Monitor element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The Control Power Monitor element logic block is illustrated in Figure 42-1. The logic input is summarized in Table 42-1. Logic outputs are available as Alarms on the I/O tab. See the *Alarms* chapter for more information on alarms.

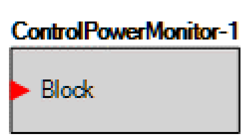


Figure 42-1. Control Power Monitor Element Logic Block

Table 42-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the Control Power Monitor function when true

Operational Settings

Control Power Monitor element operational settings are configured on the Control Power Monitor settings screen (Figure 42-2) in BESTCOMS*Plus*.

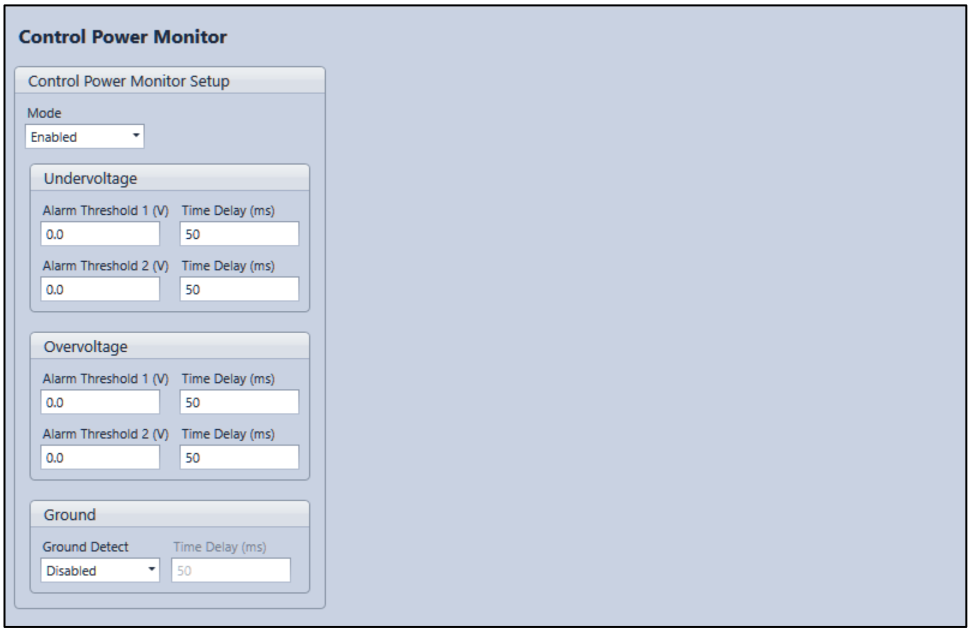


Figure 42-2. Control Power Monitor Settings Screen

Metering

Control Power Monitor element metering can be viewed on the Control Power Monitor metering screen (Figure 42-3) in BESTCOMS*Plus*.

Figure 42-3. Control Power Monitor Metering Screen

43 • Synchronizer (25A)

The synchronizer (25A) element performs the following functions:

- Compares the voltage magnitude, angle, and frequency of two circuits phase voltages
- Calculates the ideal time to close the breaker so that mechanical and electrical transients are minimized

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Synchronizer settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Control, Synchronizer (25A)

Element Operation

The synchronizer acts to align a power source's voltage magnitude, frequency, and relative phase angle across a circuit breaker. It is typically used to automatically synchronize a generator to a bus.

VT Connections

The synchronizer element compares the Source 1 voltage to the Source 2 voltage of a Breaker instance. Proper connection of the voltage transformer inputs is vital for correct operation of the synchronizer element. Breaker instance Source 1 is commonly generator voltage and Source 2 is commonly bus voltage. The remainder of this chapter discusses this configuration.

For clarification on single-phase VT connections, refer to the *Typical Connections* chapter. The single-phase parallel connections are available on VA and VX hardware input channels.

For single-phase sensing connections derived from a phase-to-neutral circuit into VA, VB, and VC inputs:

> Terminals VA, VB, and VC are connected in parallel. The single-phase signal is connected between the parallel group and terminal VN.

For single-phase sensing connections derived from a phase-to-phase circuit:

> Terminals VB, VC, and VN are connected in parallel. The single-phase signal is connected between terminal VA and the parallel group.

Note that the voltage monitor (described below) performs three of three testing for all connections. For 3W and 4W, phases A, B, and C are actually tested. For single-phase connections, the terminals are connected in parallel as described above and the single-phase is tested three times.

Mode

Two operating modes are available: Phase Lock Loop and Anticipatory. In both modes, the BE1-FLEX sends contact outputs to the governor and voltage regulator to adjust the frequency and voltage of the generator to match that of the bus (mains) at the proper relative phase angle, and then connects the generator to the bus by closing the breaker. Anticipatory mode has the added capability of compensating for the breaker closing time (the delay between when a breaker close command is issued and the breaker contacts close). The BE1-FLEX controls the slip frequency difference between the generator and the bus, and then calculates the advance angle that is required to compensate for the breaker closure time.

Voltage and frequency Synchronization is accomplished by issuing Raise and Lower correction signals to the generator governor and AVR (automatic voltage regulator). Correction signals are issued in the form of output contact closures. These correction signals can be either continuous or proportional. Proportional correction uses control pulses of varying widths and intervals. Initially, long pulses are issued when the voltage and frequency differences are large. As the correction pulses take effect and the voltage and frequency differences become smaller, the correction pulse widths are proportionally decreased. Proportional correction pulses are beneficial in applications where fixed correction pulses can result in overshooting the slip frequency and regulation offset targets.

Frequency Correction

Generator frequency correction is defined by the Slip Frequency setting and further refined by the Breaker Close Angle setting (available in PLL mode only). The Slip Frequency setting establishes the maximum allowable deviation of the generator speed (frequency) from the bus frequency. The Minimum Slip and Maximum Slip settings are used to calculate the slip frequency error and to provide slip frequency control while in phase lock synchronization. If the slip frequency magnitude is above the Maximum Slip setting, the error is set equal to the Max Error in the opposite polarity. If the slip frequency magnitude is below the Minimum Slip setting, the slip frequency error is zero (0). When it is between the two settings, the error is calculated internally by the BE1-FLEX. Slip frequency error is shown in Figure 43-1.

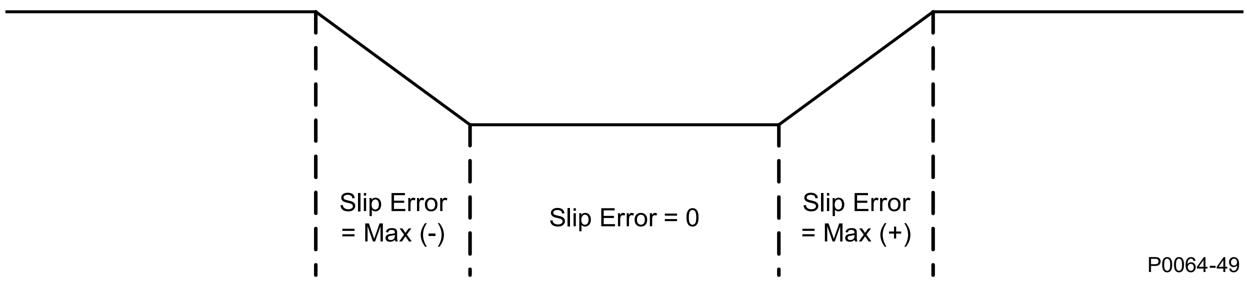


Figure 43-1. Slip Frequency Error

To minimize the impact on the bus during synchronization, the Source 1 Frequency > Source 2 Frequency setting can be enabled to force the generator frequency to exceed the bus frequency at the moment of breaker closure. If this is the case, the BE1-FLEX will drive the generator frequency higher than the bus frequency before closing the breaker.

The Breaker Close Angle setting (available in Phase Lock Loop mode only) defines the maximum allowable phase angle difference between the generator and the bus. For breaker closure to be considered in PLL mode, the slip angle must be less than or equal to the breaker close angle.

The breaker close angle is not used in Anticipatory mode. Instead, the breaker close time and metered slip frequency are used to calculate an “advance angle”. The angle is considered in sync when the slip angle equals the advance angle.

Voltage Correction

Generator voltage correction is defined by the Voltage Difference setting. This setting is expressed as a percentage difference between the generator nominal voltage and bus nominal voltage. If the Source 1 Voltage > Source 2 Voltage setting is enabled, the BE1-FLEX will drive the generator voltage to at least 0.5% greater than the bus voltage.

Synchronization Failure

The Sync Fail Activation Delay and Breaker Close Attempts settings establish the maximum duration in which synchronizing can occur. If the 25A Synchronizer element issues a breaker close, and the breaker fails to close within this time, the logic increments the Breaker Close Attempts counter. If the number of breaker close attempts has exceeded the Breaker Close Attempts setting, then generator synchronization is aborted. At this time, the Sync Fail logic output pulses high. Note that if either bus becomes unstable, the synchronizer timers are reset. The breaker close attempt counter retains its value.

Voltage Monitoring

The Volt Monitor logic output is provided for conditions where the bus and/or the line are dead. In BESTlogic*Plus*, the Volt Monitor logic output can be connected to other logic elements to annunciate the condition or control other elements in logic. The Volt Monitor logic output will only affect the 25A when connected in logic. A live condition for either the phase voltage or auxiliary voltage is determined when the measured voltage on the respective input is equal to or above the live voltage threshold established by the Live Voltage setting. A dead condition for either phase voltage or auxiliary voltage is determined when the measured voltage on the respective input is equal to or below the dead voltage threshold established by the Dead Voltage setting. The Dropout Delay setting provides hysteresis for the Volt Monitor logic output.

For the phase voltage input, if the connection is three-phase, 3W or 4W, all three phases are tested and must be above the live voltage threshold for a live condition to be true. Similarly, all three phases must be below the dead voltage threshold for a dead condition to be true.

The voltage monitor logic is illustrated in Figure 43-2. Any combination of logic settings can be selected for the Voltage Monitor Logic on the Synchronizer (25A) settings screen in BESTCOMS*Plus*. When a logic combination is selected, the synchronizer closes the respective logical switch in Figure 43-2 associated with each of the outputs.

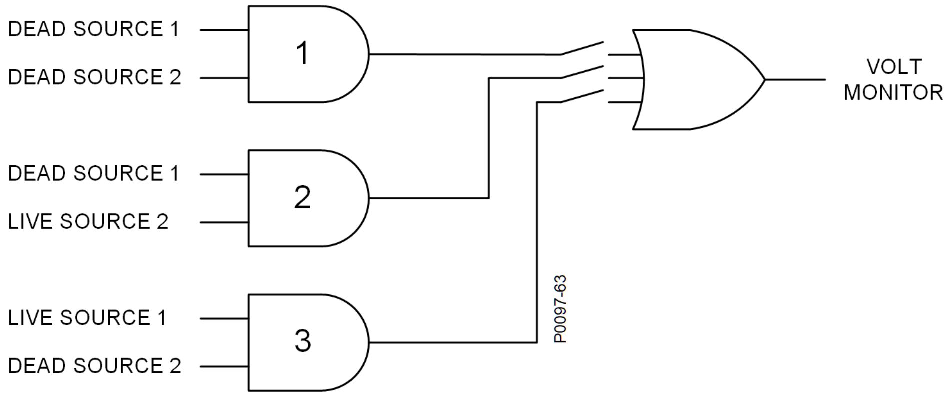


Figure 43-2. Voltage Monitor Logic

Initiate Input

The Initiate input starts the operation of the 25A when ALL of the following conditions are met:

- 25A element must be initiated (Initiate logic input pulsed or held true)
- Block input of the 25A element must be logic 0
- 60FL (Fuse Loss) alarm, if configured, must not be present
- Breaker must be open (52b). (Breaker Status logic input = 0)
- 25A element was not previously stopped by Sync Fail without being reset by pulsing the Block logic input. This assumes that the Initiate input was not switched to logic 1 for the duration of the previous synchronization cycle.
- Voltage Difference setting > 0%
- Slip Freq setting > 0 Hz
- Breaker Close Attempts setting > 0
- In Anticipatory mode:
    - Breaker Close Time setting must be set above zero (0)
- In PLL mode:
    - Max Slip setting must be set higher than Min Slip setting and zero (0)
    - Breaker Close Angle setting must be set above zero (0)

Status Output

The Status logic output becomes true when all of the synchronization parameters above are met and the generator and bus voltages are stable.

Close Breaker Output

The Close Breaker logic output signals the breaker to close when ALL of the following conditions are met:

- Source 1 and Source 2 voltages are stable
- Phase angle between sources are less than the Breaker Closing Angle setting (Phase Lock Loop only)
- Frequency error between sources is less than the Slip Frequency setting. (Note: When the Source Freq > Destination Freq is enabled, only Source 1 frequency greater than Source 2 frequency is allowed.)
- Voltage magnitude between sources is less than Voltage Difference setting. (Note: The voltage used by the BE1-FLEX for this feature is a voltage magnitude measurement, not a voltage phasor measurement. When the Voltage Source > Voltage Destination setting is enabled, only Source 1 voltage greater than Source 2 voltage is allowed.)

The Close Breaker output will remain true until the Breaker Status logic input becomes true, a Sync Failure occurs, or the synchronization parameters are no longer true.

Breaker Status

The synchronizer will not operate if the Breaker Status logic input = 1. Refer to the *Power System Configuration* chapter for information on configuring breakers.

Element Blocking

Fuse Loss

The fuse loss (60FL) element of the BE1-FLEX can be used to block the Synchronizer (25A) element when fuse loss is detected in a three-phase system.

If the 60FL element trip logic is true and Block with 60FL is enabled, the Synchronizer (25A) element is blocked. See the *Fuse Loss (60FL)* chapter for more information on the 60FL function.

Block Logic Input

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the element's outputs to logic 0. A new Initiate pulse is required to restart synchronization after the Block input is removed. Connect the element Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Synchronizer element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The synchronizer element logic block is illustrated in Figure 43-3. Logic inputs and outputs are summarized in Table 43-1.

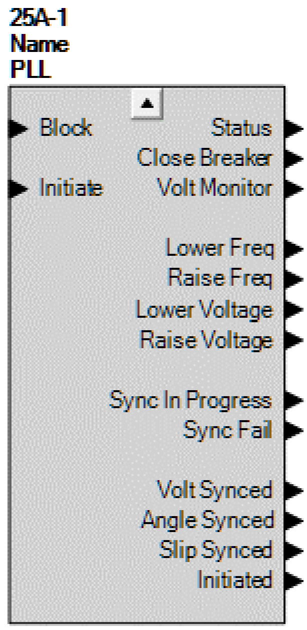


Figure 43-3. Synchronizer Element Logic Block

Table 43-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Block	Input	Disables the 25A function when true. A pulse will stop and reset the 25A function. In addition, resets the element after a sync fail.
Initiate	Input	A pulse true initiates the synchronization process. It does not have to be maintained to continue synchronization. If it is maintained and a sync fail occurs, the element will not be blocked, but continue with a new sync cycle.
Status	Output	True when the synchronization frequency, voltage, and angle criteria are met.
Close Breaker	Output	Signals the breaker to close. True after the Status output becomes true and PLL or Anticipatory conditions are met. Does not operate on voltage monitor conditions.
Volt Monitor	Output	True when the voltage monitor conditions are met.
Lower Frequency	Output	True when the 25A element is decreasing frequency.
Raise Frequency	Output	True when the 25A element is raising frequency.
Lower Voltage	Output	True when the 25A element is decreasing voltage.
Raise Voltage	Output	True when the 25A element is increasing voltage.
Sync In Progress	Output	True when the 25A has been initiated and is not inhibited. The 25A is inhibited when the Source 1 or Source 2 voltage is less than 10 V or 15 Hz.
Sync Fail	Output	A ¼-cycle pulse, true when the breaker is still open after maximum close attempts.

Name	Logic Function	Purpose
Voltage Synced	Output	True when the voltage magnitude between sources is less than or equal to the Voltage Difference setting. If the Source 1 Voltage > Source 2 Voltage setting is enabled, the Source 1 voltage must be at least 0.5% greater than the Source 2 voltage.
Angle Synced	Output	When in PLL mode, true when the angle between the sources is less than the Breaker Close Angle setting. When in Anticipatory mode, true when the angle between the sources is equal to the advance angle value (calculated from slip frequency and breaker closing time).
Slip Synced	Output	True when the frequency error between sources is less than the Slip Frequency setting. If the Source 1 Frequency > Source 2 Frequency setting is enabled, the Source 1 frequency must be higher than the Source 2 frequency.
Initiated	Output	True when the 25A has been initiated.

Operational Settings

Synchronizer element operational settings are configured on the Synchronizer (25A) settings screen (Figure 43-4) in BESTCOMS*Plus*.

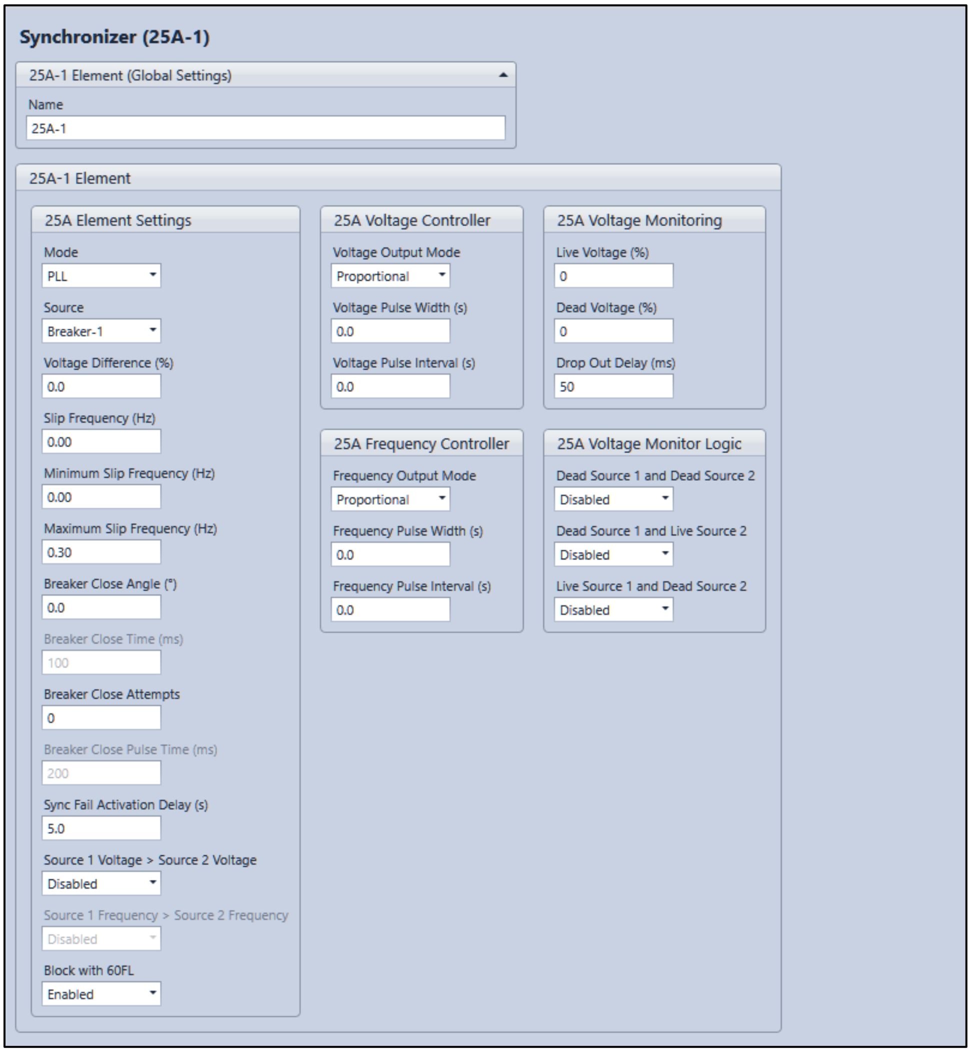


Figure 43-4. Synchronizer Settings Screen

44 • Virtual Control Switch (43)

Virtual control switch (43) elements provide manual control, locally and remotely, without using physical switches and/or interposing relays.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Virtual Control Switch (43) settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Control, Virtual Control Switch (43)

Element Operation

Virtual control switches can emulate virtually any type of binary (two-position) switch. An example would be an application that requires a ground cutoff switch. The traditional approach might be to install a switch on the panel and wire the output to a contact sensing input on the BE1-FLEX or in series with the ground trip output of the BE1-FLEX. Instead, a virtual control switch can be used to reduce costs with the added benefit of being able to operate the switch both locally through the front panel and remotely from a substation computer or through an Ethernet connection to a remote operator's console.

Mode

Three operating modes are available: Switch/Pulse, Switch, and Pulse. Because switch status information is saved in nonvolatile memory, the BE1-FLEX powers up with the switches in the same state as when the BE1-FLEX was powered down.

Switch/Pulse Mode

In Switch/Pulse mode, each switch can be controlled to reset, set, or pulse. Assertion of the Set input forces the output to set (logic 1). Assertion of the Reset input forces the output to reset (logic 0). Assertion of the Pulse input toggles the virtual output from its current state to the opposite state for 200 ms then back to the original state. An additional Hold Time can be set when the virtual output is connected to a physical output in BESTlogic*Plus* via the Output Hold setting. See *Outputs* in the *Power System Configuration* chapter for more information.

Switch Mode

In Switch mode, the switch emulates a two-position selector switch, and only set and reset commands are accepted. Assertion of the Set input forces the output to set (logic 1). Assertion of the Reset input forces the output to reset (logic 0).

Pulse Mode

In Pulse mode, a momentary close, spring-return switch is emulated and only the pulse command is accepted. When true, the Pulse input toggles the output's state in 200 millisecond intervals until the Pulse input becomes false. To create a single pulsed output, use an Edge Trigger into the Pulse input. An additional Hold Time can be set when the virtual output is connected to a physical output in BESTlogic*Plus* via the Output Hold setting. See *Outputs* in the *Power System Configuration* chapter for more information.

Customized LED Colors

Control switch status and operation confirmation is beneficial information from both the local HMI or BESTCOMS*Plus* interface as well as remotely. User specified colors can be assigned to both states of each switch (Off and On). Available colors include red, green, blue, yellow, orange, and grey/off (unlit).

Customized Labels

User-specified labels can be assigned to each virtual switch and to both states of each switch. The labels can be up to 64 characters long. In the previous ground cutoff switch example, you may enable one of the switches in the Switch mode and connect the output of that switch to the blocking input of a 59 protection element. This would disable the ground overvoltage protection when the switch is closed (logic 1) and enable it when the switch is open (logic 0). For the application, you may set the switch label to be 59N CUTOFF. The closed position of the switch may be labeled DISABLED and the open position may be labeled NORMAL.

Control of Virtual Control Switches

The state of the virtual control switches can be controlled using the touchscreen, through BESTCOMS*Plus*, and various communication protocols such as Modbus® and DNP. Perform the following steps to control a switch using BESTCOMS*Plus*:

1. Use the Metering Explorer to open the Control, Virtual Switch tree branch (Figure 44-1).
2. If Switch/Pulse mode is selected on the Virtual Control Switch (43) settings screen in BESTCOMS*Plus*, use the drop-down box to select either Switch or Pulse.
3. Click the 43 button to operate it. Login may be required. The indicator will change to the color selected on the Virtual Control Switch settings screen and display “Off” or “On”.

Figure 44-1. Virtual Switch Control Screen

Tagging of Virtual Control Switches

Virtual control switches provide tagging for each switch to indicate that the switch function is, or may be, under revision. When a Block Tag is set, the switch is not operational.

Tagging of virtual control switches can be accomplished through the touchscreen, through BESTCOMS*Plus*, and various communication protocols such as Modbus® and DNP. Use the Metering Explorer in BESTCOMS*Plus* to open the Control, Virtual Switch tree branch and click on the Set button. If tagging is successful, the indicator to the right of the Set button will turn green. A tagged switch is indicated by an amber indicator in the upper right corner of the element button. Click on the Reset button to clear a tag. Refer to Figure 44-1.

Each tag is placed with an “owner”. A tag must be removed by the same “owner” that placed it. Owners are HMI, Logic, and Remote. For example, if a remote tag is placed through BESTCOMS*Plus*, it can be removed only through BESTCOMS*Plus* or another remote interface such as Modbus. It cannot be removed through the front panel HMI or through logic. If a tag is placed through the front panel, it can be removed only through the front panel.

A Block Tag alarm indicates when a block tag is in place. Refer to the *Alarms* chapter for information on how to program alarms.

Logic Connections

Virtual control switch element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The virtual control switch element logic block is illustrated in Figure 44-2. Logic inputs and outputs are summarized in Table 44-1.

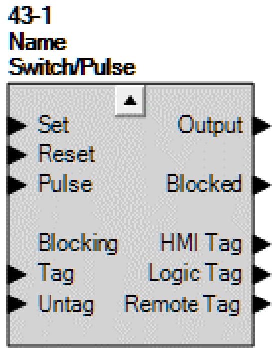


Figure 44-2. Virtual Control Switch Element Logic Block

Table 44-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Set	Input	Sets the state of the output to true
Reset	Input	Sets the state of the output to false
Pulse	Input	Momentarily changes state of the output
Blocking Tag	Input	Sets a blocking tag on the 43 element
Blocking Untag	Input	Removes the blocking tag from the 43 element
Output	Output	True when the 43 element is set
Blocked	Output	True when the 43 element is blocked
HMI Tag	Output	True when the 43 element has been tagged through the HMI
Logic Tag	Output	True when the 43 element has been tagged through logic
Remote Tag	Output	True when the 43 element has been tagged through communications

Operational Settings

Virtual control switch element operational settings are configured on the Virtual Control Switch (43) settings screen (Figure 44-3) in BESTCOMS*Plus*.

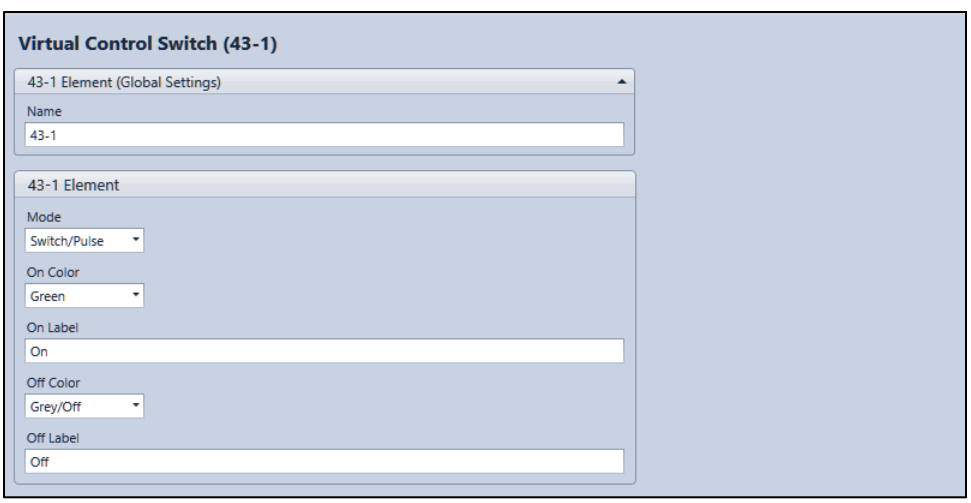


Figure 44-3. Virtual Control Switch Settings Screen

45 • Logic Timers (62)

Logic timer (62) elements provide timing of various types that are commonly used in power system applications.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Logic Timer (62) settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Control, Logic Timer (62)

Element Operation

Each timer has two time delay settings. The duration of the timers is established by the Time Delay 1 (T1) setting and the Time Delay 2 (T2) setting. With the exception of Oscillator mode, assertion of the Initiate input starts the timing sequence.

The functioning of the output is dependent upon the type of timer as specified by the mode setting. In BESTlogic*Plus*, the output can be connected to other logic elements or a physical relay output to alert the operator of a condition. If a target is enabled for the element, the BE1-FLEX will record a target when the output becomes true. See the *Fault Reporting* chapter for more information about target reporting.

Mode

Six operating modes are available: Pickup/Dropout, One-Shot/Non-Retriggerable, One-Shot/Retriggerable, Oscillator, Integrating Timer, and Latched.

Pickup/Dropout Mode

The output changes to logic true if the Initiate input is true for the Duration of Pickup Time Delay (T1). See Figure 45-1. If the Initiate input toggles to false before time T1, the T1 timer is reset. Once the output of the timer toggles to true, the Initiate input must be false for the Duration of Dropout Time Delay (T2). If the Initiate input toggles to true before time T2, the output stays true and the T2 timer is reset.

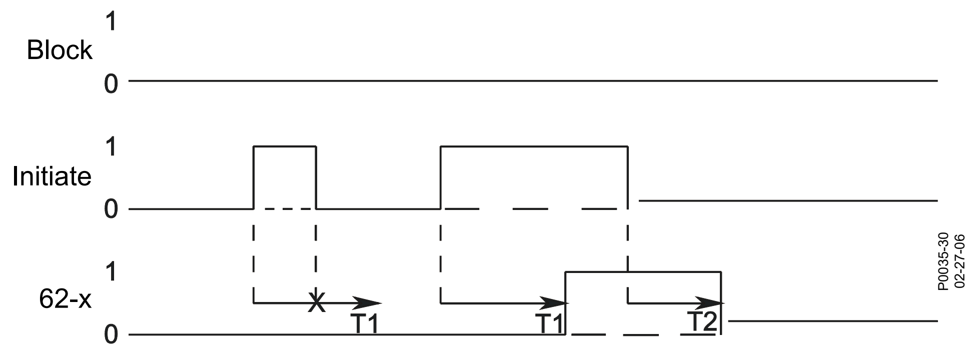


Figure 45-1. Pickup/Dropout Mode

One-Shot/Non-Retriggerable Mode

The one-shot nonretriggerable timer starts its timing sequence when the Initiate input changes from false to true. See Figure 45-2. The timer will time for Delay Time (T1) and then the output will toggle to true for Duration Time (T2). Additional initiate input changes of state are ignored until the timing sequence is completed. If the T2 timer is set to 0, this timer will not function. The timer will return to false if the Block input becomes true.

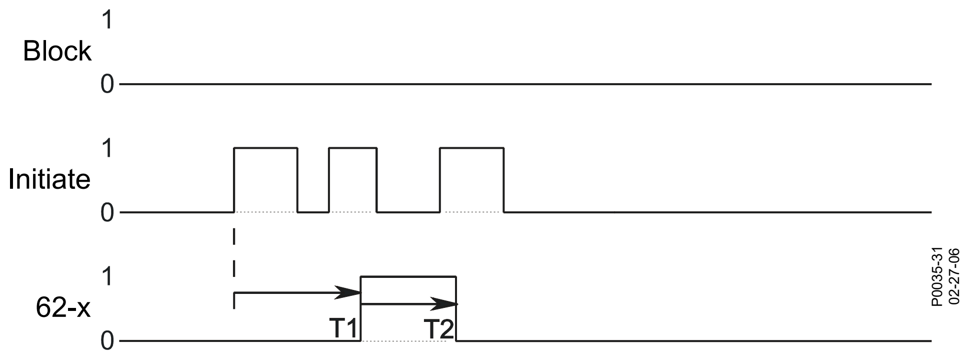


Figure 45-2. One-Shot/Non-Retriggerable Mode

One-Shot/Retriggerable Mode

The one-shot retriggerable timer starts its timing sequence when the Initiate input changes from false to true. See Figure 45-3. The timer will time for Delay Time (T1) and then the output will toggle to true for Duration Time (T2). Additional initiate input changes of state are ignored until the timing sequence has been completed. If a new false-to-true transition occurs on the Initiate input, the output is forced to logic false and the timing sequence is restarted. If the T2 timer is set to 0, this timer will not function. The timer will return to false if the Block input becomes true.

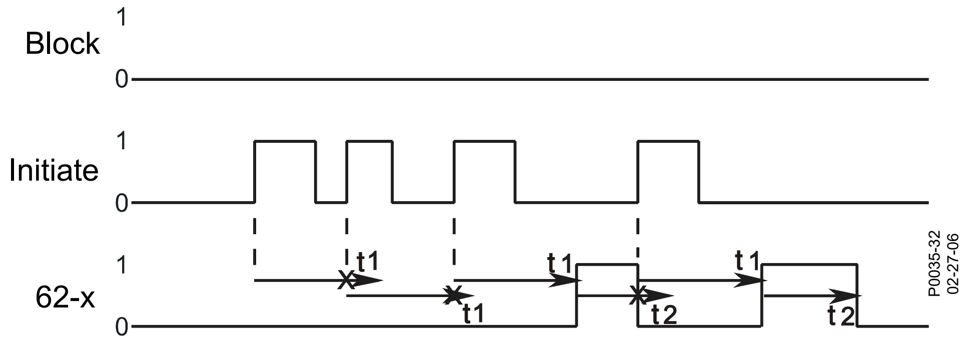


Figure 45-3. One-Shot/Retriggerable Mode

Oscillator Mode

In this mode, the Initiate input is ignored. See Figure 45-4. If the Block input is false, the output oscillates with an ON time (T1) and an OFF time (T2). When the Block input is held true, the oscillator stops and the output is held off.

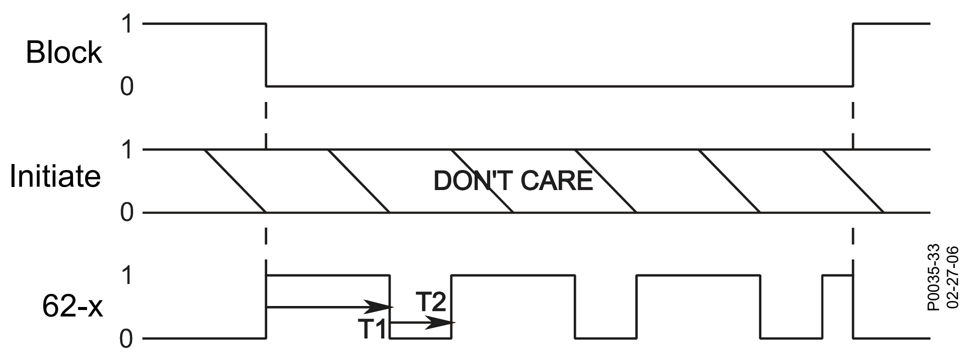


Figure 45-4. Oscillator Mode

Integrating Timer Mode

An integrating timer is similar to a pickup/dropout timer except that the Pickup Time (T1) defines the rate that the timer integrates toward timing out and setting the output to true. Conversely, the Reset Time (T2) defines the rate that the timer integrates toward dropout and resetting the output to false. T1 defines the time delay for the output to change to true if the initiate input becomes true and stays true. T2 defines the time delay for the output to change to false if it is presently true and the initiate input becomes false and stays false.

In the example shown in Figure 45-5, T2 is set to half of the T1 setting. The initiate input becomes true and the timer starts integrating toward pickup. Prior to timing out, the Initiate input toggles to false and the timer starts resetting at twice the rate as it was integrating toward time out. It stays false long enough for the integrating timer to reset completely but then toggles back to true and stays true for the entire duration of time T1. At that point, the timer's output is toggled to true. Then later, the initiate Input becomes false and stays false for the duration of T2. At that point, the output of the timer is toggled to false.

This type of timer is useful in applications where a monitored signal might be hovering at its threshold between on and off. For example, it is desired to take some action when current is above a certain level for a certain period. An instantaneous overcurrent (50) element could be used to monitor the current level. Thus, if the current level is near the threshold so that the Initiate input toggles between true and false from time to time, the function will still time out as long as the time that it is true is longer than the time that it is false. With a simple pickup/dropout timer, the timing function would reset to zero and start over each time the Initiate input became false.

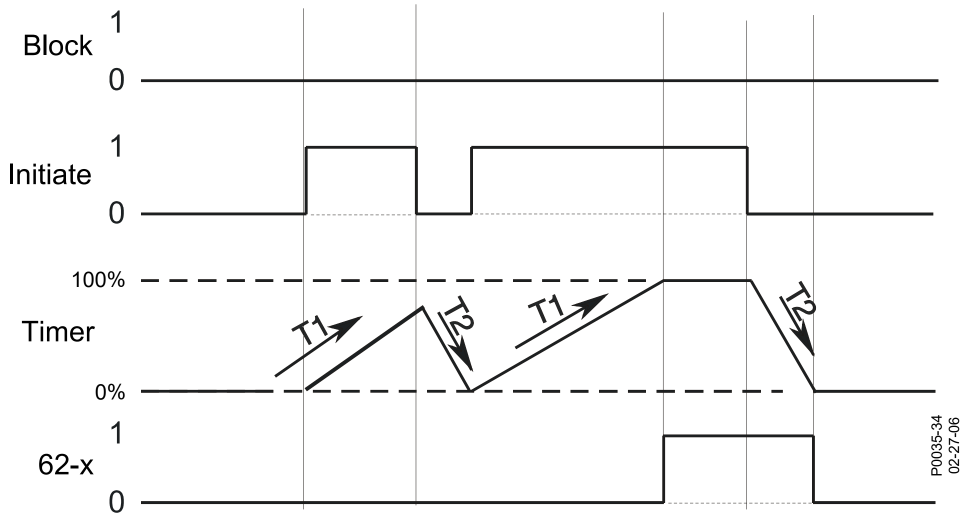


Figure 45-5. Integrating Timer Mode

Latched Mode

A one shot timer starts its timing sequence when the Initiate input changes from false to true. The timer will operate for Delay Time (T1) and then the output will latch true. The latched output will reset to false when the block input is true. Additional Initiate input changes of state are ignored. Time (T2) is ignored. Refer to Figure 45-6.

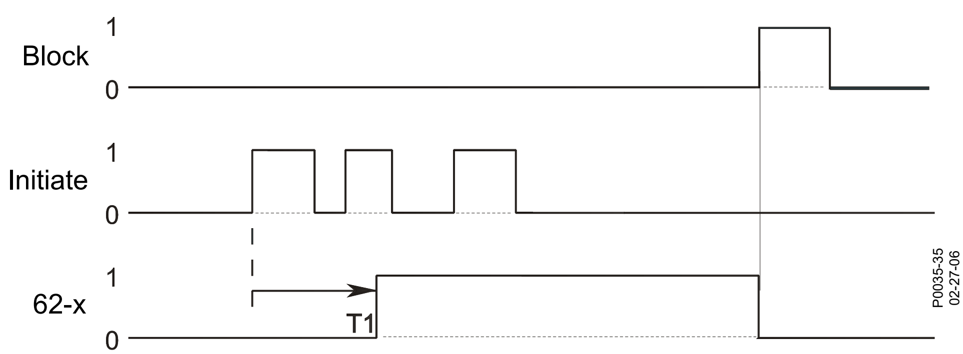


Figure 45-6. Latched Mode

Element Blocking

The Block input provides logic-supervision control of the element. When true, the Block input disables the element by forcing the element output to logic 0 and resetting the element timer. Connect the element

Block input to the desired logic in BESTlogic*Plus*. When the element is initially selected from the Elements view, the default condition of the Block input is a logic 0.

Logic Connections

Logic timer element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The logic timer element logic block is illustrated in Figure 45-7. Logic inputs and outputs are summarized in Table 45-1.

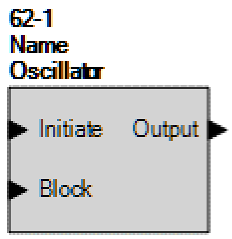


Figure 45-7. Logic Timer Element Logic Block

Table 45-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Initiate	Input	Starts the 62 timing sequence
Block	Input	Disables the 62 function when true
Output	Output	True when 62 timing criteria have been met according to mode

Operational Settings

Logic timer element operational settings are configured on the Logic Timer (62) settings screen (Figure 45-8) in BESTCOMS*Plus*.

Figure 45-8. Logic Timer Settings Screen

Viewing Logic Timer Status

Logic timer status can be viewed through BESTCOMS*Plus*, the front-panel display, and the web page interface.

To view logic timer status using BESTCOMS*Plus*, use the Metering Explorer to open the Status, Logic Timer (62) screen shown in Figure 45-9. To view logic timer status from the front-panel display, navigate to Metering, Status, Logic Timer (62).

Figure 45-9. Logic Timer Status Screen

46 • Recloser (79)

The recloser (79) element automatically recloses circuit breakers, which have been tripped by protective relays or other devices in power transmission and distribution systems.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Recloser (79) screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs, operational settings, and an overall logic diagram appears at the end of this chapter.

Navigation Path: Control, Recloser (79)

Element Operation

The recloser protection (79) element provides up to four reclosing attempts. The reclosers allow supervisory control and coordination of tripping and reclosing with other system devices.

Fault Recorder

When the Fault Recorder setting is enabled, recording starts when the Pickup output becomes true. Pre-fault cycles are included per the fault recording settings described in the *Fault Reporting* chapter.

Modes of Operation

Two modes of operation are available: Power Up to Lockout and Power Up to Reclose.

Power Up to Lockout

When power is lost during a reset condition, the BE1-FLEX goes to lockout after power is restored.

Power Up to Reclose

When power is lost during a reset condition, the BE1-FLEX initiates a first programmed reclose after power is restored if the breaker is open (52b) and the Initiate input of the 79 element is true.

Inputs and Outputs

Logic inputs and outputs are described in the following paragraphs.

Initiate Input

The Initiate input is used with the Breaker Status logic element to start the reclose timers at each step of the reclosing sequence. To start the automatic reclose timers, the Initiate input must be true and the Breaker Status logic input must be false. To ensure that the Initiate input is recognized, a recognition dropout timer holds the Initiate input true for approximately 225 milliseconds after it goes to a false state. This situation may occur if the Initiate is driven by the trip output of a protective function. As soon as the breaker opens, the protective function will drop out. The recognition dropout timer ensures that the Initiate signal will be recognized as true even if the breaker status input is slow in indicating breaker opening. Information on setting up the breaker status logic can be found in the *Power System Configuration* chapter. Figure 46-1 illustrates the recognition dropout logic and timing relationship.

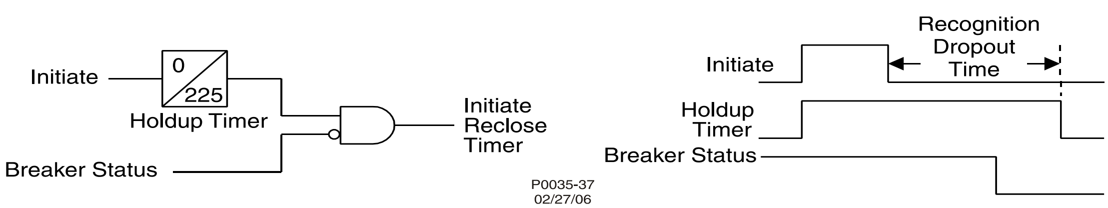


Figure 46-1. Recognition Dropout Timing

DTL (Drive to Lockout) Input

When true, the DTL input forces the reclosing function into the Lockout position. Lockout persists for the period defined by the Reset Time after the DTL input becomes false and the breaker is closed.

Wait Input

A true signal at the Wait input pauses the reclosing function. In this condition, recloser timing is interrupted. When this input returns to a false state, reclosing is enabled and recloser timing resumes.

Pilot Initiate Input and Pilot Output

If the recloser is in the reset state upon receiving a pilot initiate input signal, the reclose logic issues a pilot output after the programmed time delay. The initiate logic shall be held for 100 ms to ensure that it will be there when the Breaker Status input and the Pilot Initiate input are compared. If the recloser is in the reset state and the Pilot Initiate and Initiate inputs are received simultaneously with the breaker status open, the pilot timer shall be initiated instead of the first reclose timer. After the pilot timer expires, only the Initiate input is monitored to start the delayed reclosing sequence if the Breaker Status input indicates that the breaker opened before the reset time has expired.

Upon a trip, when the recloser is in reset, the pilot time delay is non-zero, and the first reclose time delay is zero, a reclose initiate causes the relay to use the second reclose time delay instead of the first.

Zone Pickup and Zone Trip Inputs

To coordinate tripping and reclosing sequences with downstream protective relays and reclosers, the BE1-FLEX senses fault current from downstream faults when a user programmable logic of the Zone setting picks up and then drops out without a trip output. Typically, the low-set instantaneous Pickup output (phase or neutral) or the inverse time overcurrent Pickup output (phase or neutral) is used for the zone sequence settings.

If the upstream device (BE1-FLEX) senses that a downstream device has interrupted fault current, the BE1-FLEX will increment the trip/reclose sequence by one operation. This occurs because the BE1-FLEX recognizes that a non-blocked low set (50 phase or neutral) element picked up and reset before timing out to trip.

Recloser zone-sequence coordination detects when a downstream recloser has cleared a fault and increments the upstream 79 automatic reclose count to maintain a consistent count with the other recloser. A fault is presumed cleared downstream when one or more protective functions pickup and dropout with no trip occurring. If the Zone Pickup logic becomes true and then false without a trip output operating, then the 79 automatic reclose counter should be incremented. The Max Cycle timer resets the shot counter.

Close Output

The Close output becomes true at the end of each reclose time delay and remains true until the breaker closes. Any of the following conditions will cause the Close output to become false (before the breaker close signal (52a) becomes true):

- The reclose fail timer times out.
- The recloser goes to lockout.
- The Wait logic is asserted.

Reset Output

The Reset output provides reset indication and is true when the recloser is in the Reset position.

Running Output

The Running output is true when the recloser is running (i.e., not in reset or lockout). This output is available to block the operation of a load tap changer on a substation transformer or voltage regulator during the fault clearing and restoration process.

Fail Alarm Output

The Fail Alarm output becomes true after the Fail Time has expired.

Lockout Output

The Lockout output is true when the recloser is in the Lockout state. It remains true until the recloser goes to the Reset state due to the reset timer. The recloser will go to lockout if any of the following conditions exist:

- More than the maximum number of programmed recloses is initiated before the recloser returns to the Reset state.
- The DTL input is true.
- The Reclose Fail (Fail Alarm output) is true.
- The maximum reclose cycle time is exceeded.

SCB (Sequence Controlled Blocking) Output

The SCB output becomes true when either the Breaker Status or the Close input is true and the sequence operation (shot counter) matches one of the programmed steps of the SCB function. Figure 46-2 illustrates SCB logic.

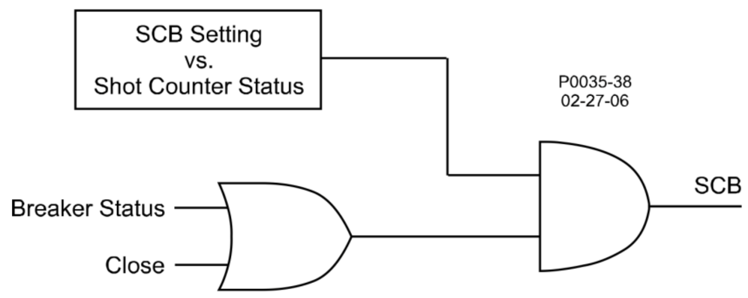


Figure 46-2. 79SCB Logic

Reclose Shots 1 through 4 Outputs

A Shot # output becomes true when the Shot # is actively timing.

Reclosing Fail Timer

This timer begins when the Close output becomes true and continues counting until the Breaker Status becomes true. If the Fail Time delay times out, the recloser function is driven to lockout and the Lockout output becomes true. The BE1-FLEX remains in lockout until the breaker is manually closed and the Breaker Status remains true for the reset time. The reset time is set on the Recloser screen in BESTCOMS*Plus*.

Maximum Cycle Timer (MAX Cycle)

Max Cycle is the reclose maximum operation time. If a reclose operation is not completed before the maximum operate time expires, the recloser goes to lockout. This timer limits the total fault clearing and restoration sequence to a definable period. The Max Cycle timer stops when the recloser is reset. If the total reclosing time between Reset states exceeds the maximum reclose cycle timer setting, the recloser will go to lockout. If not desired, the Max Cycle timer can be disabled by setting it at zero (0). The Wait input does not pause the Max Cycle timer. The maximum cycle time is set on the Recloser screen in BESTCOMS*Plus*.

Sequence Controlled Blocking (SCB)

The SCB output is true when breaker status is closed or the Close output is true and the reclose sequence step is enabled. This setting can be changed on the Recloser settings screen in BESTCOMS*Plus*.

Figure 46-3 shows a logic timing diagram showing all possible sequence controlled blocks enabled (true). In Figure 46-4, 79RTD is the reclose reset time delay and 79#TD is the reclose time delay where # is the reclose shot number.

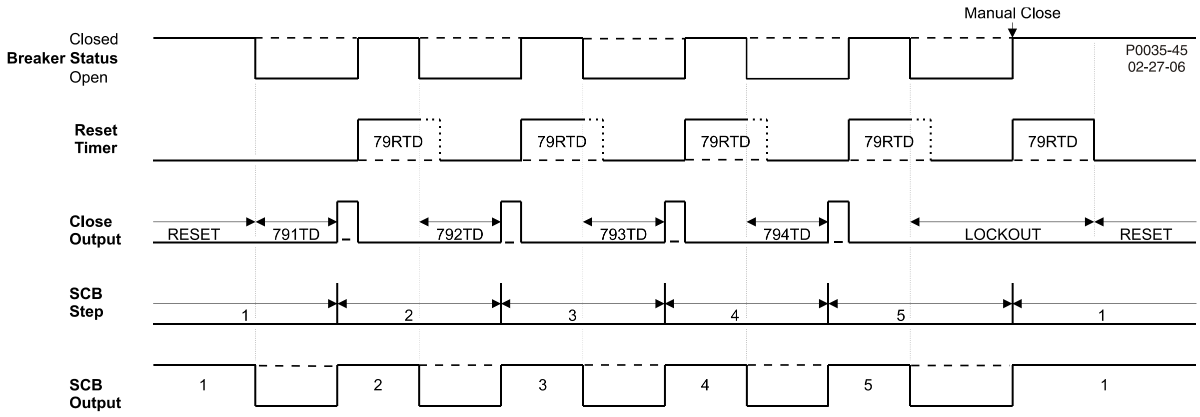


Figure 46-3. SCB=1/2/3/4/5 Logic Timing Diagram

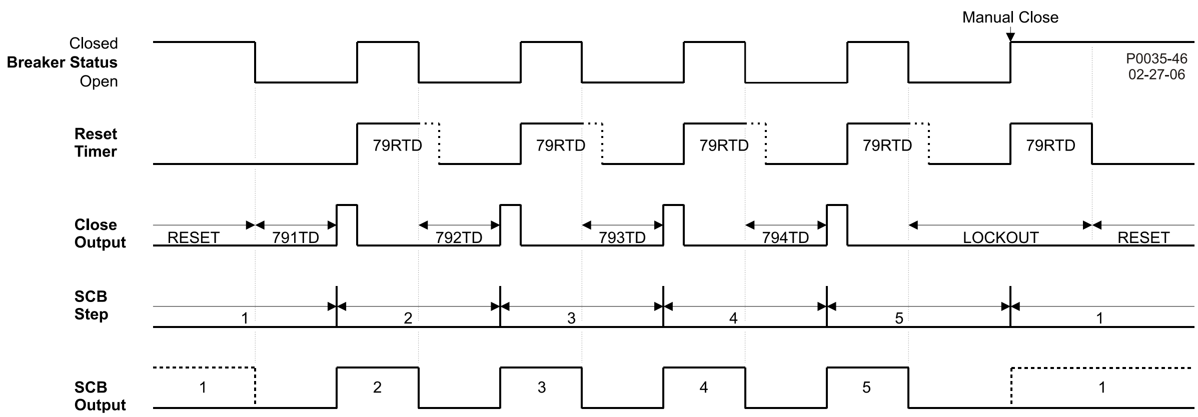


Figure 46-4. SCB=2/3/4/5 Logic Timing Diagram

Setting Group Selection

Any of the four recloser shots can be used to select a different setting group when the appropriate shot is reached in a reclosing sequence in logic. This change in setting groups allows changing protection coordination during the reclosing sequence. For example, you could have a fast 51 curve on the first two trips in the reclosing sequence and then switch to a new group on the second reclose that uses a slow 51 curve. Detailed information about BE1-FLEX setting groups can be found in the *Setting Groups* chapter.

Logic Connections

Recloser element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The recloser element logic block is illustrated in Figure 46-5. Logic inputs and outputs are summarized in Table 46-1.

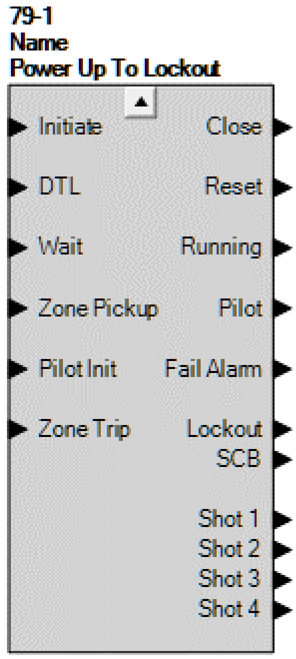


Figure 46-5. Recloser Element Logic Block

Table 46-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Initiate	Input	Initiates the operation of the reclosing function
DTL	Input	Disables the recloser (Drive To Lockout)
Wait	Input	Momentarily pauses, but does not reset the recloser
Zone Pickup	Input	Defines which logic elements should be considered zone sequence pickups
Pilot Initiate	Input	Initiates the Pilot function
Zone Trip	Input	Defines which logic elements should be considered zone sequence trips
Close	Output	True at the end of each reclose time delay and remains true until the breaker closes, wait initiate is true, or the recloser goes to lockout
Reset	Output	True when the recloser is in the Reset position
Running	Output	True when the reclose is running
Pilot	Output	True after the Pilot time delay has expired
Fail Alarm	Output	True after the Fail Time has expired
Lockout	Output	True when the recloser is in the Lockout state
SCB	Output	True when either the Breaker Status or the Close input is true and the sequence operation (shot counter) matches one of the programmed steps of the SCB function
Shots 1-4	Output	True when Shot # is active

Operational Settings

Recloser element operational settings are configured on the Recloser (79) settings screen (Figure 46-6) in BESTCOMS*Plus*.

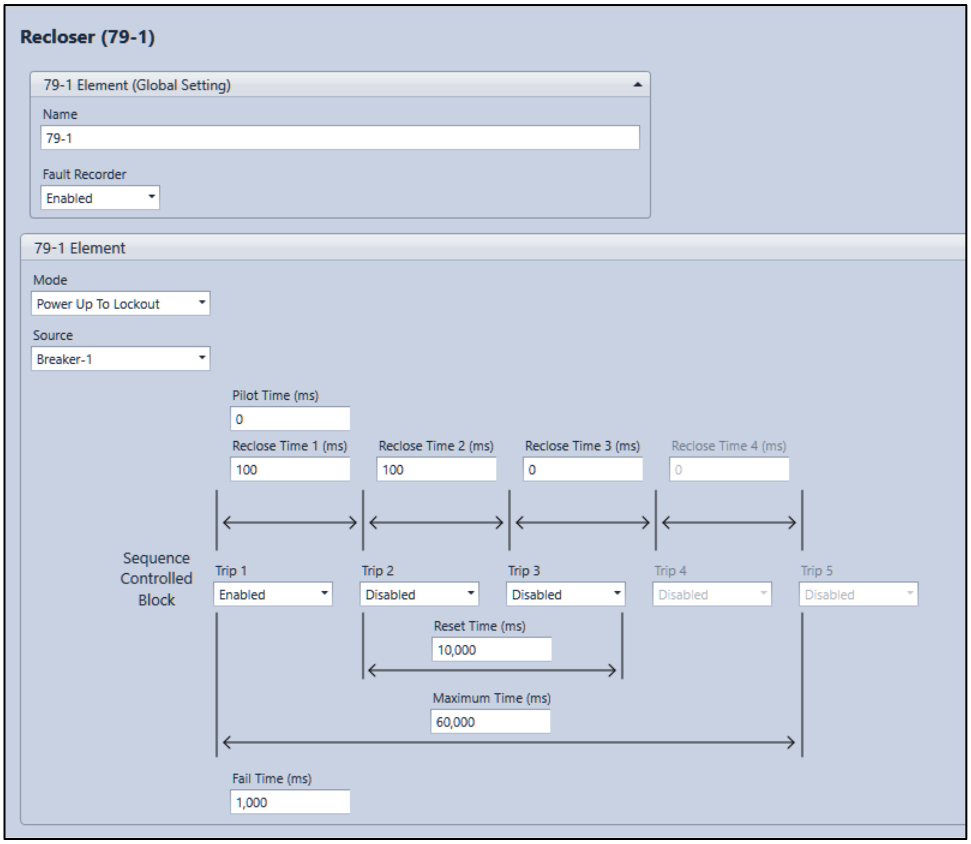


Figure 46-6. Recloser Settings Screen

Viewing Recloser Status

Recloser status can be viewed through BESTCOMS*Plus*, the front-panel display, and the web page interface.

To view recloser status using BESTCOMS*Plus*, use the Metering Explorer to open the Status, Recloser (79) screen shown in Figure 46-7. To view recloser status from the front-panel display, navigate to Metering, Status, Recloser.

Figure 46-7. Recloser Status Screen

Logic Diagram

Figure 46-8 illustrates an overall logic diagram for the recloser element.

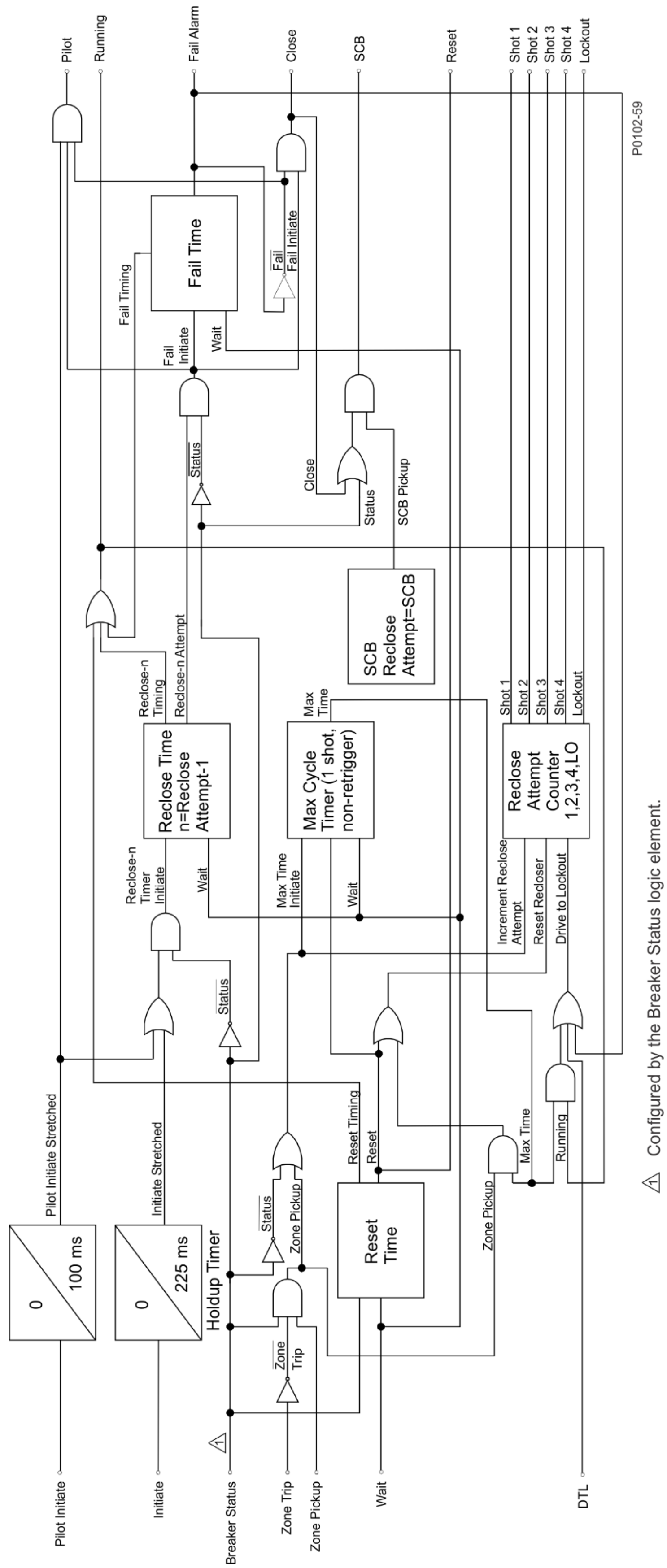


Figure 46-8. Overall Logic Diagram for Reclosing

47 • Virtual Lockout Function (86)

Virtual Lockout Function (86) elements can be used to prevent operation of circuit breakers or other devices until the condition causing lockout is eliminated.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Virtual Lockout Function screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Control, Virtual Lockout Function (86)

Element Operation

A lockout function is commonly applied to breaker control. When the Set input is asserted, the output of the function becomes latched true. The breaker trips open and is held open by the latched output. The output remains true until the Reset input is asserted. The output then becomes false. The breaker is now allowed to close. If both inputs are asserted at the same time, the Set input will have priority and drive the output to true. The state of the function is stored in nonvolatile memory.

Logic Connections

Virtual lockout function element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The virtual lockout function element logic block is illustrated in Figure 47-1. Logic inputs and outputs are summarized in Table 47-1.

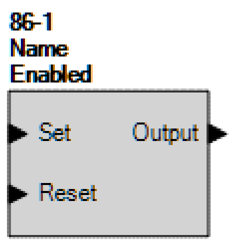


Figure 47-1. Virtual Lockout Function Element Logic Block

Table 47-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Set	Input	Sets the state of the output to true
Reset	Input	Sets the state of the output to false
Output	Output	True when the Set input is asserted

Operational Settings

Lockout function element operational settings are configured on the Lockout Function (86) settings screen (Figure 47-2) in BESTCOMS*Plus*.

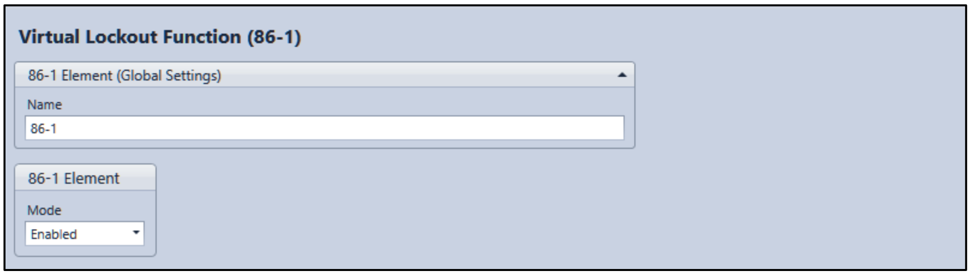


Figure 47-2. Virtual Lockout Function Settings Screen

Viewing Lockout Status

Lockout status can be viewed through BESTCOMS*Plus*, the front-panel display, and the web page interface.

To view virtual lockout status using BESTCOMS*Plus*, use the Metering Explorer to open the Status, Virtual Lockout Function (86) screen shown in Figure 47-3. To view lockout status from the front-panel display, navigate to Metering, Status, Virtual Lockout Function (86).

Figure 47-3. Virtual Lockout Function Status Screen

48 • Breaker Control Switch (101)

Breaker control switch (101) element provides manual control of a circuit breaker or switch without using physical switches or interposing relays. Both local and remote control is possible. A virtual switch can be used instead of a physical switch to reduce costs with the added benefit that the virtual switch can be operated both locally from the front panel and remotely from a substation computer or Ethernet connection to an operator's console.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and element operational settings are configured on the Breaker Control Switch (101) settings screen in BESTCOMS*Plus*. A summary of the logic inputs and outputs and operational settings appears at the end of this chapter.

Navigation Path: Control, Breaker Control Switch (101)

Element Operation

The breaker control switch emulates a typical breaker control switch with a momentary close, spring return, trip contact output (Trip), a momentary close, spring return, close contact output (Close), a trip slip contact output (TSC), and a close slip contact output (CSC). The trip slip contact output retains the status of the last trip control action. That is, it is true (closed) in the after-trip state and false (open) in the after-close state. The close slip contact output retains the status of the last close control action. It is false (open) in the after-trip state and true (closed) in the after-close state. Figure 48-1 shows the state of the TSC and CSC logic outputs with respect to the state of the Trip and Close outputs.

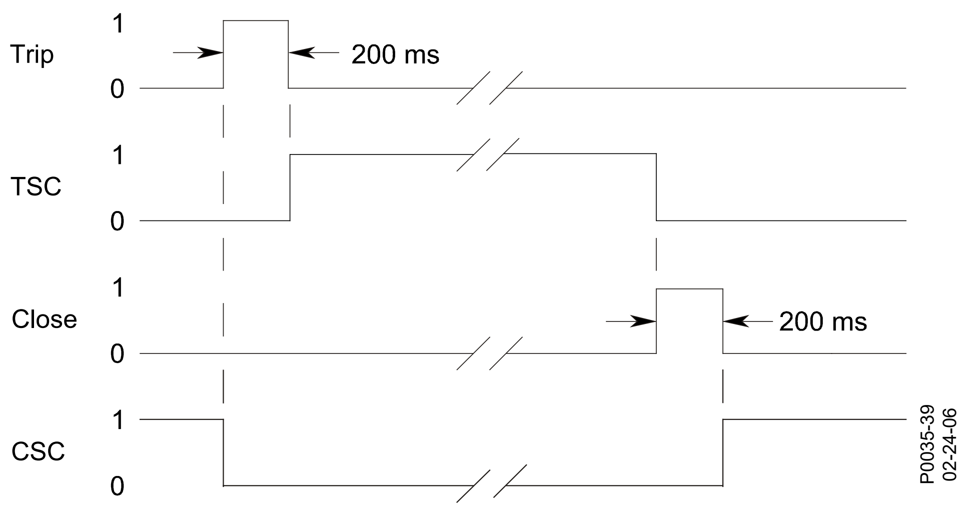


Figure 48-1. Breaker Control Switch State Diagram

When the breaker control switch is controlled to trip, the Trip output pulses true (closed) for approximately 200 milliseconds and the TSC output goes true (closed). When the breaker control switch is controlled to close, the CSC output pulses true (closed) and the TSC goes false (open). The status of the slip contact outputs is saved to nonvolatile memory so that the BE1-FLEX will power up with the contact in the same state as when the BE1-FLEX was powered down.

Customized LED Colors

Breaker control switch status and operation confirmation is beneficial information from both the local HMI or BESTCOMS*Plus* interface as well as remotely. User specified colors can be assigned to both states of each switch (Off and On). Available colors include red, green, blue, yellow, and orange.

Control of Breaker Control Switch

The state of virtual control switches can be controlled using the touchscreen, through BESTCOMS*Plus*, and various communication protocols such as Modbus® and DNP. Perform the following steps to control the switch using BESTCOMS*Plus*:

1. Use the Metering Explorer to open the Control, Breaker Control Switch tree branch (Figure 48-2).
2. Click on the Trip or Close button to operate it. Login may be required. The indicator next to *Trip* or *Close* will change to the color selected on the Virtual Control Switch settings screen.

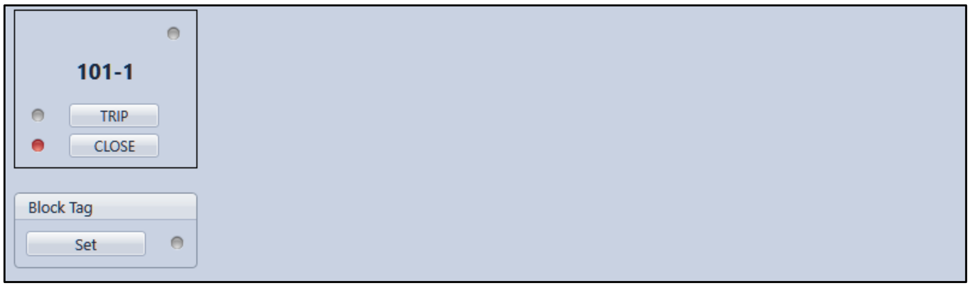


Figure 48-2. Breaker Control Switch Control Screen

Tagging of Breaker Control Switch

The breaker control switch provides tagging to indicate that the switch function is, or may be, under revision. When a Block Tag is set, the switch is not operational.

Tagging of the breaker control switch can be accomplished through the touchscreen, through BESTCOMS*Plus*, and various communication protocols such as Modbus® and DNP. Use the Metering Explorer in BESTCOMS*Plus* to open the Control, Breaker Control Switch tree branch and click on the Set button. If tagging is successful, the indicator to the right of the Set button will turn green. A tagged switch is indicated by an amber indicator in the upper right corner of the element button. Click on the Reset button to clear a tag.

Each tag is placed with an "owner". A tag must be removed by the same "owner" that placed it. Owners are HMI, Logic, and Remote. For example, if a remote tag is placed through BESTCOMS*Plus*, it can be removed only through BESTCOMS*Plus* or another remote interface such as Modbus. It cannot be removed through the front panel HMI or through logic. If a tag is placed through the front panel, it can be removed only through the front panel.

A Block Tag alarm indicates when a block tag is in place. Refer to the *Alarms* chapter for information on how to program alarms.

Logic Connections

Breaker control element logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The breaker control element logic block is illustrated in Figure 48-3. All logic inputs use rising-edge detection for recognition. Logic inputs and outputs are summarized in Table 48-1.

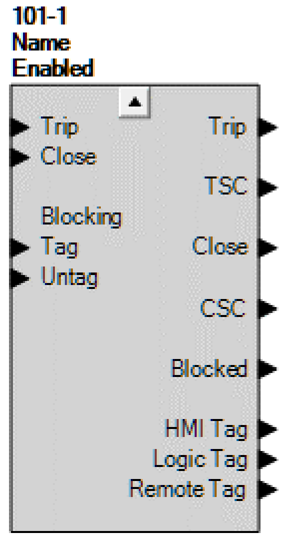


Figure 48-3. Breaker Control Element Logic Block

Table 48-1. Logic Inputs and Outputs

Name	Logic Function	Purpose
Trip	Input	Sets the state of the 101 element to Trip
Close	Input	Sets the state of the 101 element to Close
Blocking Tag	Input	Sets a blocking tag on the 101 element
Blocking Untag	Input	Removes the blocking tag from the 101 element
Trip	Output	True if the 101 element is in the Trip state
TSC	Output	True after the Trip output momentarily closes
Close	Output	True if the 101 element is in the Close state
CSC	Output	True after the Close output momentarily closes
Blocked	Output	True when the 101 element is blocked
HMI Tag	Output	True when the 101 element has been tagged through the HMI
Logic Tag	Output	True when the 101 element has been tagged through logic
Remote Tag	Output	True when the 101 element has been tagged through communications

Operational Settings

Breaker control element operational settings are configured on the Breaker Control Switch (101) settings screen (Figure 48-4) in BESTCOMS*Plus*.

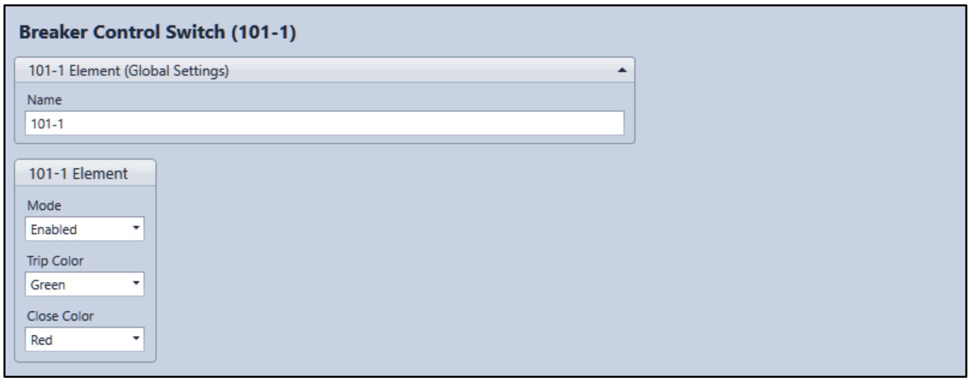


Figure 48-4. Breaker Control Switch Settings Screen

49 • Trip Circuit Monitor (52TCM)

A trip circuit monitor (52TCM) element continuously monitors a circuit breaker trip circuit for voltage and continuity. The BE1-FLEX is commonly configured with a 52TCM element for each Breaker instance configured in the device.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*® and the element enable setting is configured on the Breaker Monitor settings screen in BESTCOMS*Plus*.

Element Operation

A closed breaker with no voltage detected across the trip contacts can indicate that a trip circuit fuse is open or there is a loss of continuity in the trip coil circuit. The 52TCM element detects this condition and signals an alarm. In BESTlogic*Plus*, the Alarm output can be connected to other logic elements or a physical relay output to annunciate the condition and initiate corrective action.

Connections

This example uses configured Input 5 and Output 1. Any configured Input or Output can be configured for this functionality.

Wire jumpers to the rear of the device between IN5 and OUT1 as shown below.

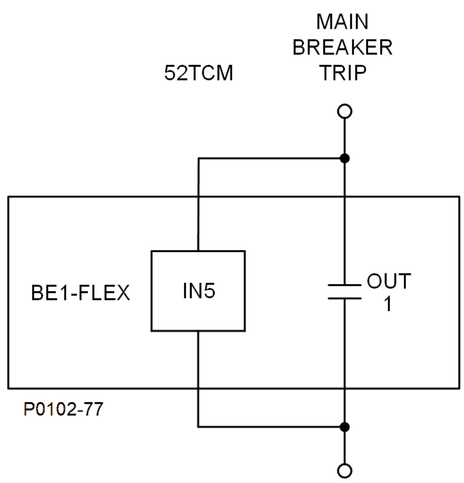


Figure 49-1. Trip Circuit Monitor Wiring Example

Breaker Status

Breaker status (open or closed) is obtained through the breaker status reporting function (configured by the Breaker Status logic block). Refer to the *Power System Configuration* chapter for more information.

Programmable Alarm

A 52 Trip Coil Monitor alarm occurs when the breaker status reporting function detects a closed breaker and no trip circuit voltage for the duration of a 500 ms coordination delay. The alarm appears on the front-panel display, web page interface, and on the Alarms metering screen in BESTCOMS*Plus*.

Input Burden

The input current depends on the contact sensing circuit burden and the applied voltage level. See the *Specifications* chapter for input burdens.

Caution

Applications that place other device inputs in parallel with the breaker trip coil may not perform as desired. The connection of other devices in parallel with the trip coil causes a voltage divider to occur when the breaker or trip circuit is open. This may cause false tripping of the other devices and prevent the BE1-FLEX trip circuit monitor from reliably detecting an open circuit. Contact Basler Electric for advice on this application.

Logic Connections

Trip circuit monitor logic connections are made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The breaker monitor element logic block is illustrated in Figure 49-2. The logic output is summarized in Table 49-1.

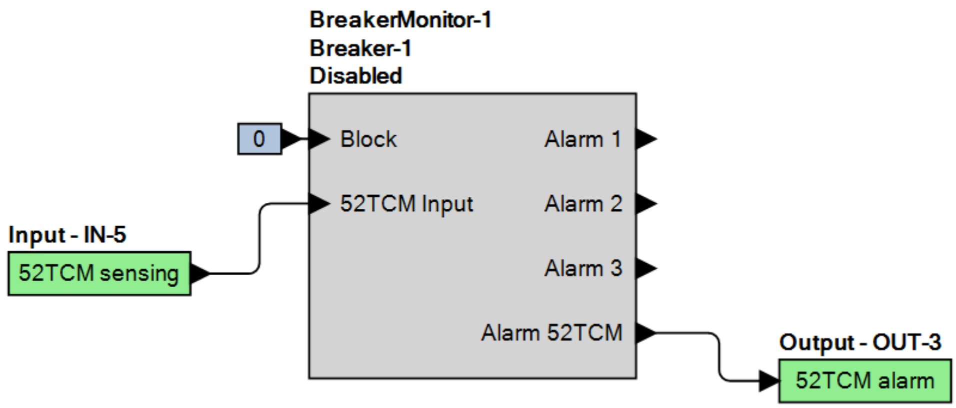


Figure 49-2. Breaker Monitor Logic Block

Table 49-1. Logic Output

Name	Logic Function	Purpose
52TCM Input	Input	Contact input assigned to monitor the trip circuit.
Alarm 1 through Alarm 3	Output	True when the user-defined breaker monitor thresholds have been exceeded.
Alarm 52TCM	Output	True when voltage is not detected in the trip circuit and the breaker is closed.

Operational Settings

Navigation Path: Configuration, Breaker Summary, Breaker Monitor

Trip circuit monitor element's Enable setting is configured on the Breaker Monitor settings screen (Figure 49-3) in BESTCOMS*Plus*.

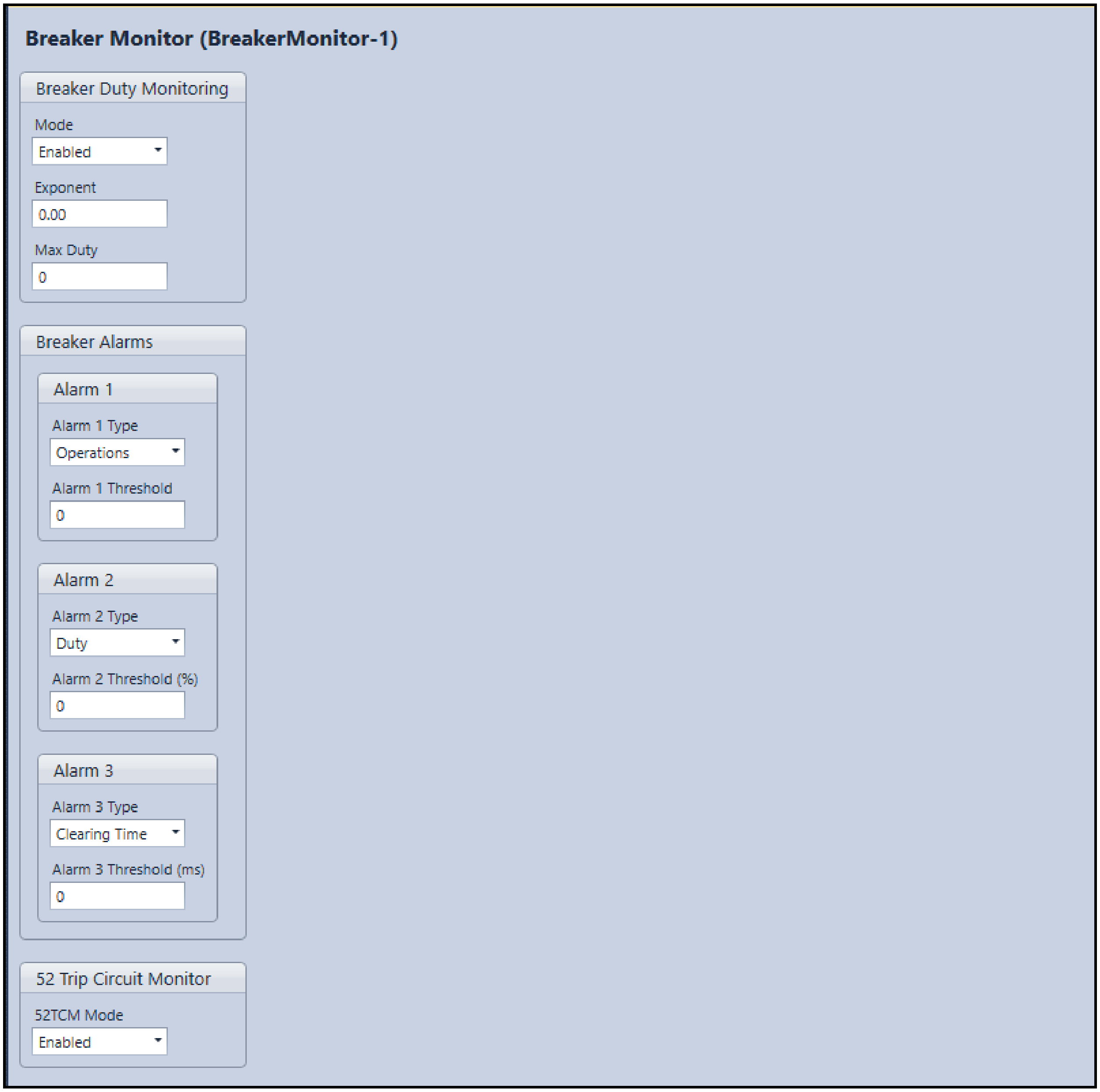


Figure 49-3. Breaker Monitor Settings Screen

50 • Fuse Loss (60FL)

The fuse loss (60FL) function detects fuse loss or loss of sensing potential in a three-phase system. It is utilized in voltage related protective functions to prevent false operation due to sensing issues.

Element logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*®. Each protective element that is related to the 60FL has a setting to utilize the 60FL logic block. When enabled on the protective element settings screen, the element will be blocked and not operational when the circuit detects a 60FL condition.

Element Operation

The 60FL element detects fuse loss and loss of potential by using voltage and current thresholds that are expressed as a percentage of the nominal voltage and current values. See the *Power System Configuration* chapter for information on changing the nominal voltage and current values.

Each Circuit has an independent 60FL function. When the 60FL element logic becomes true, the Fuse Loss output of that circuit becomes true. Elements with Source equal to the Circuit and Block with 60FL Enabled will be blocked when 60FL is true. A logic diagram is shown in Figure 50-1. Logic parameters are shown in Table 50-1.

Trip Logic: 60FL Trip = (A * C * G * J * P) + (E * F * G * J) (See Table 50-1.)

Reset Logic: 60FL Reset = H * /K */L (See Table 50-1.)

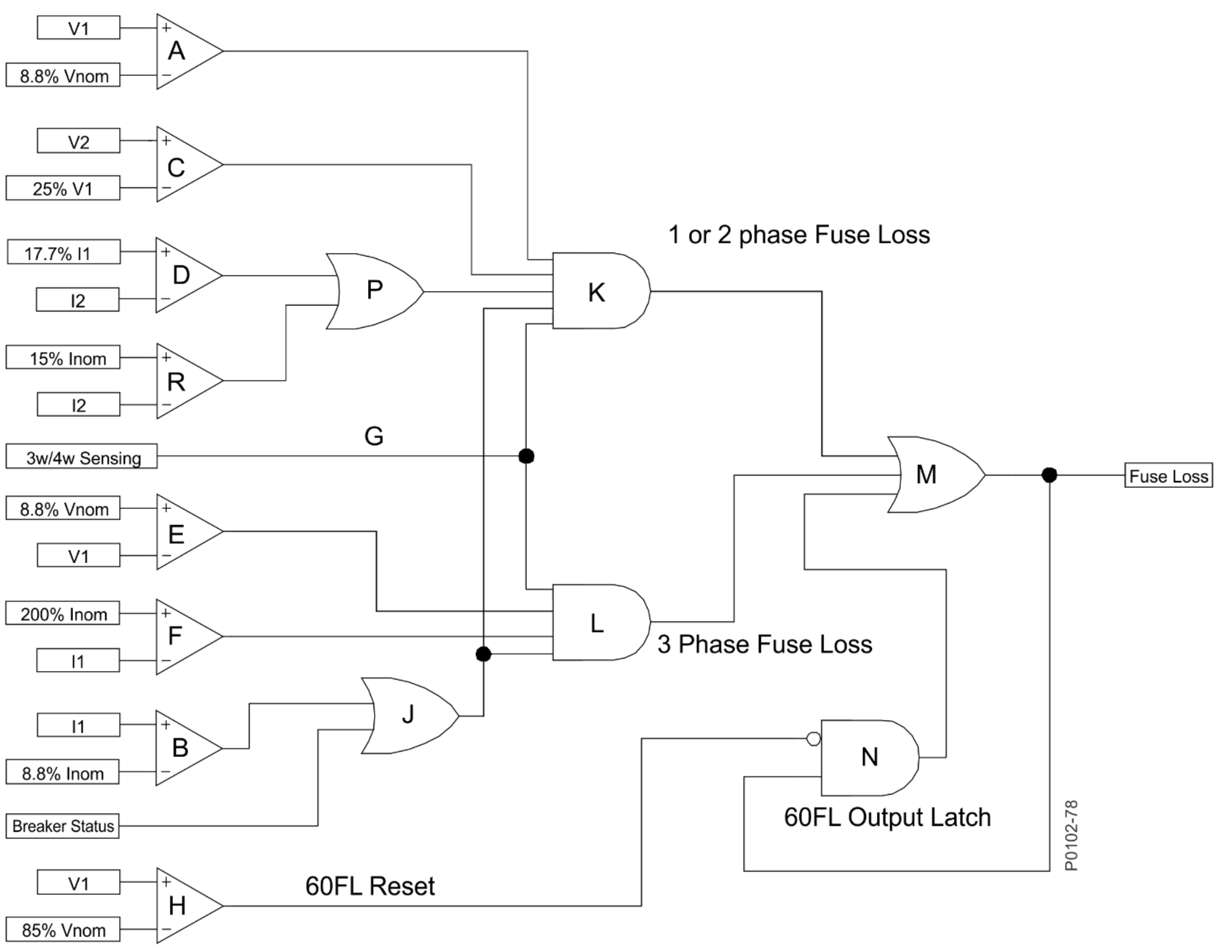


Figure 50-1. Fuse Loss Element Logic

Table 50-1. Fuse Loss Logic Parameters

Input	True Condition
A	Positive-sequence voltage greater than 8.8% of the nominal voltage; detects minimum voltage is applied.
B	Positive-sequence current greater than 8.8% of the nominal current; detects minimum current is applied.
C	Negative-sequence voltage greater than 25% of the positive-sequence voltage; detects loss of one or two phases of voltage.
D	Negative-sequence current less than 17.7% of the positive-sequence amperes; detects a normal current condition.
E	Positive-sequence voltage less than 8.8% of the nominal voltage; detects loss of three-phase voltage.
F	Positive-sequence current less than 200% of the nominal current; detects a normal load current condition.
G	Three-wire or four-wire sensing selected. 60FL is disabled when sensing is set otherwise.
H	Positive-sequence voltage greater than 85% of nominal voltage; detects a restored voltage condition.
J	(B + S); Detects breaker position and nominal current condition. See Circuit Logic Settings configuration in the *Power System Configuration* chapter for more details on breaker position setting.
K	(A * C * G * J * P); detects when either one or two phases are lost.
L	(E * F * G * J); detects when all three phases are lost.
M, N	Latches the 60FL output until the reset criteria are met.
P	(R+D); logical OR of comparators R and D to detect a normal current condition.
R	Negative-sequence current less than 15% of the nominal current; detects a normal current condition.
Breaker Status	Breaker Status is configured by the Breaker Status input of a Circuit logic node. Information on setting up the breaker status logic can be found in the *Power System Configuration* chapter.

In some applications, such as generators, Breaker Status is commonly ignored by the 60FL. In those applications where the current is too low to be sensed by I1>8.8%, the 60FL would be blocked. Therefore, it is not a false 60FL operation; it is a blocked 60FL, which in turn could result in false operation of voltage-based protection that is expecting the 60FL block. In other applications such as feeders, it is often desired to use Breaker Status to arm the 60FL anytime the breaker is closed. A 52a status into the Breaker Status input of the circuit will perform as described in the feeder application above. A Fixed or Logic 0 into the Breaker Status input will cause the 60FL to ignore the breaker status and instead require positive-sequence current greater than 8.8% nominal to arm the 60FL.

Function Blocking

Settings within each element determine if each 21P, 24, 25, 25A, 27, 32, 40Q, 40Z, 51V, 55, 59, 78OOS and 78V functions will operate when a fuse loss condition exists. Additional control can be set in logic with the 60FL output of a circuit. The Block Voltage Control (51/27) setting assumes that the voltage is V_{NOM} when Fuse Loss is true because the voltage measurement is not present or is unreliable. If the input voltage is nominal, then voltage restraint and control have no effect.

Note
Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to assure proper coordination of blocking.

Directional Supervision

Directional tests are also supervised by the fuse loss element. If the 60FL logic is true, then voltage sensing was lost or is unreliable. Under this condition positive, negative, and zero-sequence directional tests are disabled and their bits are cleared. There is no user setting to enable or disable this supervision. Current polarization is not affected by the 60FL since it does not rely on voltage sensing. Similarly, zero-sequence voltage polarization can be performed only if VT Connection in Power System VT Setup is set to 4W-Y (4 wire – WYE).

Programmable Alarm

The BE1-FLEX indicates an alarm condition when the 60FL element detects a fuse loss or loss of potential. The alarm appears on the front-panel display, web page interface, and on the Alarms metering screen in BESTCOMS*Plus*. The default setting for this alarm is Minor – Non-Latching. Refer to the *Alarms* chapter for information on how to program alarms.

Logic Connections

In addition to the 60FL Block in the protective elements, fuse loss logic connections can be made on the BESTlogic*Plus* screen in BESTCOMS*Plus*. The Circuit logic block is illustrated in Figure 50-2. The logic output is summarized in Table 50-2.

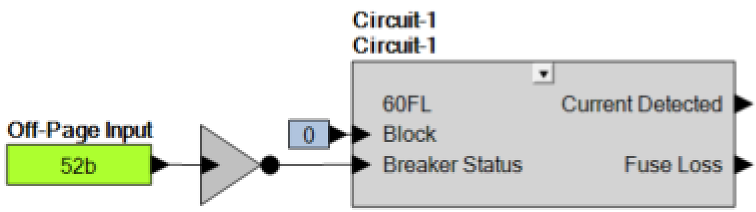


Figure 50-2. Fuse Loss Element Logic Block

Table 50-2. Logic Output

Name	Logic Function	Purpose
60FL – Block	Input	Prevents 60FL from blocking elements and inhibits the Fuse Loss output using the associated circuit
60FL – Breaker Status	Input	Provides Breaker Status for use within the 60FL element logic
Fuse Loss	Output	True when the 60FL logic is true

51 • BESTlogic™*Plus*

BESTlogic*Plus* Programmable Logic is a programming method used for managing the input, output, protection, control, monitoring, and reporting capabilities of the BE1-FLEX. Each BE1-FLEX has multiple, self-contained logic blocks that have all of the inputs and outputs of its discrete component counterpart. Each independent logic block interacts with control inputs and hardware outputs based on logic variables defined with BESTlogic*Plus*. BESTlogic*Plus* equations entered and saved in the BE1-FLEX system's nonvolatile memory integrate (electronically wire) the selected or enabled protection and control blocks with control inputs and hardware outputs. A group of logic equations defining the logic of the BE1-FLEX is called a logic scheme.

The BE1-FLEX does not contain any default logic. A logic scheme must be uploaded before placing the BE1-FLEX in service. BESTCOMS*Plus*® can be used to open a logic scheme that was previously saved as a file and upload it to the BE1-FLEX.

BESTlogic*Plus* is not used to define the operating settings (modes, pickup thresholds, and time delays) of the individual protection and control functions. Operating settings and logic settings are interdependent but separately programmed functions. Changing logic settings is similar to rewiring a panel and is separate and distinct from making the operating settings that control the pickup thresholds and time delays of a BE1-FLEX. Detailed information about operating settings is provided in each chapter of the various protection and control functions.

Caution

This product contains one or more *nonvolatile memory* devices. Nonvolatile memory is used to store information (such as settings) that needs to be preserved when the product is power-cycled or otherwise restarted. Established nonvolatile memory technologies have a physical limit on the number of times they can be erased and written. In this product, the limit is 20TBW (Terabytes Written). During product application, consideration should be given to communications, logic, and other factors that may cause frequent/repeated writes of settings or other information that is retained by the product. Applications that result in such frequent/repeated writes may reduce the useable product life and result in loss of information and/or product inoperability.

Overview of BESTlogic™Plus

BESTlogic*Plus* settings are made through BESTCOMS*Plus*. Use the Settings Explorer to open the BESTlogic*Plus* Programmable Logic tree branch as shown in Figure 51-1.

The BESTlogic*Plus* Programmable Logic screen contains a logic library for opening and saving logic files, tools for creating and editing logic documents, and protection and control settings.

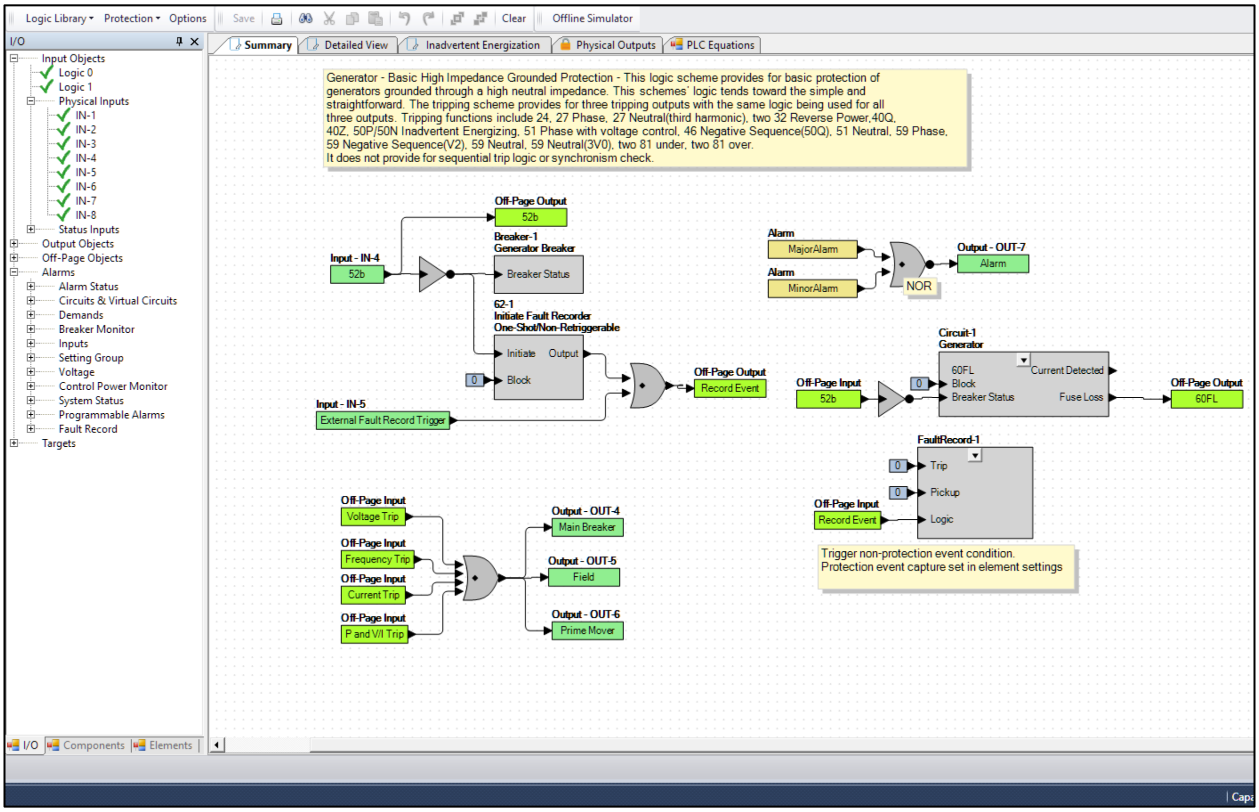


Figure 51-1. BESTlogic*Plus* Programmable Logic Tree Branch

Logic Schemes

A logic scheme is a group of logic variables that defines the operation of a BE1-FLEX. In most applications, preprogrammed logic schemes eliminate the need for custom programming. Preprogrammed logic schemes can provide more inputs, outputs, or features than are needed for a particular application. This is because a preprogrammed scheme is designed for a large number of applications with no special programming required. Unneeded logic block outputs can be left open to disable a function or a function block can be disabled through operating settings.

A variety of pre-programmed logic schemes are available to download from the Basler Electric website. Refer to the *Application Templates* chapter for more information. Any logic scheme can also be customized to suit your application.

BESTlogic™Plus File Management

To manage BESTlogic*Plus* files, use the Settings Explorer to open the BESTlogic*Plus* Programmable Logic tree branch. The BESTlogic*Plus* Programmable Logic toolbar is used to manage BESTlogic*Plus* files. Refer to Figure 51-2. For information on Settings Files management, refer the *BESTCOMSPlus Software* chapter.

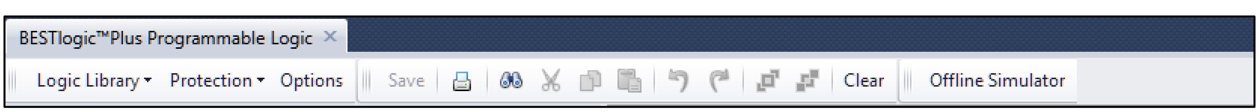


Figure 51-2. BESTlogic*Plus* Programmable Logic Toolbar

Saving a BESTlogic™*Plus* File

After programming BESTlogic*Plus* settings, click on the Save button to save the settings to memory.

Before the new BESTlogic*Plus* settings can be uploaded to the BE1-FLEX, you must select Save from the File pull-down menu located at the top of the BESTCOMS*Plus* main shell. This step will save both the BESTlogic*Plus* settings and the operating settings to a file.

The user also has the option to save the BESTlogic*Plus* settings to a unique file that contains only BESTlogic*Plus* settings. Click on the Logic Library drop-down button and select Save Logic Library File. Use normal Windows® techniques to browse to the folder where you want to save the file and enter a filename to save as.

Opening a BESTlogic™*Plus* File

To open a saved BESTlogic*Plus* file, click on the Logic Library drop-down button on the BESTlogic*Plus* Programmable Logic toolbar and select Open Logic Library File. Use normal Windows techniques to browse to the folder where the file is located.

Protecting a BESTlogic™*Plus* File

Objects in a logic diagram can be locked so that when the logic document is protected these objects cannot be changed. Locking and protecting is useful when sending logic files to other personnel to be modified. The locked object(s) cannot be changed. To view the lock status of the object(s), select Show Lock Status from the Protection drop-down menu. To lock object(s), use the mouse to select object(s) to be locked. Right click on the selected object(s) and select Lock Object(s). The gold colored padlock next to the object(s) will change from an open to a locked state. To protect a logic document, select Protect Logic Document from the Protection drop-down button. A password is optional.

Uploading a BESTlogic™*Plus* File

To upload a BESTlogic*Plus* file to the BE1-FLEX, you must first open the file through BESTCOMS*Plus* or create the file using BESTCOMS*Plus*. Then pull down the Communication menu and select Upload to Device. Check the Upload Logic to Device box.

Downloading a BESTlogic™*Plus* File

To download a BESTlogic*Plus* file from the BE1-FLEX, you must pull down the Communication menu and select Download from Device. If the logic in your BESTCOMS*Plus* has changed, a dialog box will open asking you if want to save the current logic changes. You can choose Yes or No. After you have taken the required action to save or not save the current logic, the downloading is executed.

Printing a BESTlogic™*Plus* File

To print or export the logic, click on the Print () icon located on the BESTlogic*Plus* Programmable Logic toolbar. From the Print screen, logic can be exported to file formats such as PDF, emailed, and printed.

Clearing the On-Screen Logic Diagram

Click the Clear button to clear the on-screen logic diagram on all logic pages and start over.

Programming BESTlogic™Plus

BESTCOMS*Plus* is used to program BESTlogic*Plus*. Using BESTCOMS*Plus* is analogous to physically attaching wire between discrete BE1-FLEX terminals. To program BESTlogic*Plus*, use the Settings Explorer within BESTCOMS*Plus* to open the BESTlogic*Plus* Programmable Logic tree branch as shown in Figure 51-1.

The drag-and-drop method is used to connect a variable or series of variables to the logic inputs, outputs, components, and elements. To draw a wire/link from port to port (triangles), use the primary mouse button to click on a port, pull the wire onto another port, and release the left mouse button. A red port indicates that a connection to the port is required or missing. A black port indicates that a connection to the port is not required. Drawing wires/links from input to input or output to output is not allowed. Only one wire/link can be connected to any one input. Use OR and other gates if multiple conditions need to drive input points. Use OR and other gates if multiple conditions need to drive output points. If the proximity of the endpoint of the wire/link is not exact, it may attach to an unintended port.

The view of Logic Pages 1 can be automatically arranged by clicking the right mouse button on the window and selecting Auto-Layout.

The following must be met before BESTCOMS*Plus* will allow logic to be uploaded to the BE1-FLEX:

- A minimum of two inputs and a maximum of 32 inputs on any multi-port (AND, OR, NAND, NOR, XOR, and XNOR) gate
- A maximum of 32 logic elements in series
- A maximum of 256 logic elements per diagram
- Cannot include functions not supported by the configuration
- Cannot include logic errors such as unlinked ports (shown as red arrows in logic diagram)

The BESTlogic*Plus* processing sequence is performed in non-software selectable layers. Every protective, control, input, and alarm function is scanned in the first layer in a predefined sequence. This sequence is not strictly alphabetical. Feedback loops are processed only after all other functions have been run through the full logic sequence. A logic diagram, with elements 25-4, 27-2, 32-1, and IN-3 for example, will process in that sequence regardless of where they are located in a graphical logic string. After every node's output is determined, it moves to the next layer and repeats the process. The physical position of any component and logic page do not impact the processing sequence.

Three status indicators are located in the lower right corner of the BESTlogic*Plus* window. These indicators show the Logic Save Status, Logic Diagram Status, and Logic Layer Status. Table 51-1 defines the colors for each indicator.

Table 51-1. Status Indicators

Indicator	Color	Definition
Logic Save Status (Left Indicator)	Amber	Logic has changed since last save
	Green	Logic has NOT changed since last save
Logic Diagram Status (Center Indicator)	Red	Error or unlinked port exists on presently viewed tab
	Green	Logic file does not contain any errors or unlinked ports
Logic Layer Status (Right Indicator)	Red	Error or unlinked port exists on at least one tab
	Green	Presently viewed tab does not contain any errors or unlinked ports

Pickup and Dropout Timers

Pickup and dropout timer logic blocks are shown in Figure 51-3. These simplified timers can be used in cooperation with or independently of 62 Element Logic timers, which include additional modes and features.

To program logic timer settings, use the Settings Explorer within BESTCOMS*Plus* to open the BESTlogic*Plus* Programmable Logic, Logic Timers tree branch. Enter a Name label that you want to appear on the timer logic block. The Time Delay value range is 0.0 to 1800.0 seconds in 0.1-second increments.

Next, open the Components tab inside the BESTlogic*Plus* window and drag a timer onto the program grid. Right click on the timer to select the timer you want to use that was previously set on the Logic Timers tree branch. The Logic Timer Properties Dialog Box will appear. Select the timer you want to use.

Timing accuracy is ±15 milliseconds.

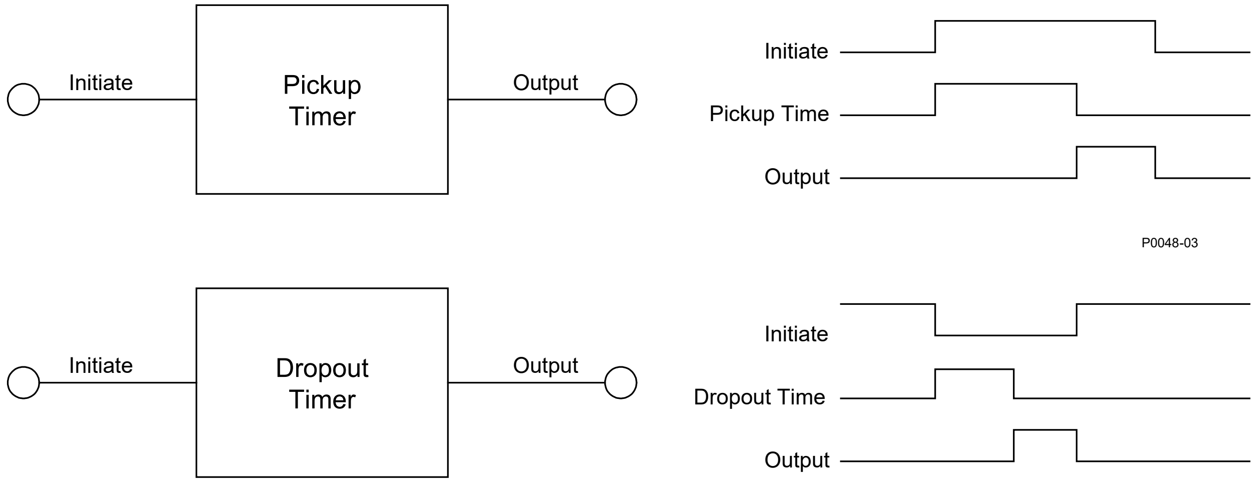


Figure 51-3. Pickup and Dropout Timer Logic Blocks

Offline Logic Simulator

You can use the offline logic simulator to test your custom logic before placing it in operation. The state of the various logic elements can be toggled to verify that the logic states travel through the system as expected.

Before running the logic simulator, you must click the Save button on the BESTlogic*Plus* toolbar to save the logic to memory and all three logic status indicators must be green. Changes to the logic (other than changing the state) are disabled when the simulator is enabled. Colors are selected by clicking the Options button on the BESTlogic*Plus* toolbar. By default, Logic 0 is red and Logic 1 is green. Using your mouse, double-click on a logic element to change its state.

An example of the offline logic simulator is shown in Figure 51-4.

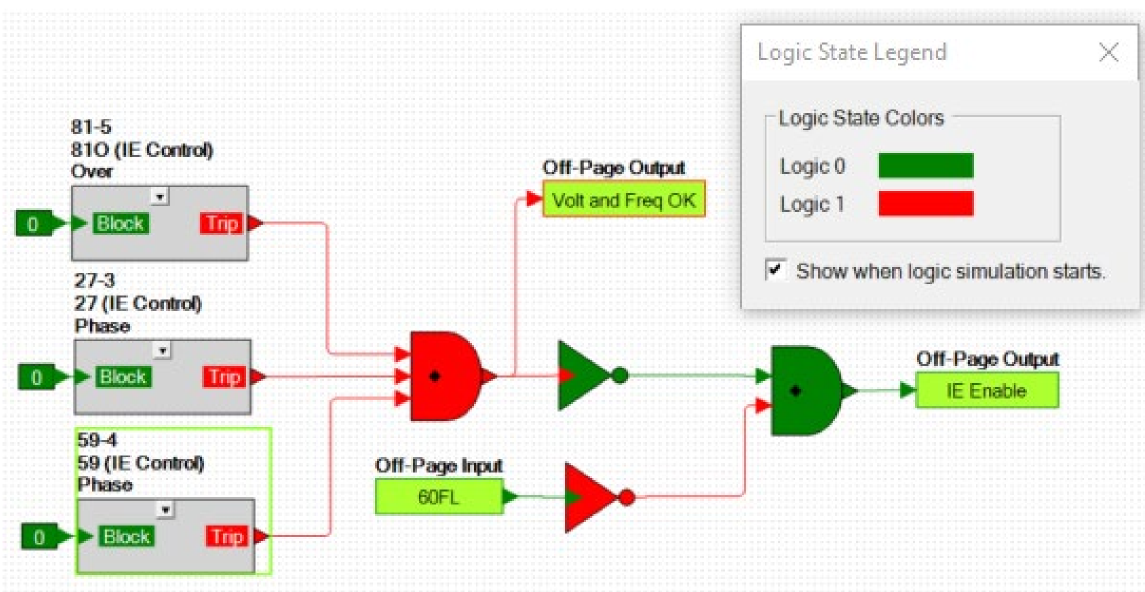


Figure 51-4. Offline Logic Simulator Example

BESTlogic™Plus Composition

There are three main groups of objects used for programming BESTlogic*Plus*. These groups are I/O, Components, and Elements.

Some components include a small arrow at the top and center of the logic node. Clicking the arrow will expand the logic node and show advanced features. Blocks cannot be shrunk into compressed mode when expanded view inputs and outputs are utilized.

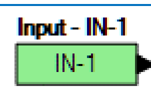
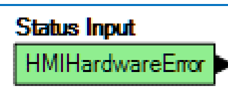
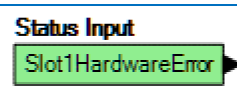
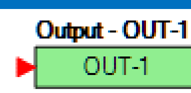
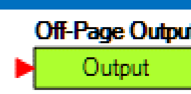
The logic workspace will expand automatically. Bring to Front and Send to Back buttons along the BESTlogic*Plus* menu bar allows intentional logic layering.

Logic can be created on up to eight tabs. Default settings include one programmable tab. Right click on the workspace to Add/Rename Logic Tabs. Tabs cannot be deleted once created within a logic file.

I/O

Input objects can be logically connected to any logic block input. Output objects can be logically connected to any logic block output. Table 51-2 lists the names and descriptions of the objects in the I/O group.

Table 51-2. I/O Group

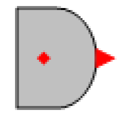
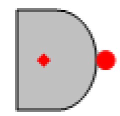
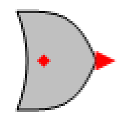
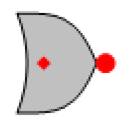
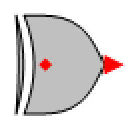
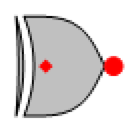
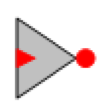
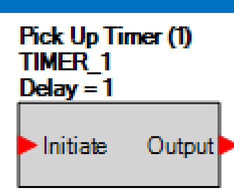
Name	Description	Symbol
Input Objects		
Logic 0 Fixed Bit	Always false (Low). Double-click or right-click on the object to change the fixed state from 0 to 1.	
Logic 1 Fixed Bit	Always true (High). Double-click or right-click on the object to change the fixed state from 1 to 0.	
Physical Inputs	True when a configured input instance is active.	
HMI Hardware Error	True when the HMI assembly has experienced a hardware error and may not be functional.	
Slots 1-7 Hardware Error	True when a style configured hardware card has a known health condition, such as disconnection from the motherboard.	
Output Objects		
Physical Outputs	Closes a configured output instance when true. Form C outputs are configured by the normally open contact and the normally closed follows as the opposite state.	
Off-Page Objects		
Off-Page Output	Used in conjunction with the Off-Page Input to consolidate logic to a single status point and to transform an output on one logic page into an input on another logic page. Outputs can be renamed by right-clicking and selecting Rename Output. Right-clicking will also show pages that the corresponding inputs can be found on. Selecting the page will take you to that page.	

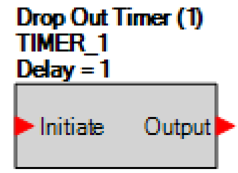
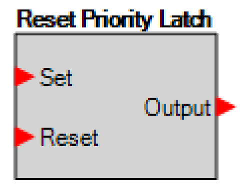
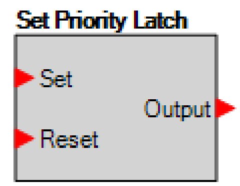
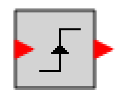
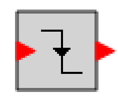
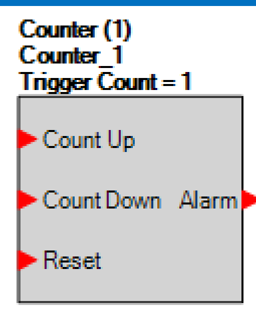
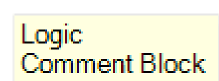
Name	Description	Symbol
Off-Page Input	Used in conjunction with the Off-Page Output to consolidate logic to a single status point and to transform an output on one logic page into an input on another logic page. Inputs can be renamed by right-clicking and selecting Rename Input. Right-clicking will also show pages that the corresponding outputs can be found on. Selecting the page will take you to that page.	Off-Page Input Output
Alarms		
Logic	True when the Logic Alarm is true.	Alarm LogicAlarm
Major	True when the Major Alarm is true.	Alarm MajorAlarm
Minor	True when the Minor Alarm is true.	Alarm MinorAlarm
Relay Trouble	True when a Relay Trouble alarm is active.	Alarm RelayTroubleAlarm
Targets	True when targets are active.	Alarm TargetsAlarm
Targets		
Any Target	True when any target is active.	Target PowerSystem-1.AnyTarget
Any Phase A Target	True when any Phase A target is active.	Target PowerSystem-1.AnyATarget
Any Phase B Target	True when any Phase B target is active.	Target PowerSystem-1.AnyBTarget
Any Phase C Target	True when any Phase C target is active.	Target PowerSystem-1.AnyCTarget
Protection Targets	True when a protection element target is active. Target logic is available for all protection elements. The 24 element target logic is shown as an example.	Target 24-1.Target

Components

Double-click or right-click on a gate to change the type. Table 51-3 lists the names and descriptions of the objects in the Components group.

Table 51-3. Components Group

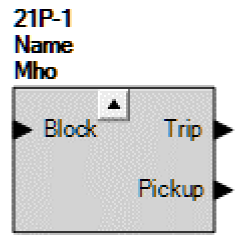
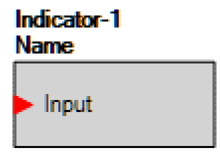
Name	Description	Symbol
Logic Gates		
AND	Input Output 0 0 0 0 1 0 1 0 0 1 1 1	
NAND	Input Output 0 0 1 0 1 1 1 0 1 1 1 0	
OR	Input Output 0 0 0 0 1 1 1 0 1 1 1 1	
NOR	Input Output 0 0 1 0 1 0 1 0 0 1 1 0	
XOR	Input Output 0 0 0 0 1 1 1 0 1 1 1 0	
XNOR	Input Output 0 0 1 0 1 0 1 0 0 1 1 1	
NOT (INVERTER)	Input Output 0 1 1 0	
Pickup and Dropout Timers		
Pick Up Timer	A pickup timer produces a true output when the elapsed time is greater than or equal to the Pickup Time setting after a false to true transition occurs on the Initiate input from the connected logic. Whenever the Initiate input status transitions to false, the output transitions to false immediately. Refer to *Programming BESTlogicPlus, Pickup and Dropout Timers*. Double-click or right-click on the logic timer to select from timers 1 through 50.	

Name	Description	Symbol
Drop Out Timer	A drop out timer produces a true output when the elapsed time is greater than or equal to the Dropout Time setting after a true to false transition occurs on the Initiate input from the connected logic. Whenever the Initiate input transitions to true, the output transitions to false immediately. Refer to *Programming BESTlogicPlus, Pickup and Dropout Timers*. Double-click or right-click on the logic timer to select from timers 1 through 50.	
Latches		
Reset Priority Latch	The latch is set when the Set input is true and the Reset input is false. The latch is cleared when the Reset input is true.	
Set Priority Latch	The latch is set when the Set input is true. The latch is cleared when the Set input is false and the Reset input is true.	
Triggers		
Rising Edge	The output of a rising edge trigger pulses true when the input goes from logic 0 to logic 1. Double-click or right-click on the logic trigger to change the type.	
Falling Edge	The output of a falling edge trigger pulses true when the input goes from logic 1 to logic 0. Double-click or right-click on the logic trigger to change the type.	
Logic Counters		
Logic Counters	A logic counter produces a true Alarm output when the elapsed count is greater than or equal to the Trigger Count setting after a false to true transition occurs on the Count Up input from the connected logic. A positive going edge on the Reset input will reset the counter. The count will be reduced by 1 each time a false to true transition occurs on the Count Down input. Double-click or right-click on the logic counter to select from counters 1 through 30.	
Other		
Logic Comment Block	The logic comment block is used to place notes on the logic.	

Elements

Table 51-4 lists the names and descriptions of the elements in the Elements group.

Table 51-4. Elements Group

Name	Symbol
Protection and Control	
21P Phase Distance Note: The 21P logic block is shown as an example. All other elements are shown in their respective chapters.	
Reporting and Alarms	
Indicator Note: The Indicator logic block is shown as an example. All other elements are shown in their respective chapters.	

52 • Communications

This chapter describes the connections and settings for BE1-FLEX communication. In addition to standard USB, RS-485, and optional Ethernet communication, the BE1-FLEX is capable of sending email messages to a selected recipient with details about a user-selected condition.

Refer to the *Communication Integration* instruction manual for information on configuring Modbus®, DNP, and IEC 61850 communication settings.

USB

A front-panel C-type USB connector provides local communication with a PC operating BESTCOMS*Plus*® software.

Ethernet

Located on the rear panel Communication Board, the optional Ethernet communication ports provide dynamic addressing (DHCP), web pages (HTTP), email alerts (SMTP), as well as communication with devices running BESTCOMS*Plus,* Modbus®*,* DNP, or IEC 61850 software.

Communications Boards include options for 10/100/1000 Base-T Copper Ethernet ports with an eight-pin RJ45 connector that connects to shielded, twisted-pair and 100 Base-FX Fiber Ethernet with LC type connector ports. 10Base-T only applies to copper Ethernet port 1. All copper ports support 100/1000 Base-T communications.

Setup

DHCP (Dynamic Host Configuration Protocol) is enabled by default allowing the BE1-FLEX to send a broadcast request for configuration information. The DHCP server receives the request and responds with configuration information. Ethernet ports are shipped with defaults set to DHCP. Ethernet settings are illustrated in Figures 52-1, 52-2, and 52-3.

Ethernet Port Configuration

1. If a DHCP server is available, connect an Ethernet cable between the BE1-FLEX and your network. If a DHCP server is not available, connect an Ethernet cable directly between the BE1-FLEX and your PC.

   If configuring over USB, connect a USB cable between the BE1-FLEX and your PC.
2. Apply operating power to the BE1-FLEX and wait until the boot sequence is complete.
3. Use BESTCOMS*Plus* to connect to the BE1-FLEX.
4. Click Communications > Download from Device. Then select Device Information and click Ok. Device Information, including Ethernet Settings, is a subset to the full settings file as they are typically unique to each device on a system.

   If communicating over Ethernet, click Scan for Connected Devices – Ethernet to discover the BE1-FLEX. Note: The BE1-FLEX and PC must be powered on and connected for up to one minute before they will be able to communicate.
5. Navigate to Device Information > Network Configuration.

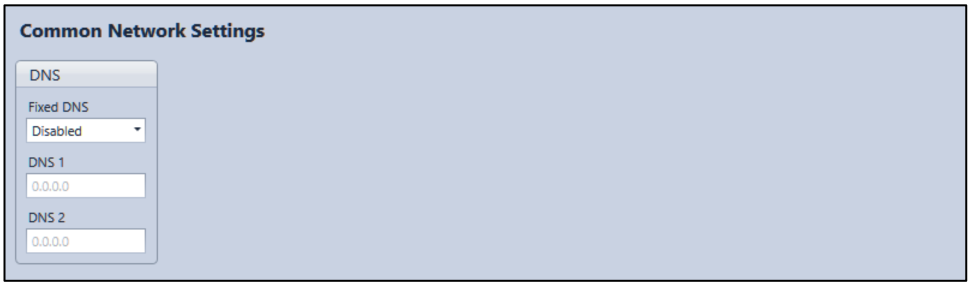


Figure 52-1. Common Network Settings Screen

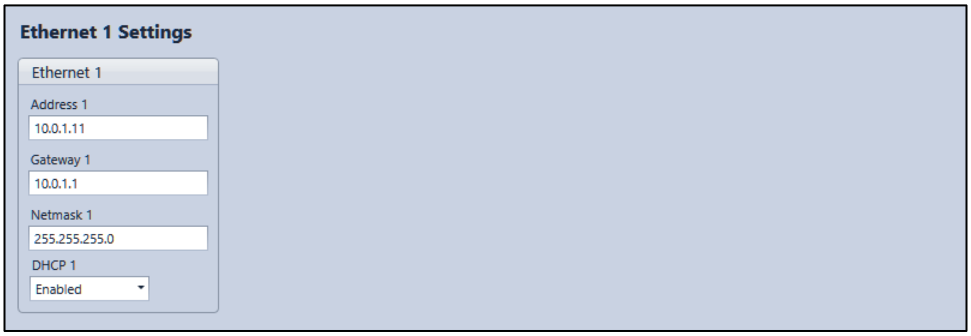


Figure 52-2. Ethernet 1 Settings Screen

Figure 52-3. Ethernet 2 Settings Screen

DHCP (Dynamic Host Configuration Protocol) is enabled by default and allows the BE1-FLEX to send a broadcast request for configuration information. The DHCP server receives the request and responds with configuration information. Use one of the following methods to locate the Active IP address of the BE1-FLEX:

- Use the Device Discovery function on the BE1-FLEX Connection screen in BESTCOMS*Plus*, or
- Navigate to Settings > Communication > Ethernet on the front panel of the BE1-FLEX.

<u>If DHCP is not enabled,</u> BESTCOMS*Plus* can be used to configure the Ethernet port as described in the following paragraphs.

Configurable Ethernet options include:

IP Address:	Internet Protocol Address to be used by the BE1-FLEX.
Default Gateway:	Default host to send data destined for a host not on the network subnet.
Subnet Mask:	Mask used to determine the range of the current network subnet.

Use DHCP: When this box is checked, the IP Address, Default Gateway, and Subnet Mask are automatically configured via DHCP. This can be used only if the Ethernet network has a properly configured DHCP server running. The BE1-FLEX does not act as a DHCP server.

6. Obtain the values for these options from the site administrator if the BE1-FLEX is intended to share the network with other devices.
7. If the BE1-FLEX is operating on an isolated network, the IP address can be chosen from one of the following ranges as listed in IETF publication RFC 1918, *Address Allocation for Private Networks.*
   - 10.0.0.0 - 10.255.255.255
   - 172.16.0.0 - 172.31.255.255
   - 192.168.0.0 - 192.168.255.255

   If the BE1-FLEX is operating on an isolated network, the Subnet Mask can be left at 0.0.0.0 and the Default Gateway can be chosen as any valid IP address from the same range as the BE1-FLEX IP address.

Note

The PC running BESTCOMS*Plus* software must be configured correctly to communicate with the BE1-FLEX. The PC must have an IP address in the same subnet range as the BE1-FLEX if the BE1-FLEX is operating on a private, local network.

Otherwise, the PC must have a valid IP address with access to the network and the BE1-FLEX must be connected to a properly configured router or switch. The network settings of the PC depend on the operating system installed. Refer to the operating system manual for instructions.

On most Microsoft® Windows® based PCs, the network settings can be accessed through the Network Connections icon located inside the Control Panel.

8. Click Communications > Upload to Device. Then select Device Information and click Ok. A confirmation pop-up will indicate that the BE1-FLEX will reboot after settings are sent. Click the Yes button to allow settings to be sent. After the unit has rebooted and the power-up sequence is complete, the BE1-FLEX is ready to be used on a network.
9. If desired, BE1-FLEX settings can be verified by selecting Download from Device from the Communication pull-down menu. Active settings will be downloaded from the BE1-FLEX. Verify that the downloaded settings match the previously sent settings.

HSR and PRP

The Redundancy Mode can be set to HSR (High-availability Seamless Redundancy) or PRP (Parallel Redundancy Protocol) for Ethernet port 2B available on Ethernet boards G3, H8, and H7. HSR or PRP provide redundant communications to Ethernet port 2A. Both HSR and PRP are defined per IEC 62439-3. A disabled setting disables the 2B port.

Email

The BE1-FLEX is capable of sending email alerts when triggered by chosen logic. A maximum of eight circumstances can be established for sending email alerts. Setup of email notifications is made on the BESTCOMS*Plus* Email Setup screens (Settings Explorer > Communications > Email) illustrated in Figures 52-4 and 52-5. A notification is configured by entering the SMTP email server address, mail from domain, and the email addresses of the intended recipients. One email address can be entered in the “To” field and one email address can be entered in the “Cc” field. The “Subject” field accepts up to 64 characters for describing the condition triggering the notification email.

With multiple emails and many protection setpoints available, the BE1-FLEX can email specific event conditions using Subject descriptions and an email Body to expedite system restoration. Including restoration or fault investigation instructions in the 1,000 character Body reduces operations training requirements.

Figure 52-4. Email Server Screen

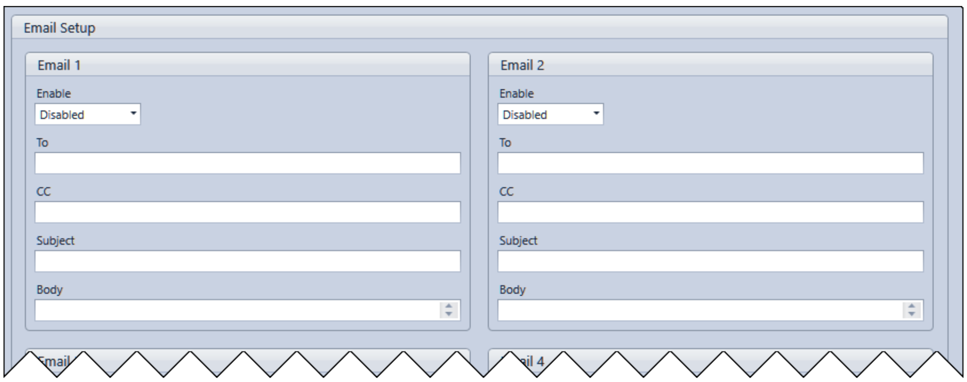


Figure 52-5. Email Setup Screen

BESTlogic™*Plus* Settings

BESTlogic*Plus* settings are made using BESTCOMS*Plus*. To program the BESTlogic*Plus* settings, use the Settings Explorer within BESTCOMS*Plus* to open the BESTlogic*Plus* Programmable Logic tree branch and select the email logic block from the list of Elements. The email logic block is shown in Figure 52-6. Use the drag-and-drop method to connect a variable or series of variables to the input. Refer to the *BESTlogicPlus* chapter for more information on setting BESTlogic*Plus* programmable logic.

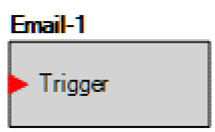


Figure 52-6. Email Logic Block

Table 52-1 lists the BESTlogic*Plus* settings for email.

Table 52-1. BESTlogic*Plus* Settings for Email

Name	Function	Purpose	Default
Trigger	Input	Triggers an email message	0

RS-485

RS-485 connections are made at a three-position terminal block connector on the Power Supply board that mates with a standard communication cable. A twisted-pair cable is recommended. Shield and ground on both ends to common ground potential as recommended by industry standards. Connector pin numbers, functions, names, and signal directions are shown in Table 52-2. An RS-485 connection diagram is provided in Figure 52-7.

Table 52-2. RS-485 Pinouts

Terminal	Function	Name	Direction
A	Send/Receive A	(SDA/RDA)	In/Out
B	Send/Receive B	(SDB/RDB)	In/Out
C	Common Ground	(SC)	n/a

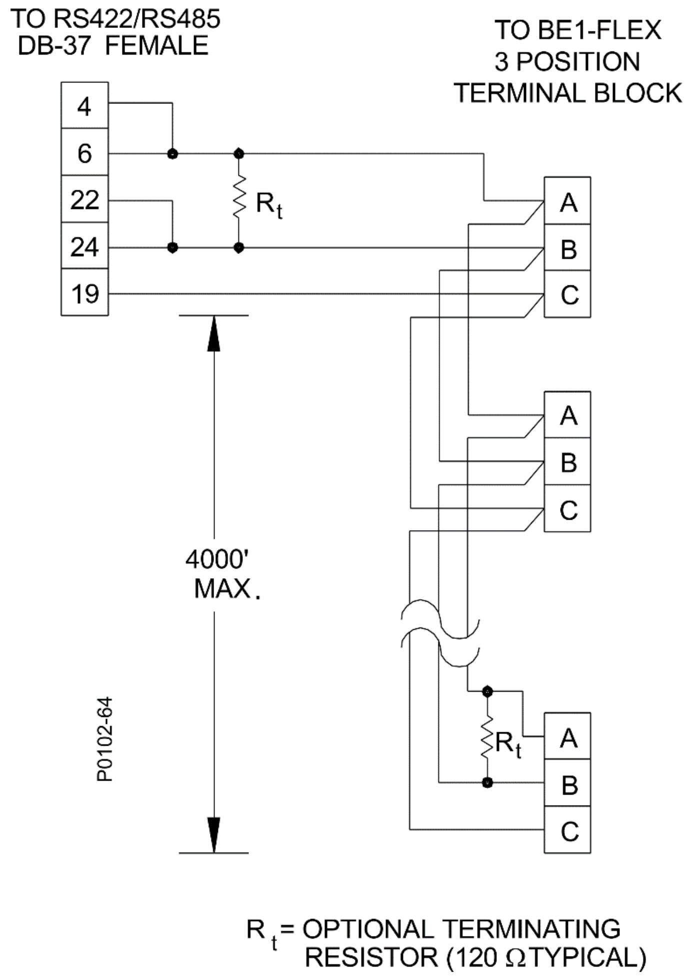


Figure 52-7. RS-485 DB-37 to BE1-FLEX

RS-485 Setup

The RS-485 Setup screen is shown in Figure 52-8. Baud rate is selectable from 9600 to 115200. Default is 115200.

Figure 52-8. RS-485 Setup Screen

53 • Fault Reporting

The fault reporting function records and reports information about faults that have been detected by the BE1-FLEX. The BE1-FLEX provides many fault reporting features. These features include Fault Summary Reports, Oscillographic Records, Distance to Fault, and Targets.

Fault Reporting Logic

Most protective elements include a setting to capture a fault record within the element itself. In addition, logic expressions can be used to define conditions for fault reporting. These conditions are Logic, Trip, and Pickup. An oscillographic record is triggered when the Trip, Pickup, or Logic input is true and when an element picks up and has its Fault Recorder setting set to enabled.

The BE1-FLEX oscillographic recording function includes two data buffers to allow recording of multiple, nearly simultaneous events. Once the buffer is full, the first fault record must be saved to nonvolatile memory before additional fault records can be captured. Saving to nonvolatile memory happens automatically. It can take up to two times the recording duration time for a save to occur.

Fault trigger logic connections are made on the BESTlogic™*Plus* screen in BESTCOMS*Plus*. The *BESTlogicPlus* chapter provides information about using BESTlogic*Plus* to program the BE1-FLEX. Figure 53-1 illustrates the Fault Record logic block.

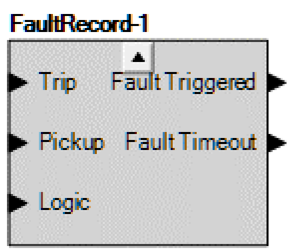


Figure 53-1. Fault Record Logic Block

Logic Block Inputs

Trip

Trip expressions are used by the fault reporting function to record fault current magnitudes at the time of trip. The trip expression is used to light the Trip LED on the front panel. The Trip LED will turn on when the trip expression is true. The Trip LED will remain on (or “sealed-in”) after the trip expression becomes false until targets are reset. The breaker monitoring function uses the trip expression to start counting the breaker operate time.

Logic

Logic trigger expressions allow the fault reporting function to be triggered even though the BE1-FLEX is not picked up. A logic trigger expression provides an input to the fault reporting function much as the pickup expression does. This logic expression is not used by the setting group selection or the front panel.

Pickup

Pickup expressions are used by the fault reporting function to time-stamp the fault summary record, time the length of the fault from pickup to dropout (fault clearing time), and to control the recording of oscillographic data. The pickup expression is used to flash the Trip LED on the front panel. The Trip LED will continue to flash on and off as long as the pickup expression is true and the trip expression is not true. A pickup expression is also used by the setting group selection function to prevent a setting group change during a fault.

Logic Block Outputs

Fault Triggered

This output is true when a fault sequence has initiated and is running.

Fault Timeout

This output is true when a fault capture has exceeded the recording duration setting. It resets if a fault recording that does not timeout. To manually clear the alarm, pulse a true signal into the Pickup and Trip inputs simultaneously.

Targets

Each protective function logs target information to the fault reporting function when a trip condition occurs and the trip output of the logic block becomes true (refer to Figure 53-9 and Table 53-1, callout B). All targets are enabled by default.

Target logging for a protective function can be disabled if the function is used in a supervisory or monitoring capacity. The following paragraphs describe how the BE1-FLEX is programmed to define which protective functions log targets.

Target Settings

Targets are enabled using BESTCOMS*Plus*. Use the Settings Explorer to open the Advanced, Targets tree branch. You can select which protective elements trigger a target by selecting Enabled or Disabled from the Mode drop-down menu next to the targets. See Figure 53-2.

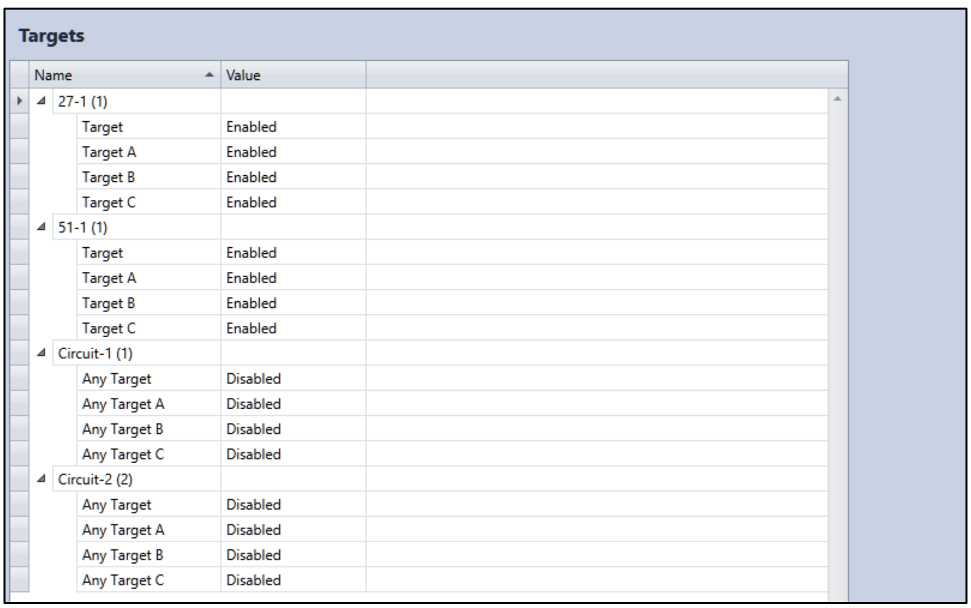


Figure 53-2. Targets Settings Screen

Grouped Targets

A grouped target is annunciated when any target in the group is active. The group targets can be enabled or disabled on the Target Settings screen in BESTCOMS*Plus* per circuit. Circuits can provide a general Target as well as Target A, Target B, and Target C. Phase targets are available for protective elements that have per phase values. Other elements, such as the 55 Power Factor elements, only provide the main Target.

Retrieving Target Information

The BE1-FLEX provides targets occurring after the most recent target reset operation. If multiple event targets are simultaneously active, utilize the *Sequence of Events* to determine when individual targets became true.

When a protective trip occurs, as determined by the Fault Recorder Trip input, the front-panel Trip LED seals-in. Active targets can be viewed on the front-panel touchscreen by navigating to Reports > Targets & Alarms. To view target status using BESTCOMS*Plus*, use the Metering Explorer to open the Status, Targets screen shown in Figure 53-3.

Figure 53-3. Active Targets Screen

Resetting Targets

Targets can be cleared through BESTCOMS*Plus*, other communication protocols, or by pressing the front-panel Reset Targets & Alarms button while the Targets & Alarms screen is being displayed.

A BESTlogic*Plus* expression can be used to reset the targets. Use the Settings Explorer within BESTCOMS*Plus* to open the BESTlogic*Plus* Programmable Logic tree branch. Select the Alarm Status logic block from the list of Elements. Use the drag-and-drop method to connect a variable or series of variables to the Targets Reset input. The Alarm Status logic block is shown in Figure 53-4. Use caution when using this feature to avoid conditions where a target is set and reset constantly as it can cause excessive flash memory wear.

Figure 53-4. Alarm Status Logic Block

Pressing the touchscreen or web interface Reset Targets & Alarms button will prompt the user to define which sections to clear. Selecting Targets will reset the Targets and the Trip LED. Depending on device security setup, a username and password may be required to reset targets at the front panel. Logging in is not required if the Unsecured Access Level is set to Operator or higher. Target reset can also be set outside of security control, allowing reset without logging in. Refer to the *Security* chapter for more information.

A Targets Reset logic block is available as a status input in BESTlogic*Plus*. See Figure 53-5. The Targets Reset status input goes momentarily high when the targets are cleared.

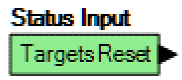


Figure 53-5. Targets Reset Logic Block

Fault Reports

The BE1-FLEX records information about faults and creates fault summary reports. The most recent 63 fault summary reports, with corresponding oscillography records, are stored in nonvolatile memory. When a new fault summary report is generated, the BE1-FLEX discards the oldest of the events and replaces it with a new one. Each fault summary report is assigned a sequential number (from 1 to 63) by the BE1-FLEX. After event number 63 has been assigned, the numbering starts over at 1.

Five different event types are generated by the BE1-FLEX: Trip, Pickup, Logic, Breaker Failure, and Forced Trigger.

BE1-FLEX protection systems have three identification fields: Device ID, Station ID, and User ID. These fields are used in the header information lines of the fault reports. Refer to the *BESTCOMSPlus* Software chapter for information on BE1-FLEX identification settings.

Viewing and Downloading Fault Data through BESTCOMS*Plus*®

To view fault summary reports using BESTCOMS*Plus*, use the Metering Explorer to open the Reports, Fault Records screen shown in Figure 53-6. This screen shows a list of faults along with number, date, time, event type, and number of oscillographic records for each fault.

From this screen, you can choose to View Fault Details or View Fault Sequence of Events by selecting your choice at the top of the screen and then highlighting the fault to be displayed to populate the view window on the right side of the window. Fault Details is a summary of the fault. The Sequence of Events is a sequential list of data points with time stamps that transitioned during the selected fault recording time window.

The Download button allows you to download and save all files associated with the selected fault. Multiple records can be selected from the list for grouped download. These files include oscillographic records. The Refresh button refreshes the list of fault reports on the screen (Figure 53-6) that are available to view/download. The Trigger button manually triggers a fault.

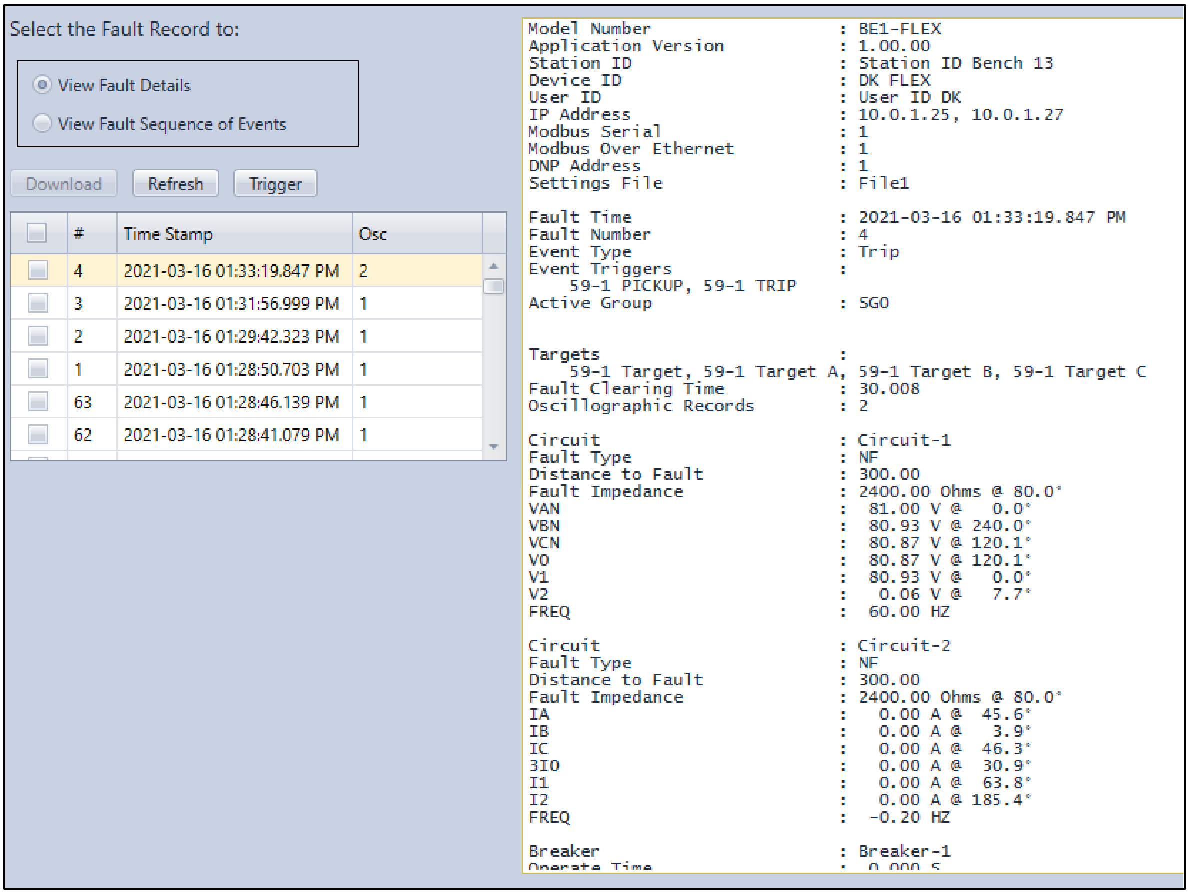


Figure 53-6. Fault Reports Screen

Viewing Fault Data through the Front-Panel Display

Fault report data for all faults can be viewed through the front-panel display and web pages by navigating to Fault Summary page from the Reports menu.

Fault Summary Report Items

A fault summary report collects several items of information about a fault that can aid in determining why a fault occurred without having to sort through all of the detailed information available. The following items are contained in a typical fault summary report.

Model Number

This line reports the product model type.

Application Version

This line reports the version of firmware inside the product at the time of the fault.

Station ID, Device ID, and User ID

These lines report station, device, and user information as defined by *BESTCOMSPlus* on the Device Info screen.

Relay Address

This line reports the communications port address(es) that the report was requested from. The addresses are assigned using BESTCOMS*Plus*.

Settings File Name

This line reports the name of the settings file that was active at the time of the fault.

Fault Time

This line reports the BE1-FLEX's time and date of the initial trigger of the event. This is based on either the pickup logic expression or the logic trigger expression becoming true as defined by the Fault Trigger logic. Refer to Figure 53-9 and Table 53-1, call-out A.

Fault Number

This line reports the sequential number (from 1 to 63) assigned to the report by the BE1-FLEX.

Event Type

This line reports the type of event that occurred. There are five event categories:

- Trip: A fault was detected as defined by the pickup expression and the BE1-FLEX tripped to clear the fault.
- Pickup: A fault was detected as defined by the pickup expression but the BE1-FLEX never tripped indicating that the fault was cleared by another device.
- Logic: A fault report was recorded by the logic trigger expression but no fault was detected as defined by the pickup expression.
- Breaker Failure: A fault was detected as defined by the pickup expression and the breaker failure trip became true before the fault was cleared.
- Forced Trigger: A fault report was triggered through the BESTCOMS*Plus* interface.

Event Trigger

This line reports the logic variables in the picked up or logic trigger expressions that became true to trigger the recording of the event.

Active Group

This line reports what setting group was active at the time that the fault occurred.

Targets

This line reports the targets that were active at the time of fault recording. Refer to Figure 53-9 and Table 53-1, call-out B.

Fault Clearing Time

This line reports the time from when the BE1-FLEX detected the fault until the BE1-FLEX detected that the fault had cleared. Refer to Figure 53-9 and Table 53-1, call-out C.

- If the fault report was triggered through the BESTCOMS*Plus* interface, the recording of the report was terminated after 60 seconds and this line is reported as n/a.
- If the pickup or logic expressions stay true for more than 60 seconds, an alarm bit in the programmable alarm function is set and this line is reported as n/a. In this situation, the fault reporting functions (including targets) will not operate again until the pickup and logic trigger expressions return to a false state to enable another trigger.

Oscillographic Record

This line reports the number of oscillographic records that are stored in memory for this fault report. Refer to Figure 53-9 and Table 53-1, call-out E. Recording of oscillographic records is described later in this chapter.

Circuits

The BE1-FLEX provides Fault Summary details for each configured Circuit. This line reports the user-defined Circuit name.

Fault Type

This line indicates the phases of the circuit involved in the fault.

Distance to Fault

This line reports the distance to the fault on the line when the circuit includes voltage and current. Units are the same as the units used to determine line length. Refer to Figure 53-9 and Table 53-1, call-out F.

Fault Impedance

This line reports the calculated impedance magnitude and angle when the tie circuit includes voltage and current.

Voltage, Current and Frequency

These lines report the phase voltage and current magnitudes and angles measured two power system cycles immediately following the trip trigger. If the fault is cleared prior to the BE1-FLEX tripping, the recorded fault voltages and currents are for the power system cycle two cycles prior to the end of the fault. Values recorded, pending circuit configuration, are per phase voltage, per phase current, positive-, negative-, and zero-sequence voltage and current, ground voltage, third harmonic ground voltage and circuit frequency. Refer to Figure 53-9 and Table 53-1, call-out F.

Breaker

A breaker summary is provided for each configured breaker. This line reports the breaker name.

Breaker Operate Time

This line reports the breaker trip time from the breaker monitoring and alarm function. This is the time measured from when the breaker is trigged until the fast current detector function detects that the arc has been extinguished.

Slip Freq

This line reports the slip frequency measurement of the breaker.

Slip Angle

This line reports the slip angle measurement of the breaker.

RTD and Analog Inputs

These lines report the values of all configured RTDs, Shunts, and Analog Inputs.

Battery Voltage

These lines report the measured Control Power voltage magnitude as well as positive and negative voltage to ground.

Oscillographic Records

Recording Oscillographic Records

Each time the fault reporting function starts recording a fault summary report as initiated by the Fault Recorder pickup input, it freezes a user-defined cycle pre-fault buffer. If the pickup condition is not cleared within that time, the fault reporting function records a second oscillographic record when the Fault Record Trip input goes high. This second record is intended to capture the end of the event. Oscillographic records are stored in nonvolatile memory. As additional faults are recorded, the oldest records are overwritten. The fault reporting function will record the most recent 63 oscillographic records based on IEEE Std C37.111-2013 - *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems*. Maximum data capture resolution is 128 samples per cycle and is user selectable. At 128 samples per cycle, the BE1-FLEX will store 32 cycles of data for all analog channels. Digital channel recording duration is a minimum of 1 second. If multiple events occur nearly simultaneously, digital data of the second trigger may be included only in the previous record.

All channels are recorded (I1-I7, VA, VB, VC, VX, Analog Inputs, RTDs, I/O, and Digital Point status per slot) as they happen in real time. Scaling ratios, such as CT and PT ratios, are included in the COMTRADE standard configuration file, which allow the COMTRADE viewers to typically display primary values.

BE1-FLEX protection systems have three identification fields: Device ID, Station ID, and User ID. These fields are used in the header information lines of the oscillographic records. Refer to the *Device Information* chapter for information on BE1-FLEX identification settings.

Oscillographic Records Settings

The oscillographic records settings are programmed through BESTCOMS*Plus*. Use the Settings Explorer to open the Advanced, Fault Records screen as shown in Figure 53-7. Enter the values for Sample Resolution from 8 to 128 Samples per Cycle and Prefault Cycles from 0 to 16. The default setting is 128 samples/cycle.

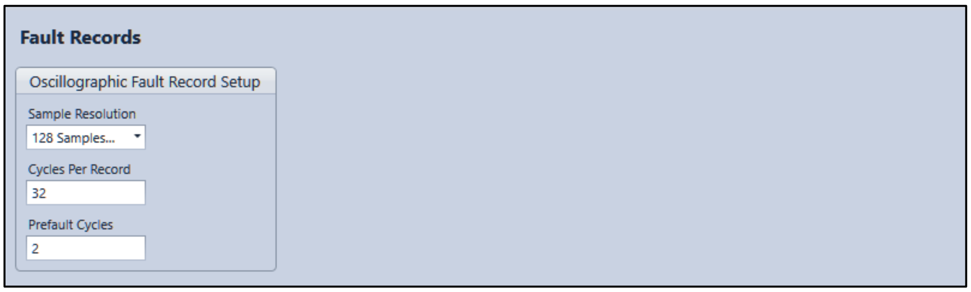


Figure 53-7. Fault Records Screen

Retrieving Oscillographic Records

Oscillographic records can be downloaded through the Reports, Fault Reports screen in BESTCOMS*Plus* (Figure 53-6). See *Fault Reports* earlier in this chapter. Oscillographic records can also be downloaded through the web page interface. For more information, refer to the *Human Machine Interface (HMI)* chapter.

Distance to Fault

The BE1-FLEX calculates the distance to a fault when a fault record is triggered. Distance to fault is calculated and displayed based on the power line parameters entered using BESTCOMS*Plus*.

Line Length describes the power line parameters for calculating distance. The parameters should be entered in units per line length with line length being the actual length of the power line. Line length is entered as unit-less quantities and, therefore, can be entered in kilometers or miles. Therefore, the distance results would be in whatever units the line length represented.

Using the Settings Explorer in BESTCOMS*Plus*, power line parameters can be entered on the Directional Control screen under Circuits. Settings are provided for Positive-Sequence Impedance, Zero-Sequence Impedance, and Line Length. These settings affect both protective elements that require directionality as well as the distance to fault recorder calculation. Multiple circuits can be created from the same hardware if parameters are different for various purposes. Refer to Figure 53-8.

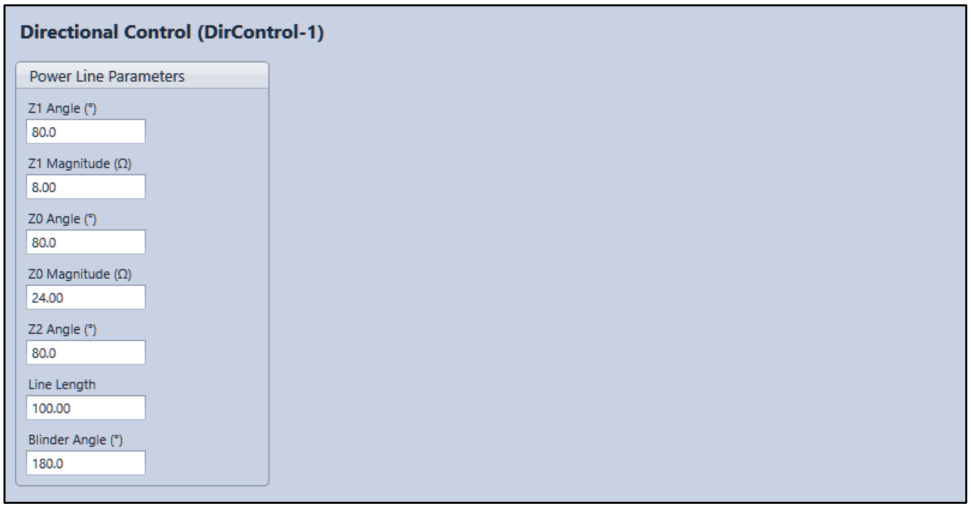


Figure 53-8. Directional Control Screen

Distance calculations are performed post-fault using vector data captured during the actual fault. Pre-fault current vectors are captured three cycles prior to pickup. Fault voltage and current vectors are captured two cycles after the trip command is issued. The two-cycle wait time allows line transients to settle to provide results that are more accurate.

To perform the actual distance calculation, the BE1-FLEX first must determine the faulted phase. Faults can be categorized depending on the lines faulted. The various categories are LLL, LL, LLG, or LG where L = line and G = ground.

To determine the faulted phase, the fault vectors are compensated for load flow using the pre-fault data. Next, the compensated vectors are run through a series of sequence component comparisons. Once the faulted phase is determined, the fault data along with the line parameters are applied using the load-compensated Takagi algorithm to determine the impedance of the faulted line. The impedance is divided by the impedance per unit length to determine the distance to fault. This method assumes the line is homogenous and that the line parameters do not change over the length specified. For a non-homogenous line, the distance would need to be manually corrected.

The distance-to-fault results are limited to ±300% of the specified line length. This limit prevents erroneous results from being displayed for non-overcurrent type faults, such as overvoltage or undervoltage faults.

Protective Fault Analysis

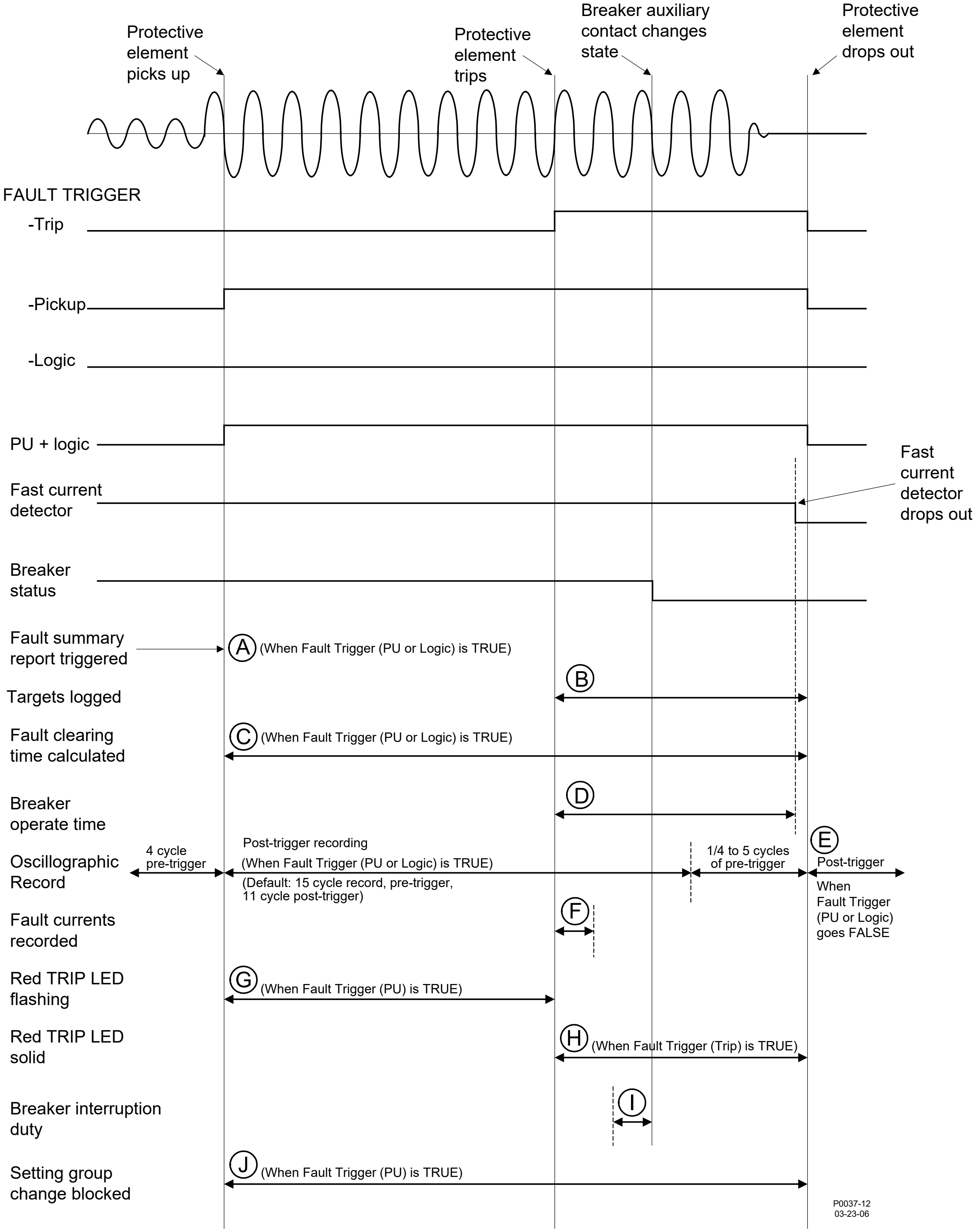


Figure 53-9. Protective Fault Analysis

Table 53-1. Legend for Figure 53-9

Locator	Description
A	A fault summary report and an oscillography record are triggered when the Pickup logic expression becomes true.
B	During the time that the Trip expression is true, active targets are polled. If a protective function is not being used for tripping purposes, the associated target function can be disabled through BESTCOMS*Plus*.
C	Fault clearing time is calculated as the duration of the time that the Pickup logic expression is true.
D	Breaker operate time is calculated as the time from when the Trip logic expression becomes true until the fast current detector senses that the breaker has successfully interrupted the current in all poles of the breaker.
E	A second oscillographic record is triggered to record the end of the fault if the Pickup logic expression remains in the true state at the time that the first oscillographic record ends. This second record will have from ¼ to five cycles of pre-trigger data depending upon when the Pickup logic expression becomes false.
F	Recorded fault phase voltage frequency, auxiliary voltage frequency, and voltage, current angles, and distance magnitudes are displayed on the Fault Records screens of BESTCOMS*Plus*, the HMI, and webpages. The same information including are recorded in the fault summary report. The magnitude, angle, and distance results are based on data captured two cycles after the trip output goes true. This two-cycle delay allows the line transients to settle to provide data that is more accurate. The post fault current vectors are compared to pre-fault current vectors captured three cycles prior to protective pickup to perform distance calculations. If the Trip expression does not become true, the fault was cleared by a down-stream device. For these pickup-only events, fault current, voltage, angle, and distance recorded in the fault summary report will be for the power system cycle ending two cycles prior to the end of the fault record. This is also the case if the fault record was triggered through BESTCOMS*Plus*.
G	During the time that the Pickup expression is true, the red Trip LED on the front panel flashes indicating that the BE1-FLEX is picked up.
H	During the time the Trip expression is true, the red Trip LED on the front panel lights steadily indicating that the BE1-FLEX is in a tripped state. The Trip LED is sealed in until the targets have been reset.
I	Breaker operations and interruption duty functions are driven by the breaker status function. The operations counter is incremented on breaker opening. The magnitudes of the currents that are used for accumulating breaker duty are recorded for the power system cycle ending when the breaker status changes state. Thus, breaker duty is accumulated every time that the breaker opens even if it is not opening under fault.
J	Setting group changes are blocked when the Pickup expression is true to prevent protective functions from being reinitialized with new operating parameters while a fault is occurring.

54 • Alarms

The BE1-FLEX monitors internal systems, external interfaces, and power system equipment. An alarm is annunciated when a component fails. A diagnostic log is available to assist in defining Relay Trouble conditions and facilitate quick field repairs.

Relay Trouble alarms are not programmable. They will always trigger the relay trouble LED and disable outputs. Table 54-1 below shows these alarms.

Table 54-1. Relay Trouble Alarms

Name	Description	Logic Block Name	Default
Board Authentication Error	A board has failed validation check	BrdAuthEr	Latching
Configuration Error	The configuration settings do not match the hardware configuration.	ConfigurationError	Latching
Device Validation Error	Internal device information has failed validation check	DeviceValidationError	Latching
Hardware Error	A critical hardware error has been detected	HRDWRERR	Latching
Non-Recoverable Error	The device is not able to self-recover from an error	NonRecoverableError	Latching
Style Mismatch Error	Board configuration does not match configuration settings	StyleErr	Latching

The remaining alarms can be configured as latching or non-latching with a status of major, minor, or logic. They can also be used as an input to other logic blocks in BESTlogic™*Plus*. Latching alarms are stored in nonvolatile memory and are retained even when BE1-FLEX operating power is lost. Active alarms are displayed on the front-panel HMI, web page interface, and through BESTCOMS*Plus*® until they are cleared. Non-latching alarms are cleared when the alarm condition is no longer true.

If an alarm is configured as Major and becomes active, a front-panel Major Alarm LED lights and the Alarm banner appears at the top of the HMI. The front-panel Minor Alarm LED operates in a similar manner. Logic alarms populate a digital register only in the device that can be displayed in BESTCOMS*Plus* metering or polled by remote communications. Each alarm provides a logic output that can be connected to a physical output or other logic input using BESTlogic*Plus* Programmable Logic.

The ability to program the reporting and display of alarms along with the automatic display priority feature of the front-panel display gives the BE1-FLEX the functionality of a local and remote alarm annunciator. When any alarm or target is active, the HMI and web pages will annunciate as a banner in the upper right corner of every screen. Pressing the annunciation navigates to the Targets & Alarms screen with a detailed view.

A detailed list of the first instance of the alarms is provided in Table 54-2. Additional alarms of the same type will populate when extra instances exist in the settings configuration.

Table 54-2. Available Alarms

Alarm Name	Description	Logic Block Name	Default
101-1 Blocked	101-1 block tag set	101-1.Blocked	Disabled
24-1 Alarm	24-1 alarm is active	24-1.Alarm	Disabled
43-1 Blocked	43-1 block tag set	43-1.Blocked	Disabled
50BF-1 Alarm	50BF-1 alarm is active	50BF-1.Alarm	Disabled
51TF-1 Alarm	51TF-1 alarm is active	51TF-1.Alarm	Disabled

Alarm Name	Description	Logic Block Name	Default
79-1 Fail Alarm	79 is in a fail condition	79-1.Fail Alarm	Disabled
79-1 Lockout	79 is in a lockout condition	79-1.Lockout	Disabled
87-1 Alarm	87 Alarm is active	87-1.Alarm	Disabled
87-1 Alarm A	87 phase A alarm is active	87-1.PhaseAAlarm	Disabled
87FB-1 Alarm	87FB alarm is active	87-1.Alarm	Disabled
87FB-1 Alarm A	87FB phase A alarm is active	87FB-1.PhaseAAlarm	Disabled
AIN-1 Out of Range	True when the auxiliary input 1 connection is out of the 0 to 10 V or 4 to 20 mA range	AIN-1.OutofRange	Disabled
Breaker-1 Alarm 1	Breaker monitor alarm 1 is active	BreakerMonitor-1 Breaker Monitor-1.Alarm 1	Disabled
Breaker-1 Alarm 52TCM	Monitored trip circuit open	BreakerMonitor-1.Alarm 52TCM	Disabled
Circuit-1 3I0 Demand	Neutral current unbalance demand	Demands-1.3I0Alarm	Disabled
Circuit-1 Frequency Out of Range	Frequency is out of range	PowerSystem-1.FreqOutofRange	Disabled
Circuit-1 Fuse Loss	One or more phases of voltage lost	PowerSystem-1.Fuse Loss	Non-Latching (Minor)
Circuit-1 I2 Demand	Negative-sequence current unbalance demand	Demands-1.I2Alarm	Disabled
Circuit-1 IG Demand	Ground current demand	Demands-1.IGAlarm	Disabled
Circuit-1 IP Demand	Phase current demand	Demands-1.IPHAalarm	Disabled
Circuit-1 VA Demand	Apparent power demand	Demands-1.VAAlarm	Disabled
Circuit-1 var Negative Demand	Negative var demand maximum exceeded	Demands-1.NegvarAlarm	Disabled
Circuit-1 var Positive Demand	Positive var demand maximum exceeded	Demands-1.PosvarAlarm	Disabled
Circuit-1 Watt Negative Demand	Negative watt demand maximum exceeded	Demands-1.NegWattAlarm	Disabled
Circuit-1 Watt Positive Demand	Positive watt demand maximum exceeded	Demands-1.PosWattAlarm	Disabled
Control Power Monitor Battery(-) Grounded	Negative Power Supply is Grounded	NegGndAlarm	Disabled
Control Power Monitor Battery(+) Grounded	Positive Power Supply is Grounded	PosGndAlarm	Disabled

Alarm Name	Description	Logic Block Name	Default
Control Power Monitor Overvoltage 1 Alarm	Control Power voltage exceeds Overvoltage 1 threshold	OV1Alarm	Disabled
Control Power Monitor Overvoltage 2 Alarm	Control Power voltage exceeds Overvoltage 2 threshold	OV2Alarm	Disabled
Control Power Monitor Undervoltage 1 Alarm	Control Power voltage is less than Undervoltage 1 threshold	UV1Alarm	Disabled
Control Power Monitor Undervoltage 2 Alarm	Control Power voltage is less than Undervoltage 2 threshold	UV2Alarm	Disabled
Fault Record Fault Timeout	True after a fault capture has exceeded recording duration setting	FaultRecord-1.FaultTimeout	Disabled
IN-1 Thresh Alarm	True when board voltage is set to 24 Vdc and voltage exceeds approximately 125 V	IN-1.ThreshAlarm	Disabled
Programmable 1 Alarm	Programmable alarm 1 is true	ProgAlarm-1.Alarm	Disabled
RTDIN-1 Out of Range	True when the RTD input 1 connection is open	RTDIN-1.OutofRange	Disabled
Setting Group SG0	Setting group 0 is active	SG0	Disabled
Setting Group SGC Active	Active setting group changed	SGC Active	Disabled
Setting Group SGC Logic Override	Setting group control was overridden by logic	SGC Logic Override	Disabled
System Alarms Database Error	The device has detected and has attempted to repair a memory error. A relay trouble alarm will assert if error is not recoverable.	DatabaseError	Non-Latching (Major)
System Alarms Default Logic	Device has default (empty) logic	DefaultLogic	Non-Latching (Major)
System Alarms Default Network Configuration	Device has default network configuration settings	DefaultNetworkConfiguration	Disabled
System Alarms Default Security Settings	Device has default security settings	DefaultSecuritySettings	Disabled
System Alarms Default Settings	Device has default (empty) settings	DefaultSettings	Non-Latching (Major)

Alarm Name	Description	Logic Block Name	Default
System Alarms Error Recovery Attempt	Device has detected an error and attempted to recover. Non-recoverable errors escalate to a relay trouble alarm	ErrorRecoverAttempt	Latching (Minor)
System Alarms Security Changed – Password	A user password has changed	SecurityChangedPassword	Disabled
System Alarms Security Changed – Settings	Security settings have changed	SecurityChangedSettings	Disabled
System Alarms Settings Changed	Setting(s) change made by user	SettingsChanged	Disabled
System Status CPU Overload	Microprocessor cannot keep up with demand	Upoverload	Latching (Major)
System Status Ethernet 1 Link Lost	Ethernet 1 communication lost	ETH1Lost	Disabled
System Status Ethernet 2 Link Lost	Ethernet 2 communication lost	ETH2Lost	Disabled
System Status IRIG Lost	True when the IRIG signal is lost. The alarm monitors for IRIG signal loss once a valid signal is detected at the IRIG port	IRIGLostAlarm	Disabled
System Status LCD Backlight Fault	The HMI has a backlight failure and may not be illuminated	HMIBacklightAlarm	Latching (Minor)
System Status Login Failed	Invalid login credentials have been entered	Login Failed	Disabled
System Status NTP Lost	True when the NTP (Network Time Protocol) signal is lost. The alarm monitors for NTP signal loss once the real-time clock is synchronized to the network	NTPLostAlarm	Disabled
System Status Output Override	One or more output contacts have logic output override condition	OutputOverrideAlarm	Non-Latching (Major)
System Status Power Loss	Operating power lost	Power Loss	Disabled
System Status Rate Limit Error	Experiencing excessive write conditions. Possible circular logical condition	RateLimitErrorAlarm	Disabled
System Status Real Time Clock Not Set	Real time clock is not set	Real Time Clock Not Set	Disabled

Alarm Name	Description	Logic Block Name	Default
System Status Time Source Changed	Time sync source has changed. Commonly due to lack of availability of primary source	Time Source Changed	Disabled

Alarm Settings

Navigation Path: Advanced, Alarms

Alarms are enabled using BESTCOMS*Plus*. Configure alarms by selecting Disabled, Latching, or Non-Latching from the Minor, Major, and Logic drop-down menus next to the alarms. Selecting multiple alarms settings via mouse drag or standard keyboard multi-select allows for bulk editing. Select (highlight) the settings you want to change, change the one setting, then click or tab away from that setting to update all selected items to the same setting. Refer to Figure 54-1.

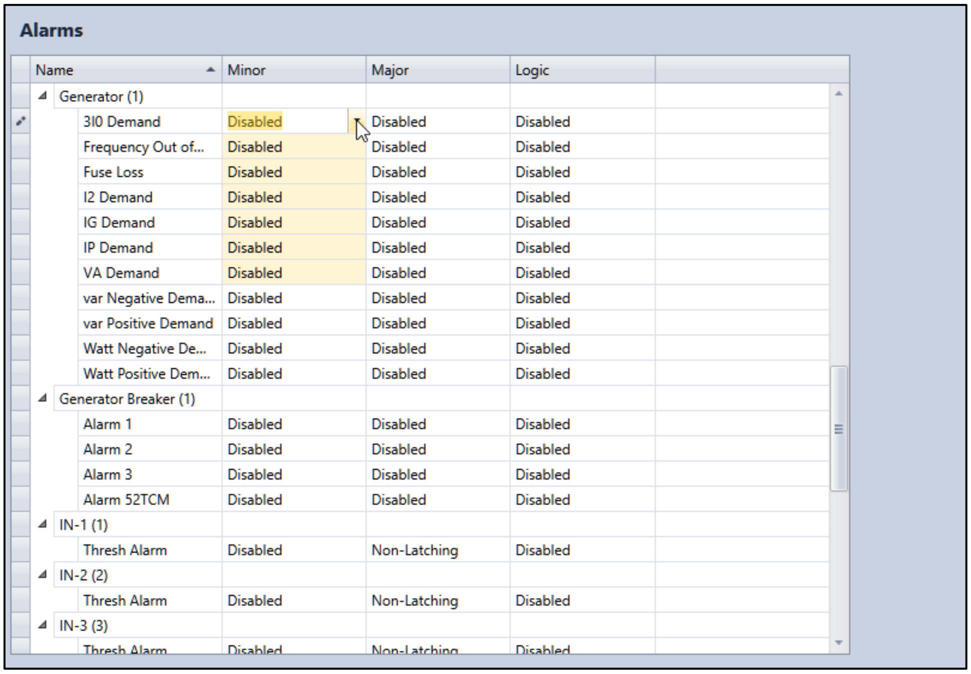


Figure 54-1. Alarms Settings Screen

Programmable Alarms Settings

Navigation Path: BESTlogic*Plus* Programmable Logic, Programmable Alarms

Sixteen user programmable alarms are available. BESTlogic*Plus* Programmable Logic is used to set up alarm logic. User alarm labels are programmed on the User Programmable Alarms screen (Figure 54-2) under Alarm Configuration. When active, the label of a user alarm is displayed on the Alarms screen on the front-panel display and in the fault report and/or sequence of events report.

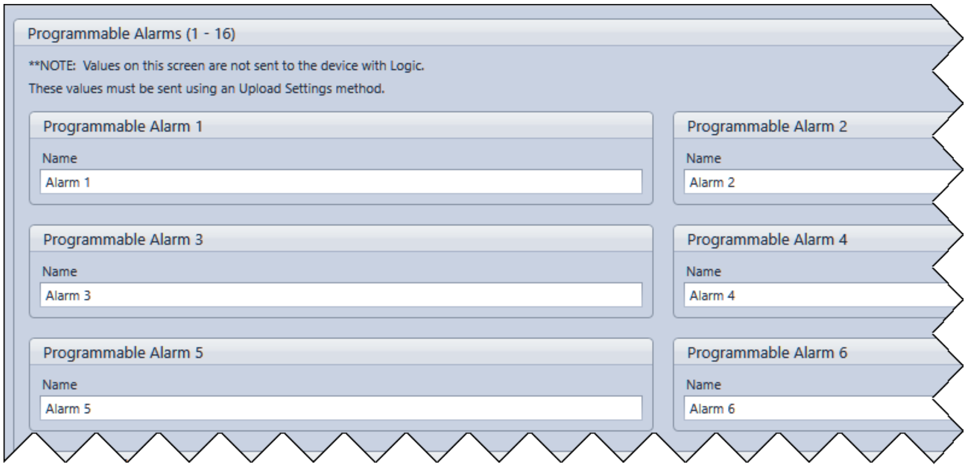


Figure 54-2. Programmable Alarms Settings Screen

Retrieving Alarm Information

Navigation Path: Status, Alarms

Major and Minor alarms can be viewed through BESTCOMS*Plus*, the front-panel display and LED indicators, and the web page interface. Alarms are displayed in the fault reports and sequence of events reports.

To view alarms at the front-panel display, navigate to Reports > Targets & Alarms or press the Target and Alarm annunciator banner when active. All active alarms will be shown on this screen. The touchscreen can be used to scroll through the list of active alarms.

The BESTCOMS*Plus* Active Alarms screen is shown in Figure 54-3. Alarms can be reset by clicking the Reset Alarms button under the appropriate column.

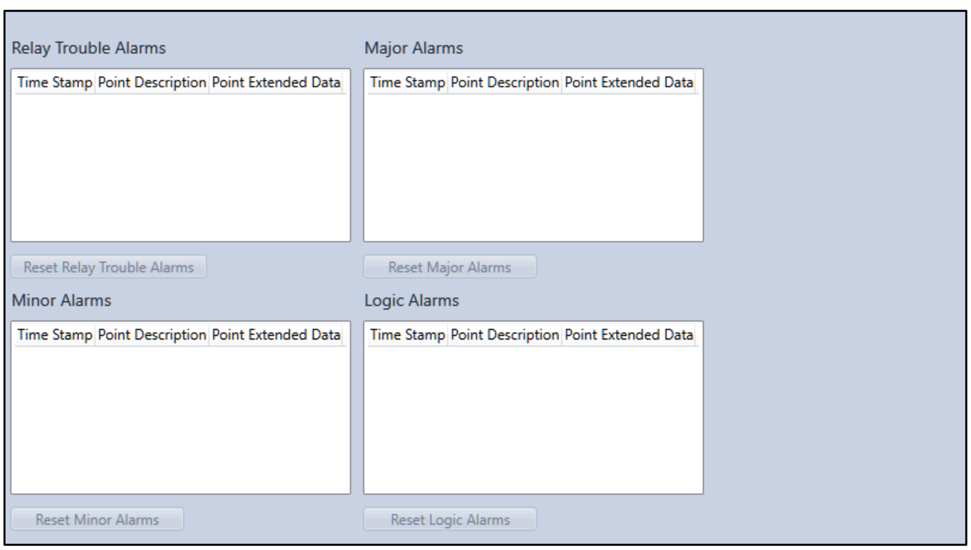


Figure 54-3. Active Alarms Screen

Diagnostic Log

Navigation Path: Reports, Advanced, Diagnostic Log

The Diagnostic Log reports health and other internal conditions of the BE1-FLEX. Along with Fault Recordings, Sequence of Events logs, Settings and Logic files, the Diagnostic Log can assist with diagnosing events and facilitate field repairs when applicable. Messages in the Diagnostic Log may not be intuitive. Please contact Basler Technical Support for interpretation as needed. Boards and firmware are designed to be updated or changed in the field. Diagnostic Logs can be download and cleared from BESTCOMS*Plus* by navigating to Metering, Reports, Advanced, Diagnostic Log.

Resetting Alarms

A BESTlogic*Plus* expression can be used to reset the alarms. Use the Settings Explorer within BESTCOMS*Plus* to open the BESTlogic*Plus* Programmable Logic tree branch. Select the Alarm Status logic block from the list of Elements. The Logic Reset input will reset all logic alarms. The Minor Reset input will reset all minor alarms. The Major Reset input will reset all major alarms. Use the drag-and-drop method to connect a variable or series of variables to the Reset inputs. The Alarm Status logic block is shown in Figure 54-4.

Figure 54-4. Alarm Status Logic Block

Major and Minor alarms can be cleared by pressing the Reset Targets & Alarms button on the front-panel interface or web page interface from the Targets & Alarms screen or through BESTCOMS*Plus*.

Resetting targets or alarms clears the associated alarm LEDs. Depending on device security setup, a username and password may be required to reset alarms. Logging in is not required if the Unsecured Access Level for the access channel includes Control access. Alarm reset via the HMI can be set outside of security control via setting if desired, allowing reset without logging in. If not set outside, Control access is required. Refer to the *Security* chapter for more information.

An alarm reset is available as a status input in BESTlogic*Plus*. The Alarms Reset status input goes momentarily high when the Major, Minor, and Logic alarms are cleared. The Alarms Reset logic block is shown in Figure 54-5.

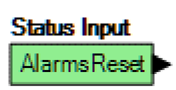


Figure 54-5. Alarms Reset Logic Block

55 • Sequence of Events

A Sequence of Events recorder (SoE) report is very useful in reconstructing the exact sequence and timing of events during a power disturbance or even normal system operations. The SoE tracks hundreds of data points by monitoring the internal and external status of the BE1-FLEX. Data points are recorded every 4 ms. All changes of state that occur during each scan are time tagged to 1 millisecond resolution. Over 8,000 records are stored in nonvolatile memory; when the SoE memory becomes full, the oldest record is replaced by the latest one acquired.

The SoE monitors the following points and conditions:

- Single-state events such as resetting demands or targets, changing settings, etc.
- Programmable logic variables
- Targets
- Relay trouble alarm variables
- Programmable alarm variables
- Output contact status
- Fault reporting trigger expressions

BE1-FLEX systems have three identification fields: Device ID, Station ID, and User ID. These fields are used in the header information lines of the sequence of events records. Refer to the *Device Information* chapter for information on BE1-FLEX identification settings.

For user-programmable logic variables (contact sensing inputs, contact outputs, and virtual control switches), the user-programmed variable name, and state names are logged in the SoE report instead of the generic variable name and state names.

When a monitored event occurs or a monitored variable changes state, the SoE logs all event data listed in Table 55-1.

Table 55-1. Event Data Recorded

Event Data Recorded	Description
Time Stamp	Relay Time, formatted to user time settings.
Elapsed Time	Time since last SOE record. True time increment may not be clear between records when the relay time is updated.
Time Status	Last successful time set source.
Point Description	SOE trigger condition.
Point Status	Status of condition.
Point Extended Data	Extended trigger condition description.

Sequence of Events Setup

Sequence of Events filtering may be desired to minimize data overload of non-pertinent information. The SoE Filtering screen is shown in Figure 55-1. Select events to be recorded in the Sequence of Events Log. All events are enabled by default.

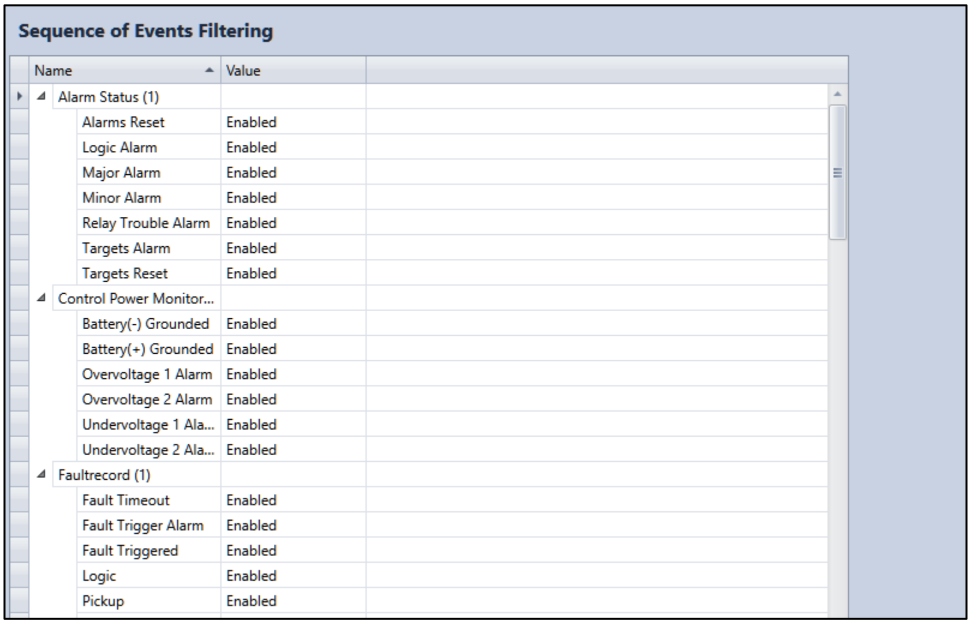


Figure 55-1. Sequence of Events Filtering Screen

Retrieving SoE Information

Sequence of events data can be obtained through BESTCOMS*Plus* and the web page interface.

Viewing and Downloading SoE Data through BESTCOMS*Plus*®

Use the Metering Explorer to open the Reports, Sequence of Events screen. If an active connection to a BE1-FLEX is present, the Sequence of Events will automatically download. Using the Options drop-down menu, you can copy, print, or save the Sequence of Events. The Refresh button is used to refresh/update the list of events. The Clear button will clear all events. Hover the mouse on the column headers and click on the filter icon in the column header to filter items. See Figure 55-2.

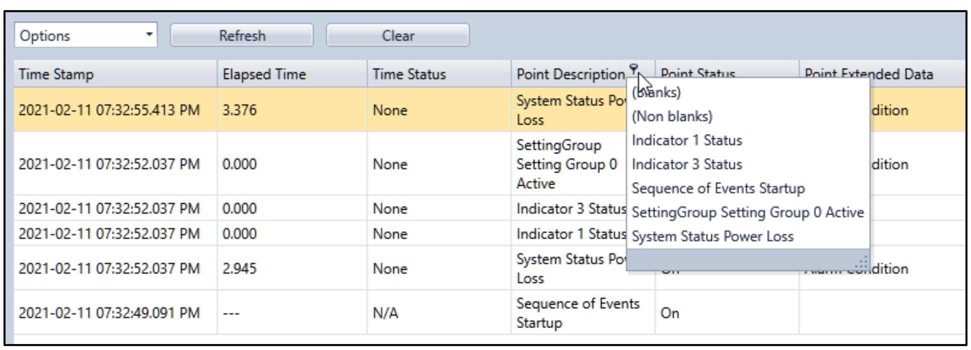


Figure 55-2. Sequence of Events Screen

Viewing SoE Data through the Web Page Interface

Sequence of Events summary can be viewed through the web page interface.

56 • Timing Characteristics

This chapter describes the operation timing for BE1-FLEX protection elements and time curve information.

Calculating Element Operation Time

As Figure 56-1 illustrates, total operation time for each element is the sum of the operation times for pickup, intentional time delay or time dial, logic, and output. Total breaker trip time includes breaker operation and possibly other time delays external to the BE1-FLEX.

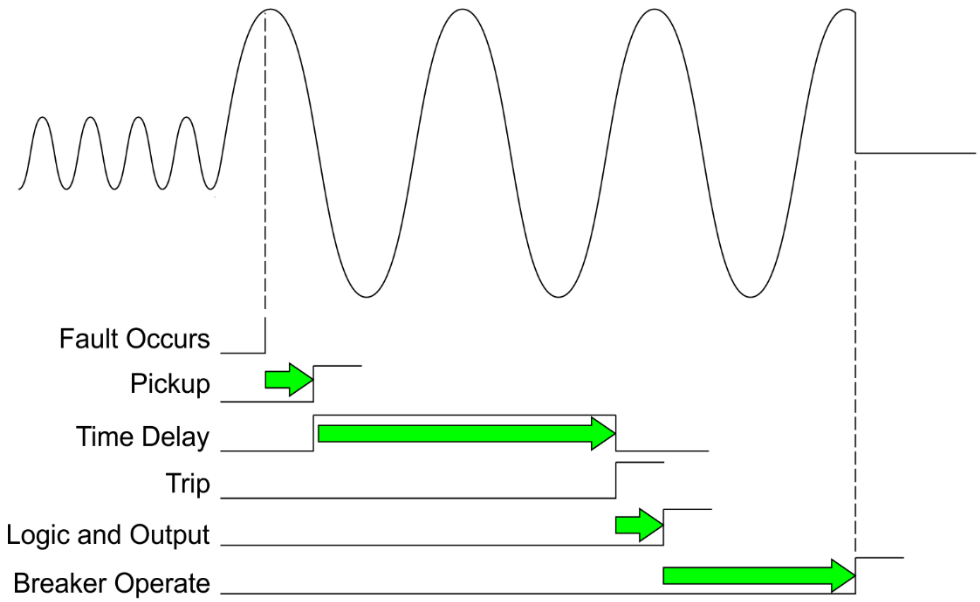


Figure 56-1. Element Operation Time

To calculate the total operation time for any BE1-FLEX element, add the pickup time, logic and output time, and any user-defined time delay or time dial. Element pickup times vary depending upon the function algorithm to enhance performance security.

Pickup times may be up to 20 milliseconds for all elements with the exceptions noted below:

- Add ¾ cycle when element inhibit is set to a non-zero value
- Add ¼ cycle when element directionality is set to forward or reverse
- 0 to 12 milliseconds for instantaneous overcurrent (50) elements set to Peak Detect Mode
- 2 to 3 cycles for Overfrequency/Underfrequency (81) elements
- 1 to 16 cycles for frequency rate of change (81 ROC) elements pending multiple of pickup (See the *Specifications* chapter for details.)

Logic and Output times may be up to 4 milliseconds for standard outputs.

Note
Protective elements blocked by 60FL should be set so that trip times are 20 milliseconds or greater to ensure proper coordination of blocking.

Configurable Inverse Timing (27, 51, 59 and 76)

General

The BE1-FLEX offers multiple inverse timing methods. Standard inverse overcurrent curves are selectable. In addition, user defined Programmable (P) Curves and Table (T) Curves can be created for Over and Under, AC and DC Voltage and Current Elements (27, 51, 59 and 76). Default setting curves are shown below in Figure 56-2, Figure 56-3, and Figure 56-4.

Table Curves provide for user curve creation from 2 to 40 points. Curves can be edited graphically or numerically and export/imported from external sources.

Characteristic curves for the inverse and definite time functions are defined by the following equations and comply with IEEE Std C37.112 - 2018 - *IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays*. Programmable curves follow these equations and are created by settings for A, B, C, N and R.

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

Equation 56-1 – Over Current and Voltage Trip

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

Equation 56-2 - Over Current and Voltage Reset

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

Equation 56-3 – Under Voltage Trip

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

Equation 56-4 – Under Voltage Reset

T_T = Time to trip when $M \geq 1$

T_R = Time to reset if BE1-FLEX is set for integrating reset when $M < 1$. Otherwise, reset is 50 milliseconds or less

D = Time Dial setting (0.0 to 9.9)*

M = Multiple of Pickup setting (0 to 40)

A, B, C, N, K = Constants for the particular curve

R = Constant defining the reset time.

* Timing range is one second times the Time Dial setting when the F (fixed) curve is selected.

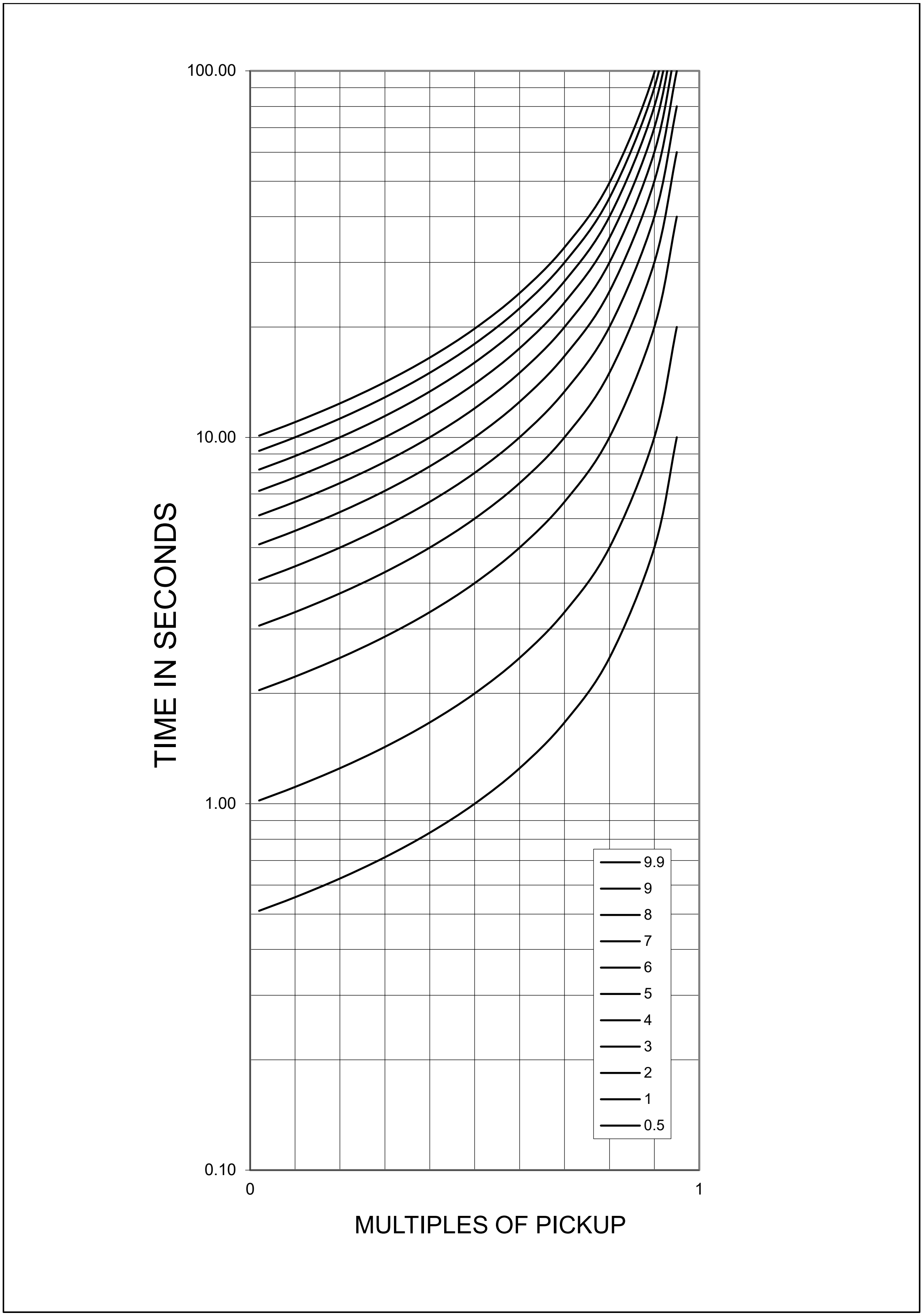


Figure 56-2. Undervoltage (27) Inverse Time Curve (Default Constants)

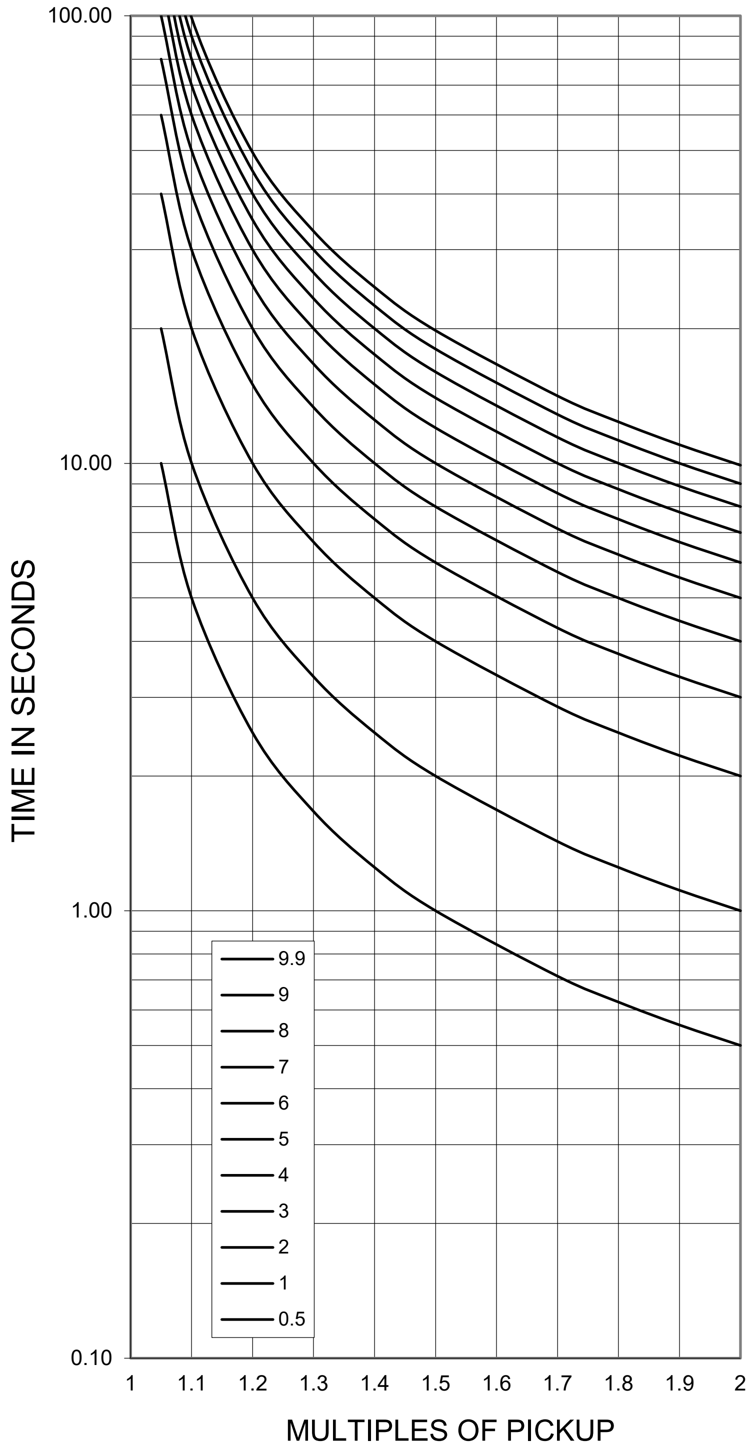


Figure 56-3. Overvoltage (59) Inverse Time Curve (Default Constants)

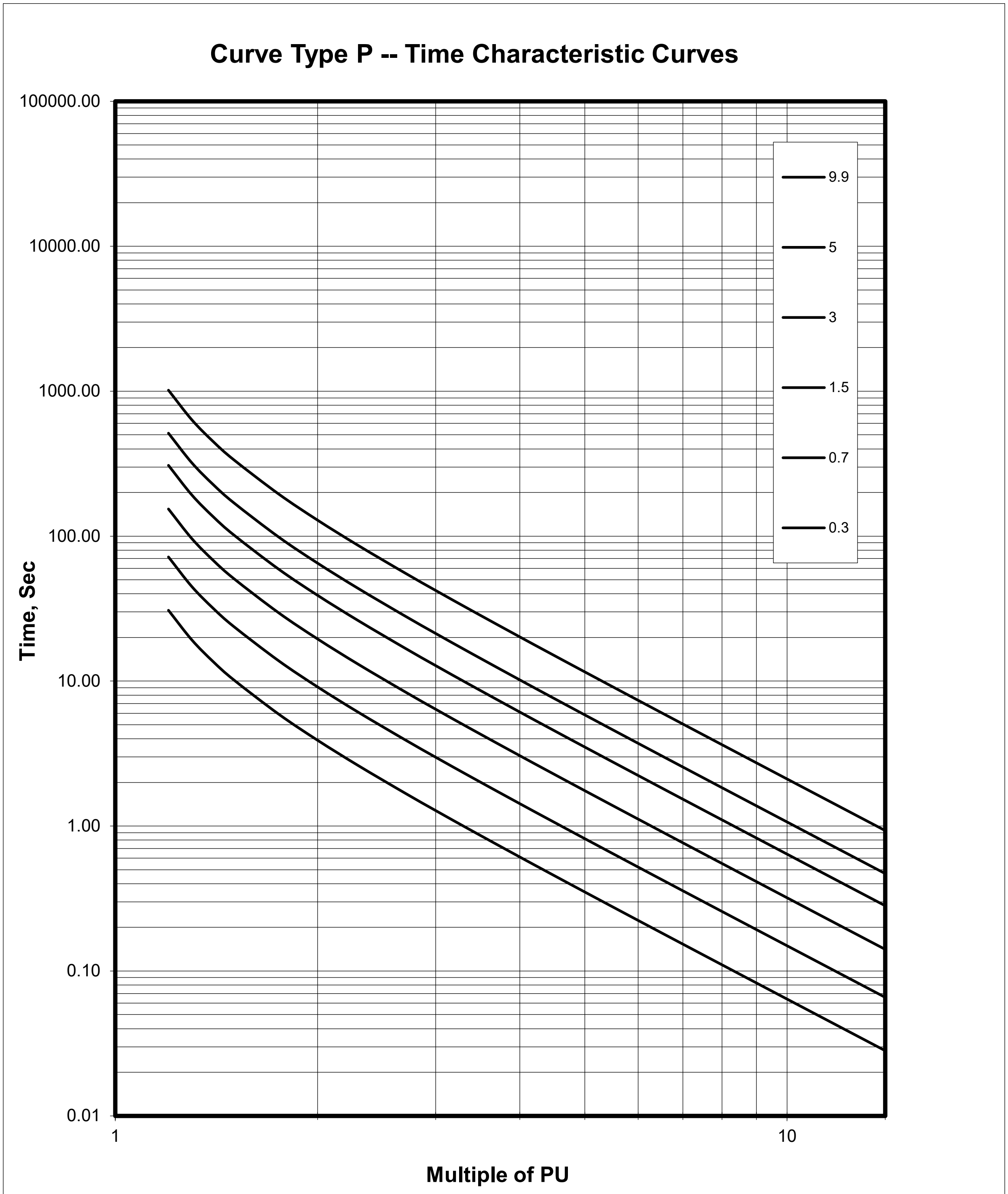


Figure 56-4. DC Overcurrent (76) Inverse Time Curve (Default Constants)

Standard Inverse Overcurrent (51)

General

The inverse overcurrent (51) time curves provided by the BE1-FLEX emulate most of the common electromechanical, induction-disk, overcurrent relays. Additionally, IEEE, IEC, and User curves are available to provide nearly any time characteristic needed. To further improve proper BE1-FLEX coordination, selection of integrated reset or instantaneous reset characteristics is also provided.

Curve Specifications

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

Twenty-two inverse time functions, one fixed time function, one 46 time function, one programmable time function, and Table Curve functions can be selected.

Table 56-1 lists time characteristic curve constants. See the figures after the tables for graphs of the characteristics.

Table 56-1. 51 Time Characteristic Curve Constants

Curve Selection	Curve Name	Trip Characteristic Constants					Reset *
		A	B	C	N	K	R
S1	CO Short Inverse	0.2663	0.03393	1	1.2969	0	0.5
S2	IAC Short Inverse	0.0286	0.0208	1	0.9844	0	0.094
A	Standard Inverse	0.01414	0	1	0.02	0	2
A1	IEC Inverse	0.14	0	1	0.02	0	2
I1	CO Inverse Time	8.9341	0.17966	1	2.0938	0	9
I2	IAC Inverse Time	0.2747	0.10426	1	0.4375	0	0.8868
M	CO Moderately Inverse	0.3022	0.1284	1	0.5	0	1.75
D1	IEEE Moderately Inverse	0.0515	0.114	1	0.02	0	4.85
L1	CO Long Inverse	5.6143	2.18592	1	1	0	15.75
L2	IAC Long Inverse	2.3955	0	1	0.3125	0	7.8001
G	Long Time Inverse (I^2t)	12.1212	0	1	1	0	29
V1	CO Very Inverse	5.4678	0.10814	1	2.0469	0	5.5
V2	IAC Very Inverse	4.4309	0.0991	1	1.9531	0	5.8231
B	Very Inverse (I^2t)	1.4636	0	1	1.0469	0	3.25
B1	IEC Very Inverse	13.5	0	1	1	0	3.25
E3	IEEE Very Inverse	19.61	0.491	1	2	0	21.6
E1	CO Extremely Inverse	7.7624	0.02758	1	2.0938	0	7.75
E2	IAC Extremely Inverse	4.9883	0.0129	1	2.0469	0	4.7742
C	Extremely Inverse (I^2t)	8.2506	0	1	2.0469	0	8
C1	IEC Extremely Inverse	80	0	1	2	0	8
F1	IEEE Extremely Inverse	28.2	0.1217	1	2	0	29.1
D	CO Definite Time	0.4797	0.21359	1	1.5625	0	0.875
F	Fixed Time ‡	0	1	0	0	0	1
46	K Factor	†	0	0	2	0	100

∗ Instantaneous or integrating reset is selected on the Inverse Overcurrent setup screen in BESTCOMS*Plus*®.

† Constant A is variable for the 46 curve and is determined, as necessary, based on system full-load current setting, minimum pickup, and K factor settings.

‡ Curve F has a fixed delay of one second times the Time Dial setting.

Time Overcurrent Characteristic Curve Graphs

The figures after the tables illustrate the characteristic curves of the BE1-FLEX. Table 56-2 cross-references each curve to existing electromechanical relay characteristics. Equivalent time dial settings were calculated at a value of five times pickup.

Table 56-2. Characteristic Curve Cross-Reference

Curve	Curve Name	Similar To
S1	CO Short Inverse	ABB CO-2
S2	IAC Short Inverse	GE IAC-55
A	Standard Inverse	Refer to BS 142
A1	IEC Inverse	Refer to IEC 60255-151 Ed. 1
I1	CO Inverse Time	ABB CO-8
I2	IAC Inverse Time	GE IAC-51
M	CO Moderately Inverse	ABB CO-7
D1	IEEE Moderately Inverse	Refer to IEC 60255-151 Ed. 1
L1	CO Long Inverse	ABB CO-5
L2	IAC Long Inverse	GE IAC-66
G	Long Time Inverse (I^2t)	Refer to BS 142
V1	CO Very Inverse	ABB CO-9
V2	IAC Very Inverse	GE IAC-53
B	Very Inverse (I^2t)	Refer to BS 142
B1	IEC Very Inverse	Refer to IEC 60255-151 Ed. 1
E3	IEEE Very Inverse	Refer to IEC 60255-151 Ed. 1
E1	CO Extremely Inverse	ABB CO-11
E2	IAC Extremely Inverse	GE IAC-77
C	Extremely Inverse (I^2t)	Refer to BS 142
C1	IEC Extremely Inverse	Refer to IEC 60255-151 Ed. 1
F1	IEEE Extremely Inverse	Refer to IEC 60255-151 Ed. 1
D	CO Definite Time	ABB CO-6

Time Dial Setting Cross-Reference

Although the time characteristic curve shapes have been optimized for each BE1-FLEX, time dial settings of Basler Electric protection systems are not identical to the settings of electromechanical induction disk overcurrent relays. Table 56-3 helps you convert the time dial settings of induction disk relays to the equivalent setting for Basler Electric protection systems. Enter time dial settings using BESTCOMS*Plus*. For more information, refer to the *Inverse Overcurrent (51)* chapter.

Using Table 56-3

Cross-reference table values were obtained by inspection of published electromechanical time current characteristic curves. The time delay for a current of five times tap was entered into the time dial calculator function for each time dial setting. The equivalent Basler Electric time dial setting was then entered into the cross-reference table.

If your electromechanical relay time dial setting is between the values provided in the table, it will be necessary to estimate the correct intermediate value between the electromechanical setting and the Basler Electric setting.

Basler Electric protection systems have a maximum time dial setting of 9.9. The Basler Electric equivalent time dial setting for the electromechanical maximum setting is provided in the cross-reference table even if it exceeds 9.9. This allows interpolation as noted above.

Basler Electric time current characteristics are determined by a linear mathematical equation. The induction disk of an electromechanical relay has a certain degree of non-linearity due to inertial and friction effects. For this reason, even though every effort has been made to provide characteristic curves with minimum deviation from the published electromechanical curves, slight deviations can exist between them.

In applications where the time coordination between curves is extremely close, we recommend that you choose the optimal time dial setting by inspection of the coordination study. In applications where coordination is tight, it is recommended that you retrofit your circuits with Basler Electric protection systems to ensure high timing accuracy. Table and programmable curves can provide more defined coordination if standard curves are insufficient.

Table 56-3. Time Dial Setting Cross-Reference

Curve	Equivalent To	Electromechanical Relay Time Dial Setting											
		0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
		Basler Electric Equivalent Time Dial Setting											
S1	ABB CO-2	0.3	0.8	1.7	2.4	3.4	4.2	5.0	5.8	6.7	7.7	8.6	9.7
S2	GE IAC-55	0.2	1.0	2.0	3.1	4.0	4.9	6.1	7.2	8.1	8.9	9.8	n/a
I1	ABB CO-8	0.3	0.7	1.5	2.3	3.2	4.0	5.0	5.8	6.8	7.6	8.7	n/a
I2	GE IAC-51	0.6	1.0	1.9	2.7	3.7	4.8	5.7	6.8	8.0	9.3	n/a	n/a
M	ABB CO-7	0.4	0.8	1.7	2.5	3.3	4.3	5.3	6.1	7.0	8.0	9.0	9.8
L1	ABB CO-5	0.4	0.8	1.5	2.3	3.3	4.2	5.0	6.0	7.0	7.8	8.8	9.9
L2	GE IAC-66	0.4	0.9	1.8	2.7	3.9	4.9	6.3	7.2	8.5	9.7	n/a	n/a
V1	ABB CO-9	0.3	0.7	1.4	2.1	3.0	3.9	4.8	5.7	6.7	7.8	8.7	9.6
V2	GE IAC-53	0.4	0.8	1.6	2.4	3.4	4.3	5.1	6.3	7.2	8.4	9.6	n/a
E1	ABB CO-11	0.3	0.7	1.5	2.4	3.2	4.2	5.0	5.7	6.6	7.8	8.5	n/a
E2	GE IAC-77	0.5	1.0	1.9	2.7	3.5	4.3	5.2	6.2	7.4	8.2	9.9	n/a
D	ABB CO-6	0.5	1.1	2.0	2.9	3.7	4.5	5.0	5.9	7.2	8.0	8.9	n/a

The 46 Curve

The 46 curve (Figure 56-27) is a special curve designed to emulate the $(I_2)^2$ t withstand ratings of generators using what is frequently referred to as the generator K factor.

The 46 Curve Characteristics

46 Pickup Current

Generators have a maximum continuous rating for negative sequence current. This is typically expressed as a percent of stator rating. When using the 46 curve, the user should convert the continuous I^2 rating data to actual secondary current at the BE1-FLEX. This value (plus some margin, if appropriate) should be entered as the pickup setting. For example, if a generator's rated full-load current is 5 amperes, a pu setting of 0.5 A would allow 10% continuous I_2.

46 Time Dial (= Generator K factor)

The amount of time that a generator can withstand a given level of unbalance is defined by Equation 56-5.

$$t = \frac{K}{(I_2)^2}$$

Equation 56-5

The K factor gives the time that a generator can withstand 1 per unit negative sequence current. For example, with a K factor of 20, since $(I_2)^2$ becomes 1 at 1 per unit of current, the generator can withstand the condition for 20 seconds. Typical values for generator K factors are in the 2 to 40 range. The BE1-FLEX uses the Circuits Secondary Phase Current Nominal (I_{nom}) Setting to determine what corresponds to 1 per unit current in the generator.

When curve 46 is selected, the BE1-FLEX changes the range of the allowed time dial to 1 to 99 (instead of the time dial range of 0.1 to 9.9 for all the other curves). The user should enter the "K" factor of the generator into the time dial field.

BE1-FLEX Equation

When the 46 function is used, the BE1-FLEX uses the K factor (i.e., 46 time dial setting), 46 minimum pickup setting and generator full-load current to create a constant Z (see Equation 56-6).

$$Z = 46\, Time\ Dial \left(\frac{I_{Nom\ Setting}}{46\ Pickup\ Setting}\right)^2$$

Equation 56-6

The time to trip equation used in the BE1-FLEX is:

$$T_T = \frac{Z}{M^2} + 0.028\ seconds$$

Equation 56-7

where:

$$M = \frac{Measured\ I_2}{46\ Pickup\ Setting}$$

Equation 56-8

which, when M > 1, reduces to:

$$T_T = 46\, Time\ Dial \left(\frac{I_{Nom\ Setting}}{I_2 Measured}\right)^2$$

Equation 56-9

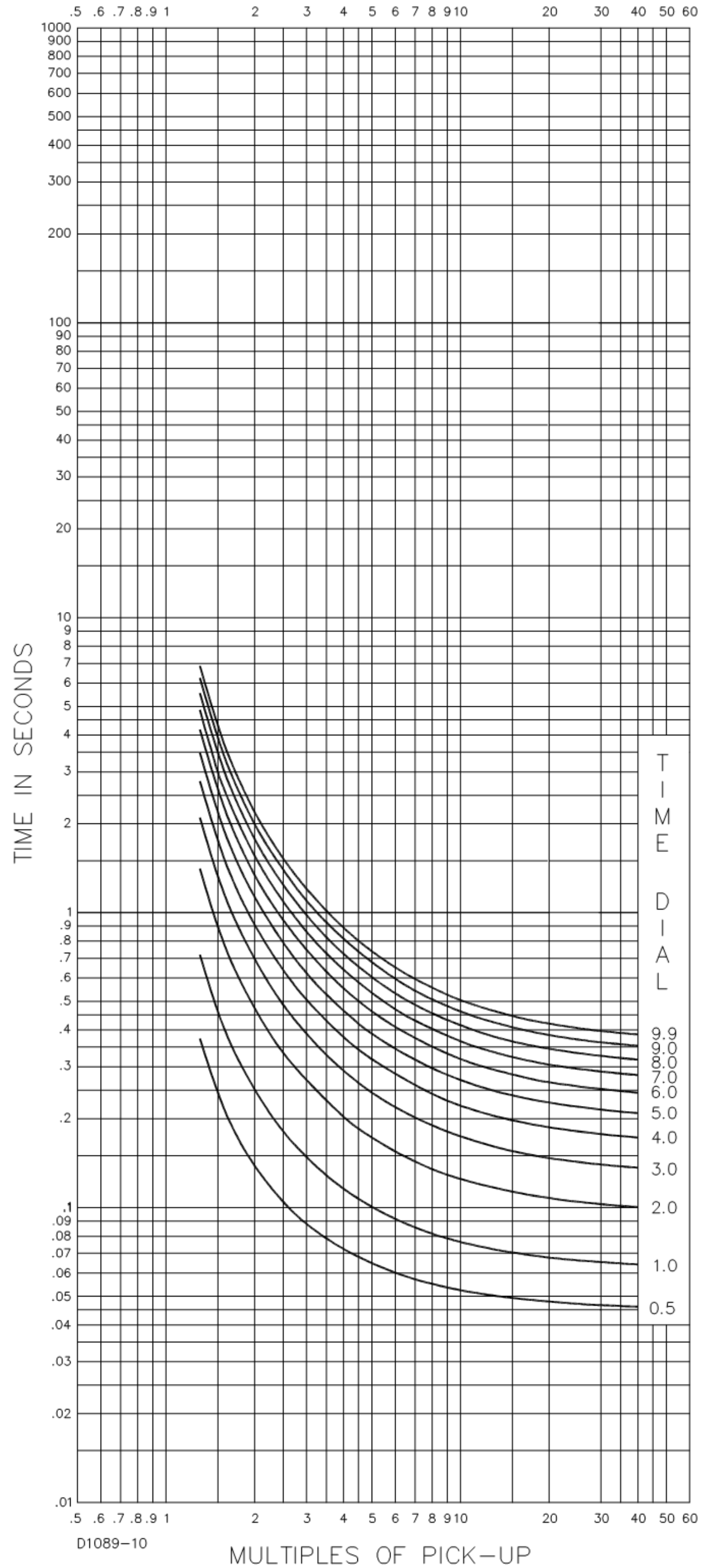


Figure 56-5. Time Characteristic Curve S1, Short Inverse (Similar to ABB CO-2)

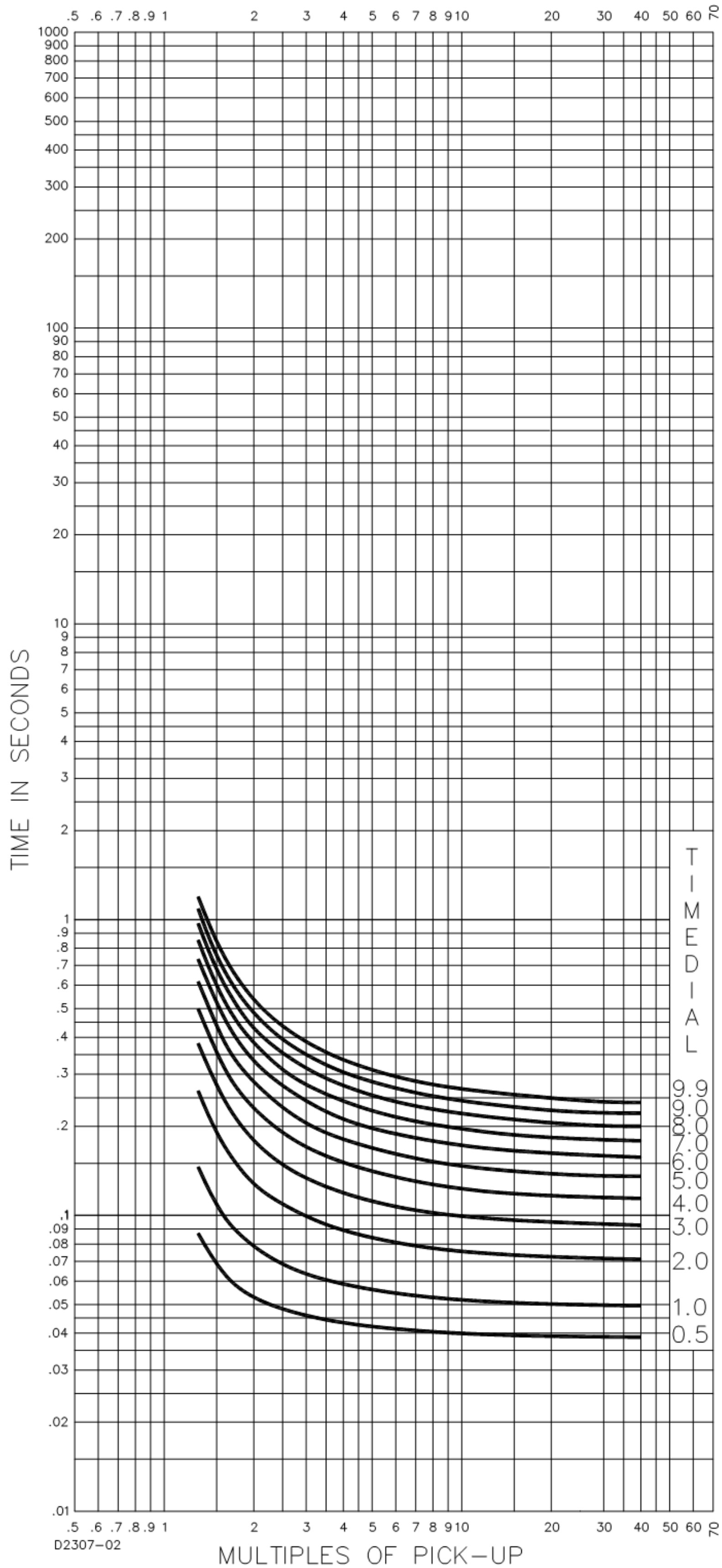


Figure 56-6. Time Characteristic Curve S2, Short Inverse (Similar To GE IAC-55)

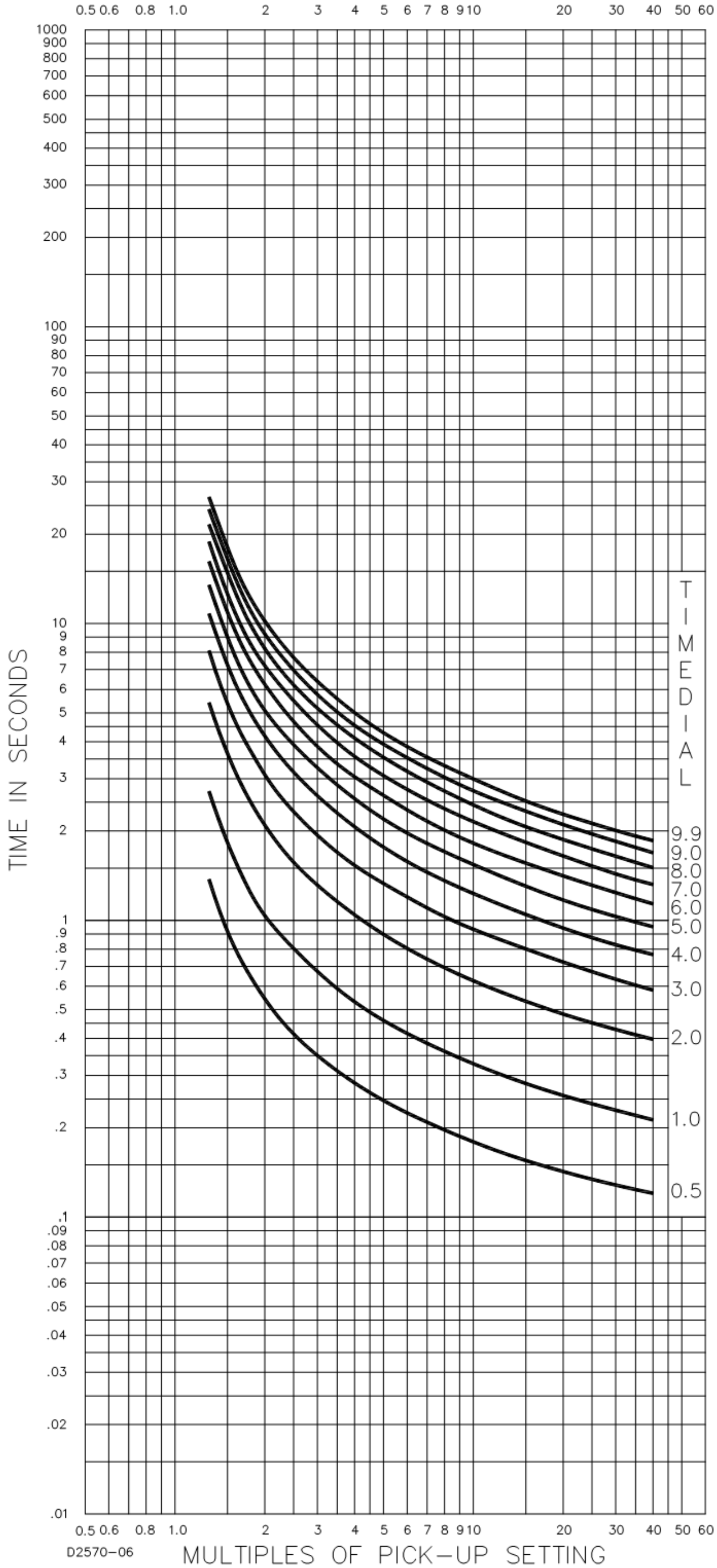


Figure 56-7. Time Characteristic Curve A, Standard Inverse (BS 142)

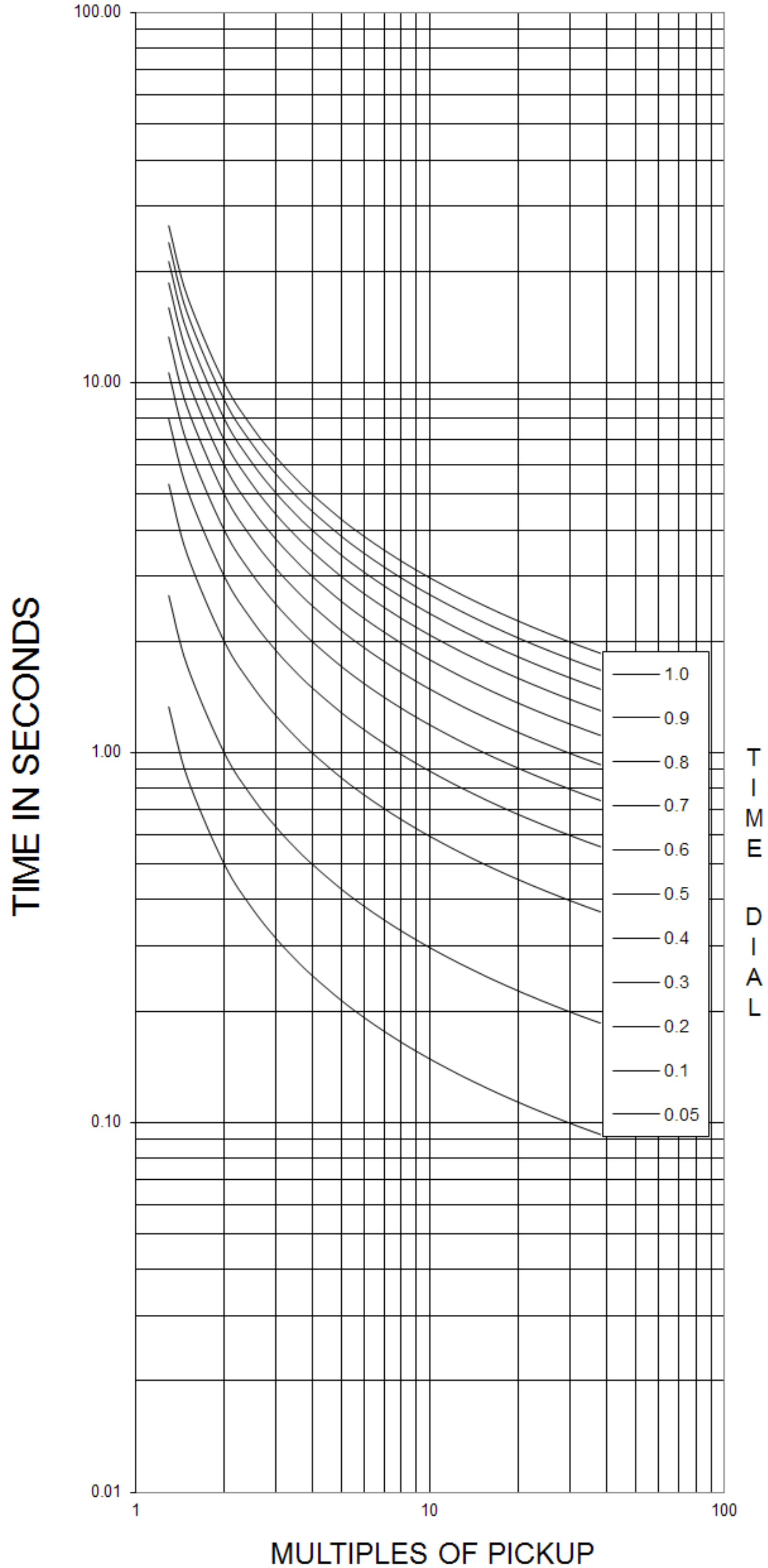


Figure 56-8. Time Characteristic Curve A1, Inverse (IEC 60255-151 Ed. 1)

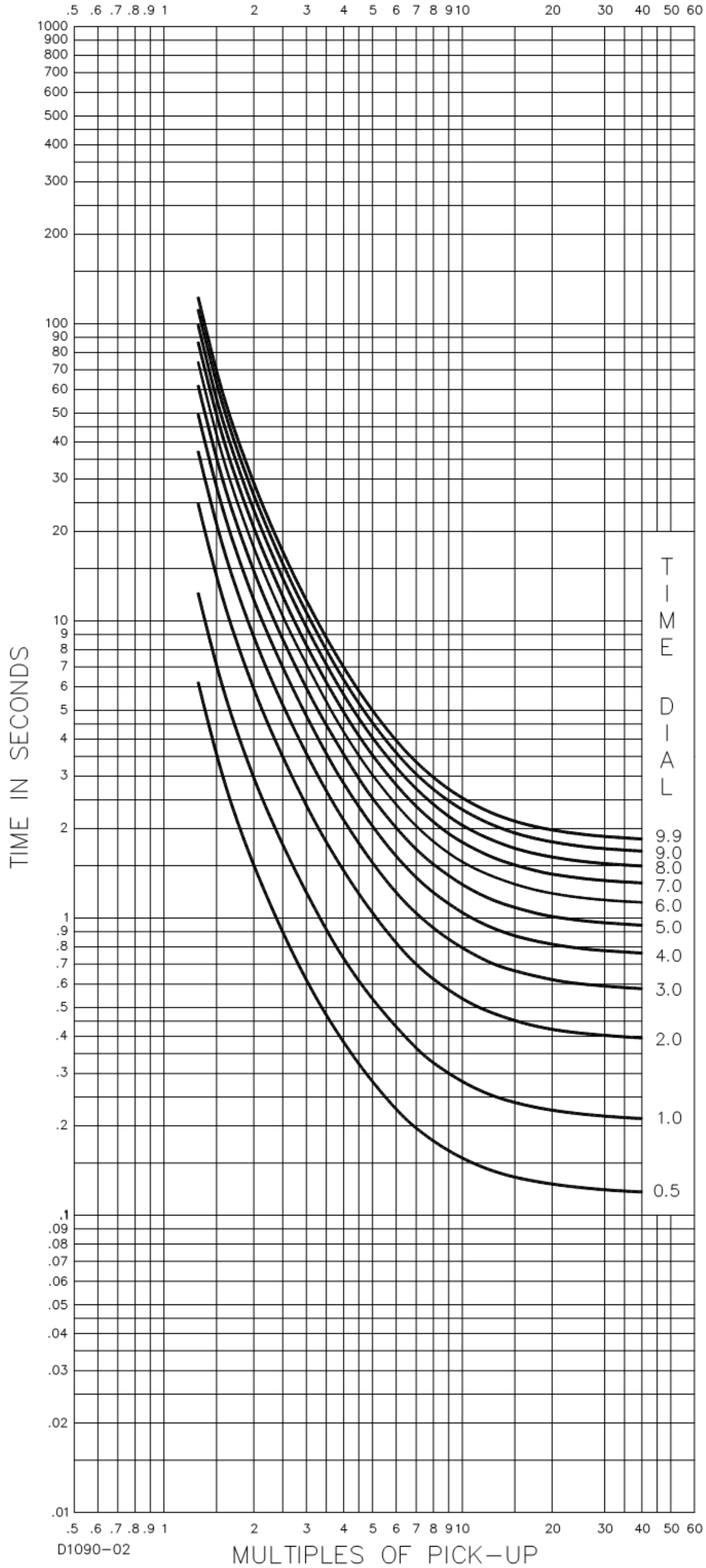


Figure 56-9. Time Characteristic Curve I1, Inverse Time (Similar to ABB CO-8)

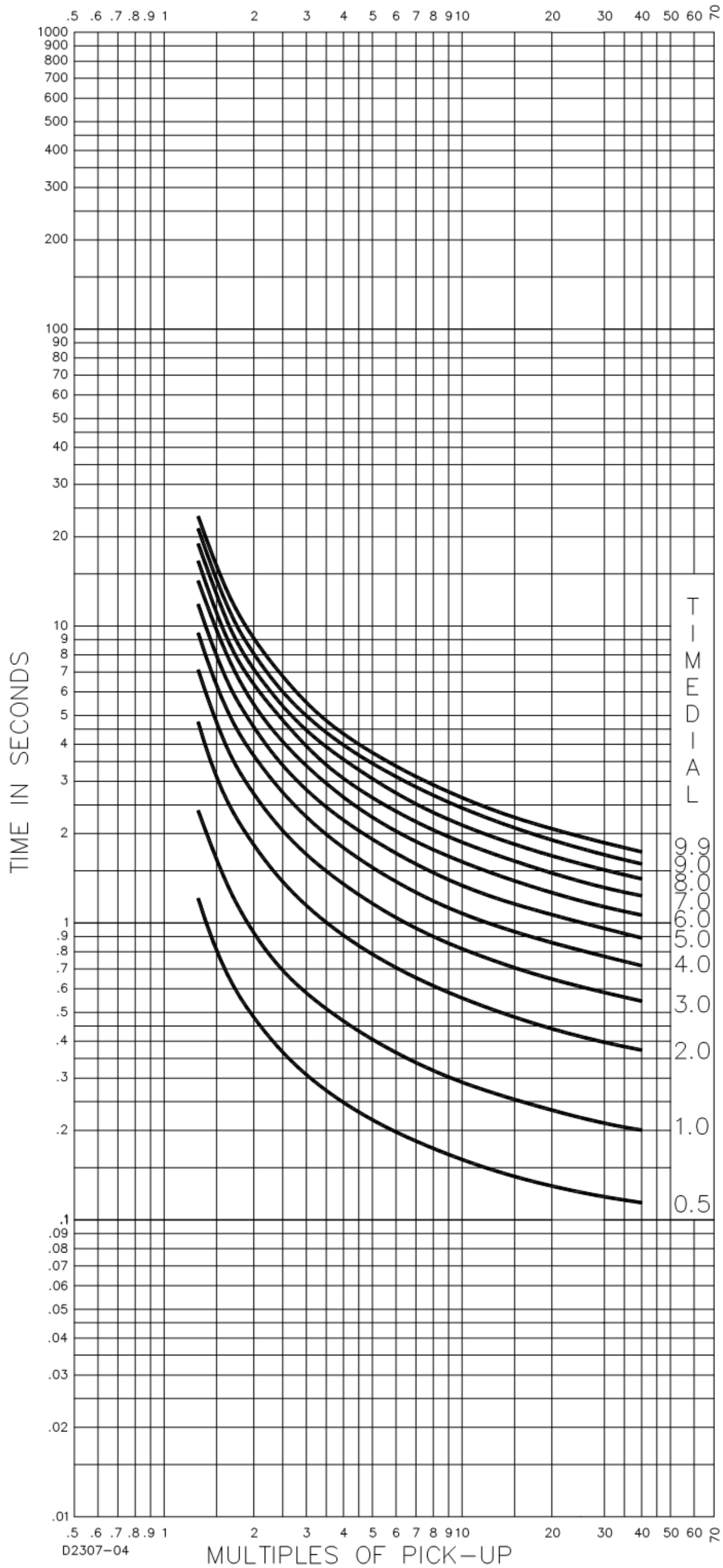


Figure 56-10. Time Characteristic Curve I2, Inverse Time (Similar to GE IAC-51)

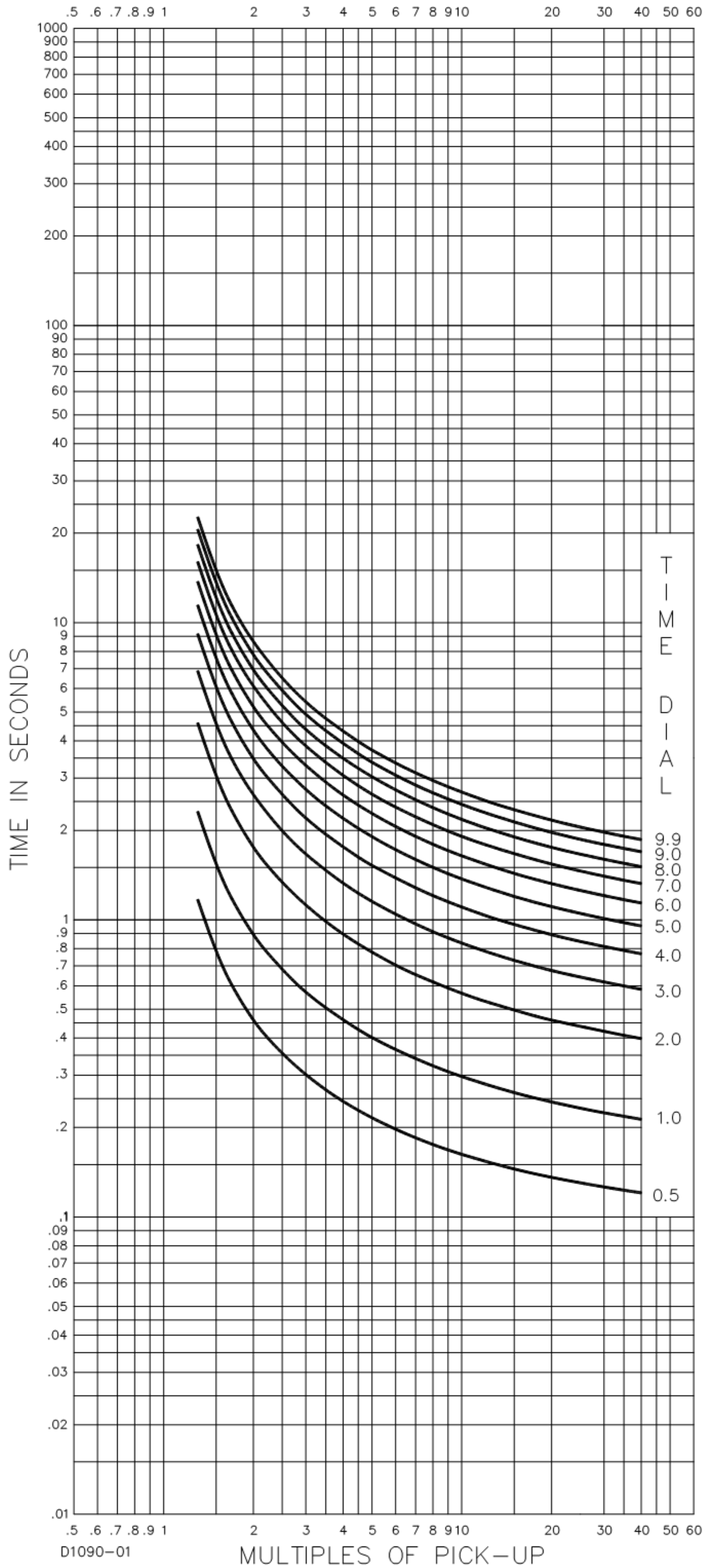


Figure 56-11. Time Characteristic Curve M, Moderately Inverse (Similar to ABB CO-7)

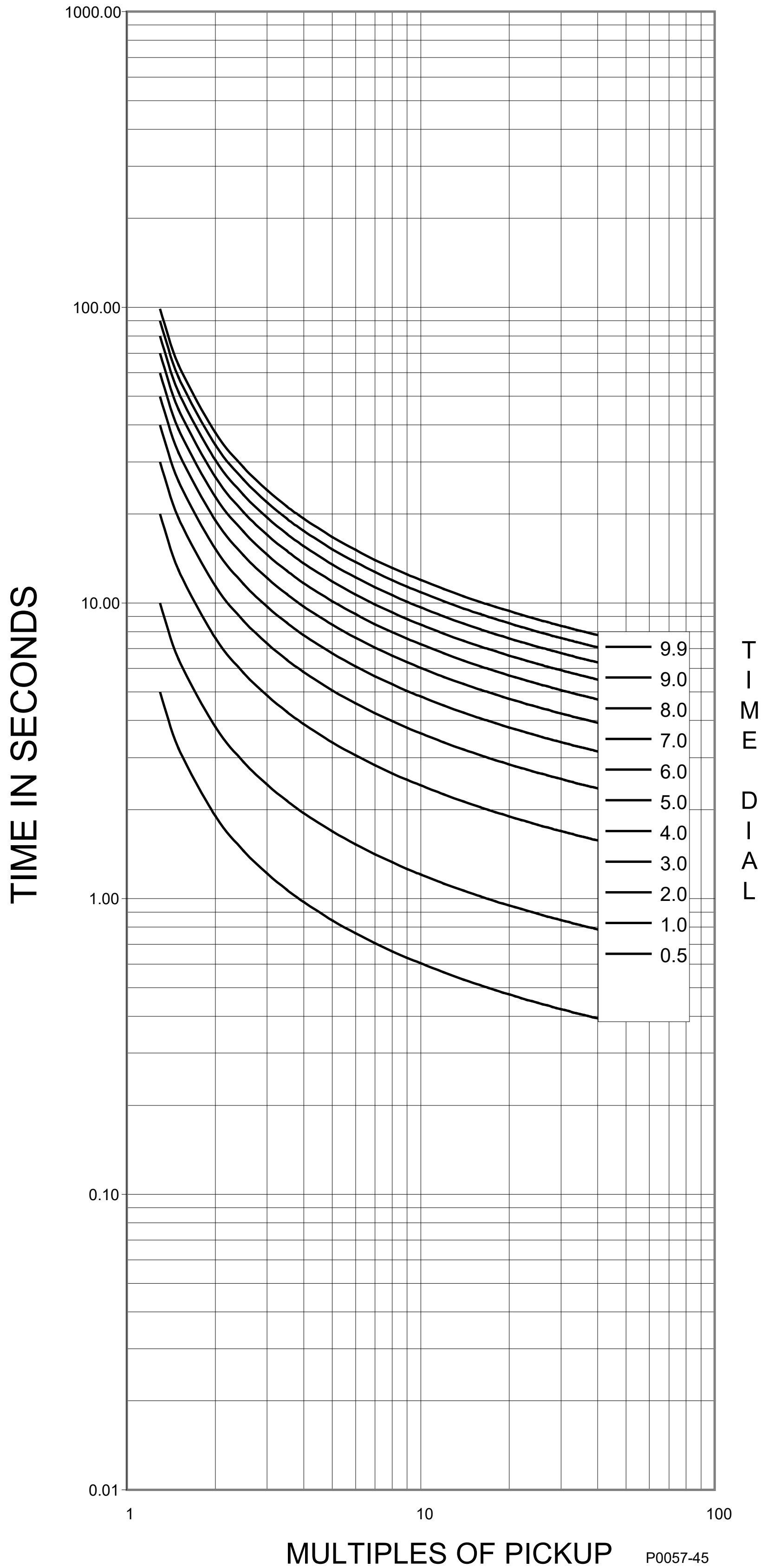


Figure 56-12. Time Characteristic Curve D1, Moderately Inverse (IEC 60255-151 Ed. 1)

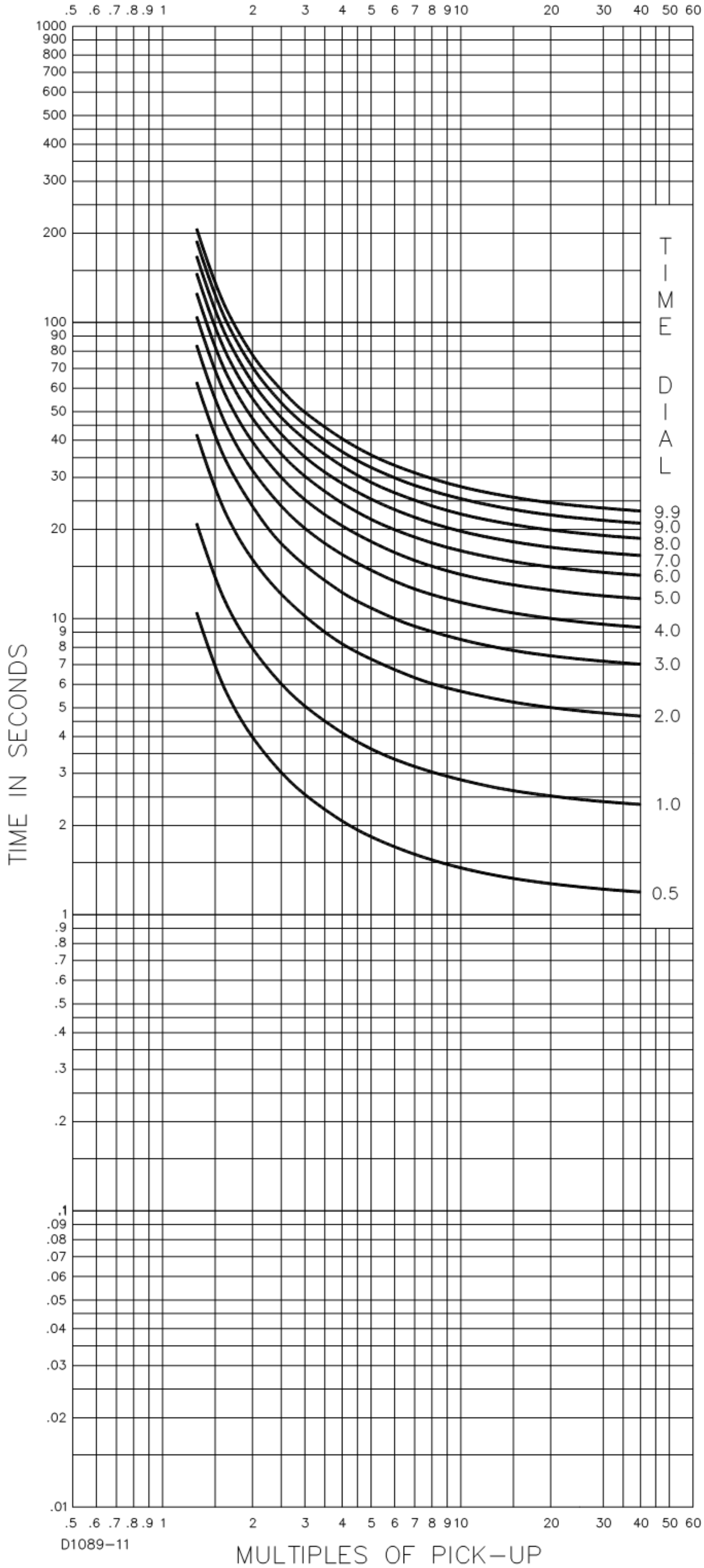


Figure 56-13. Time Characteristic Curve L1, Long Inverse (Similar to ABB CO-5)

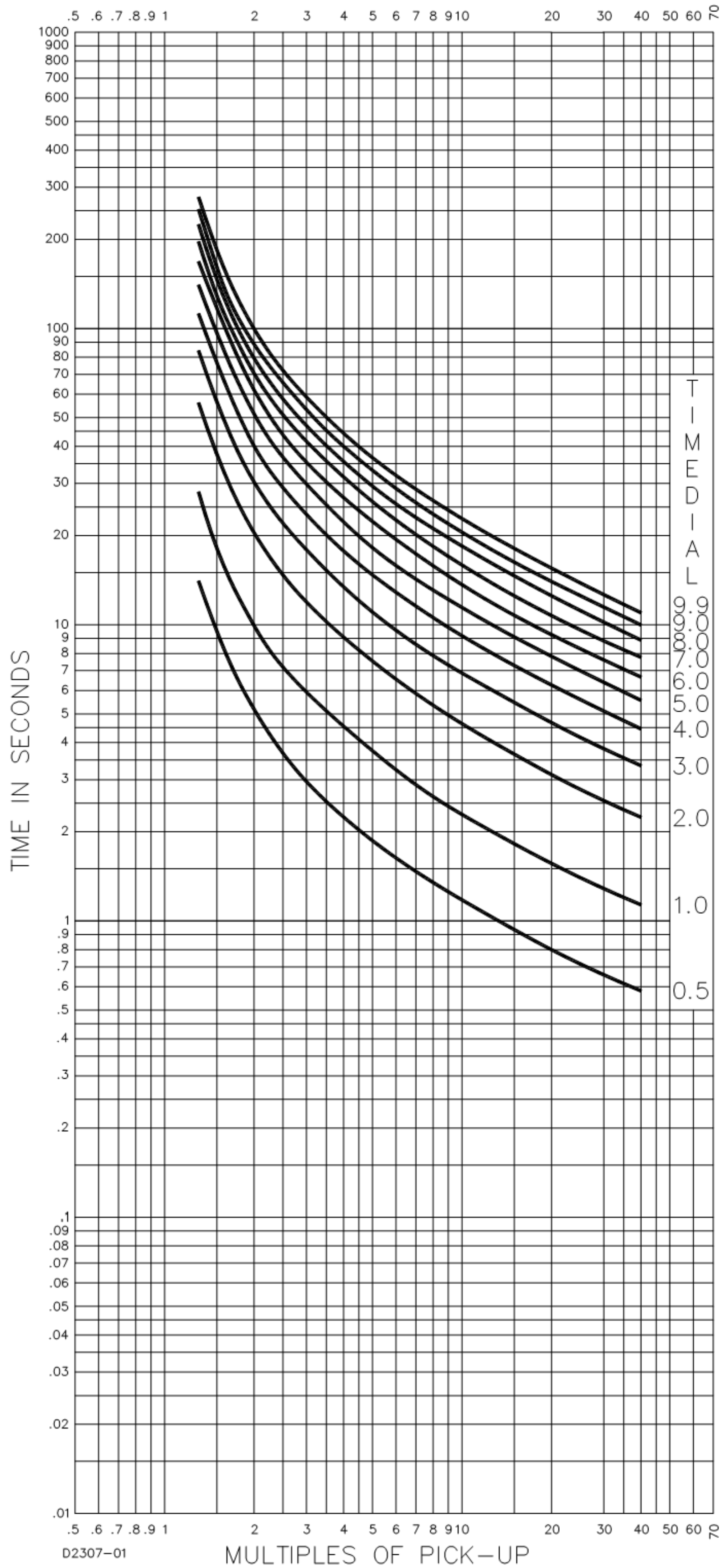


Figure 56-14. Time Characteristic Curve L2, Long Inverse (Similar To GE IAC-66)

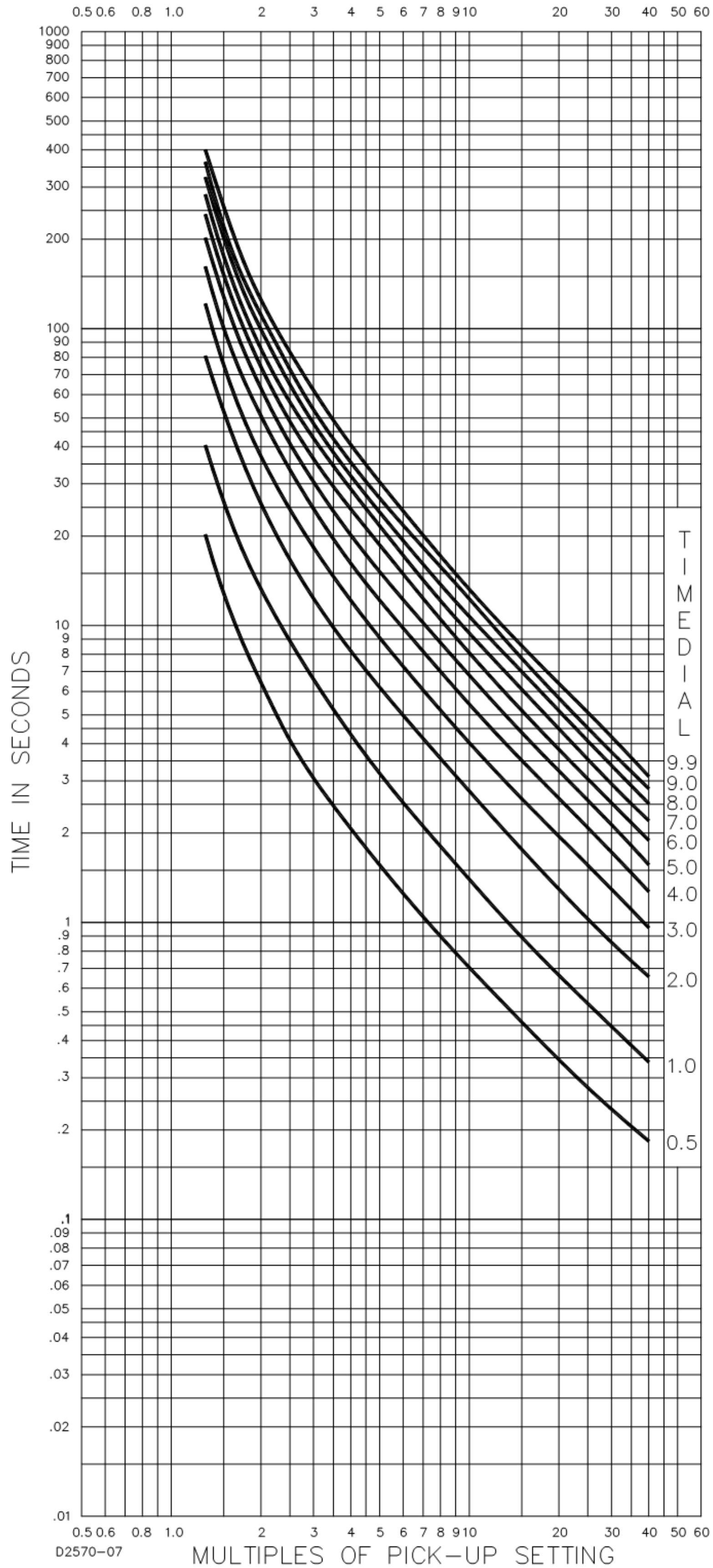


Figure 56-15. Time Characteristic Curve G, Long Time Inverse (BS 142)

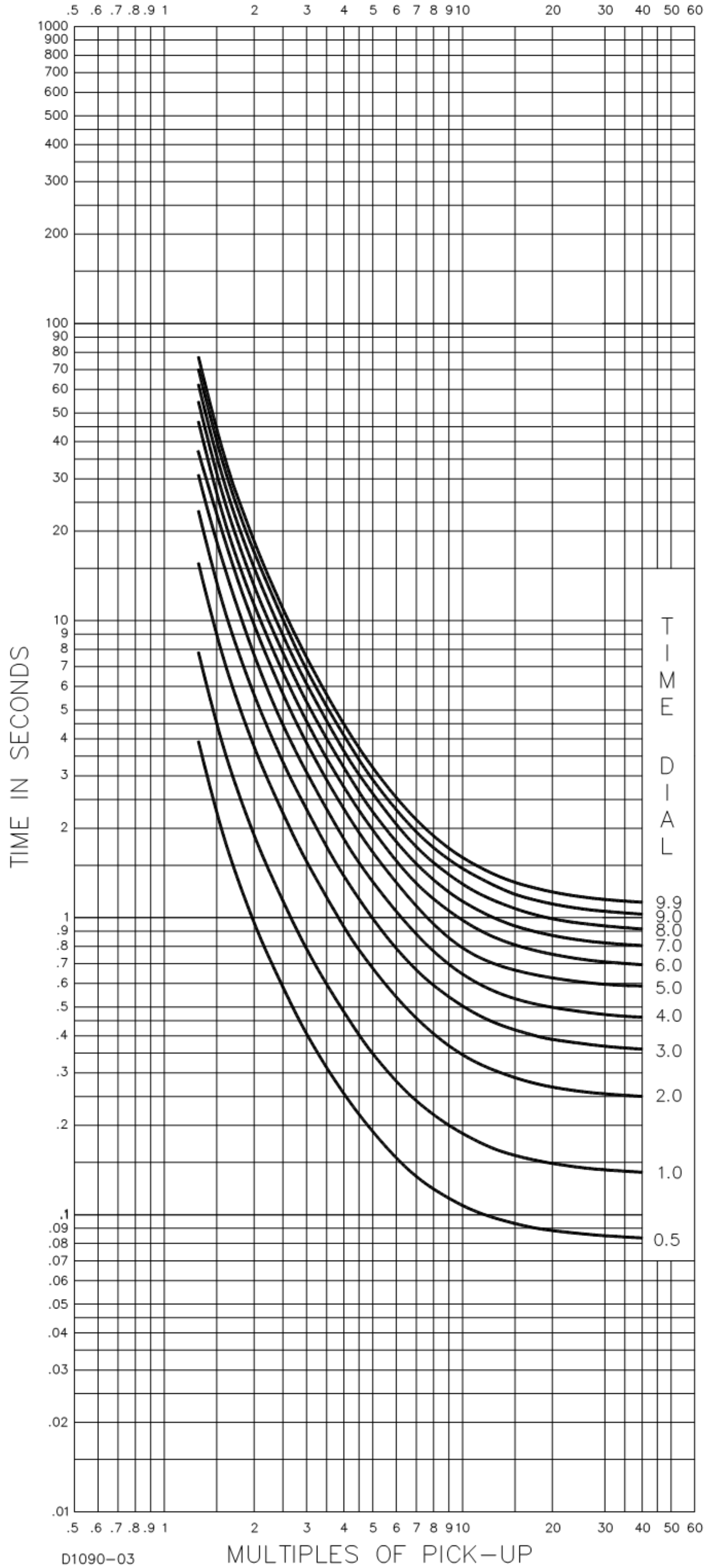


Figure 56-16. Time Characteristic Curve V1, Very Inverse (Similar to ABB CO-9)

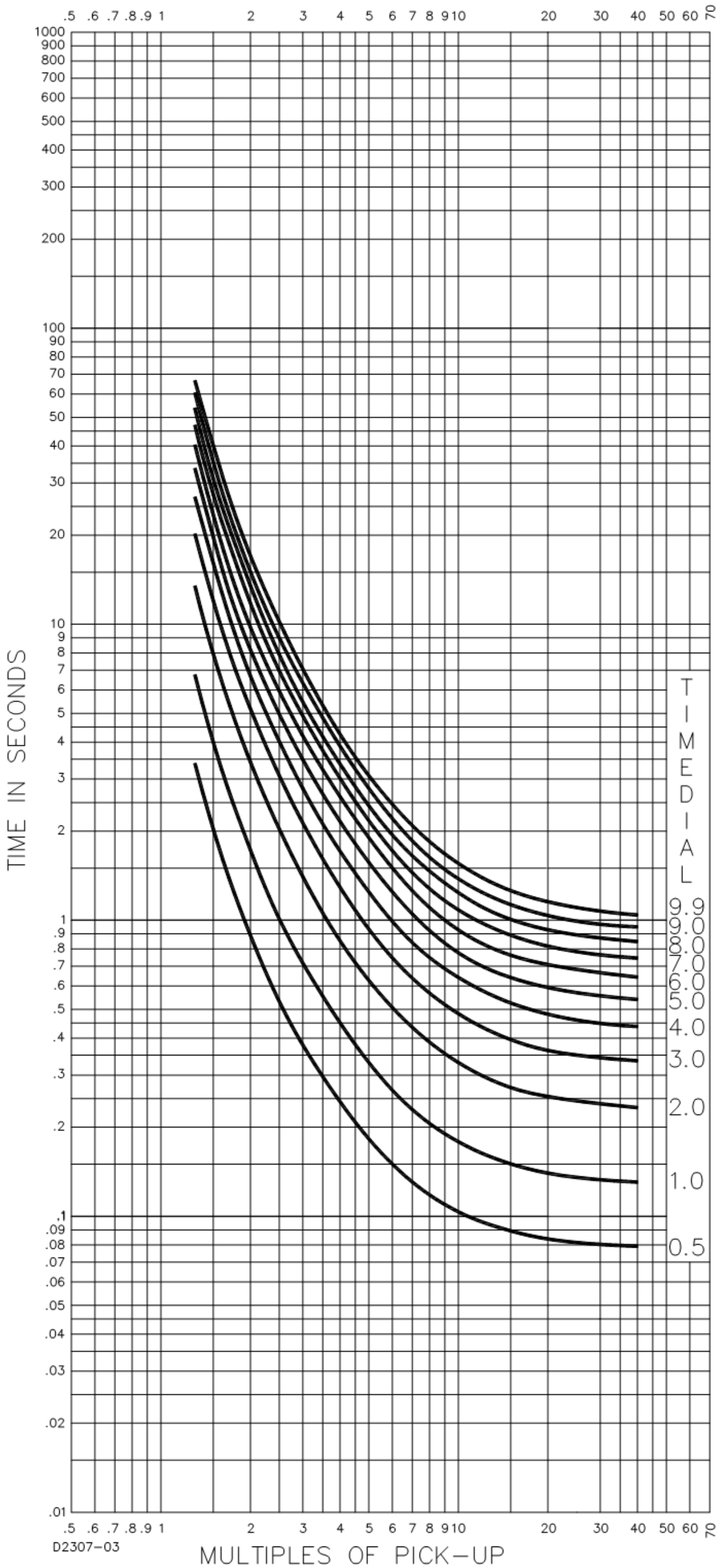


Figure 56-17. Time Characteristic Curve V2, Very Inverse (Similar to GE IAC-53)

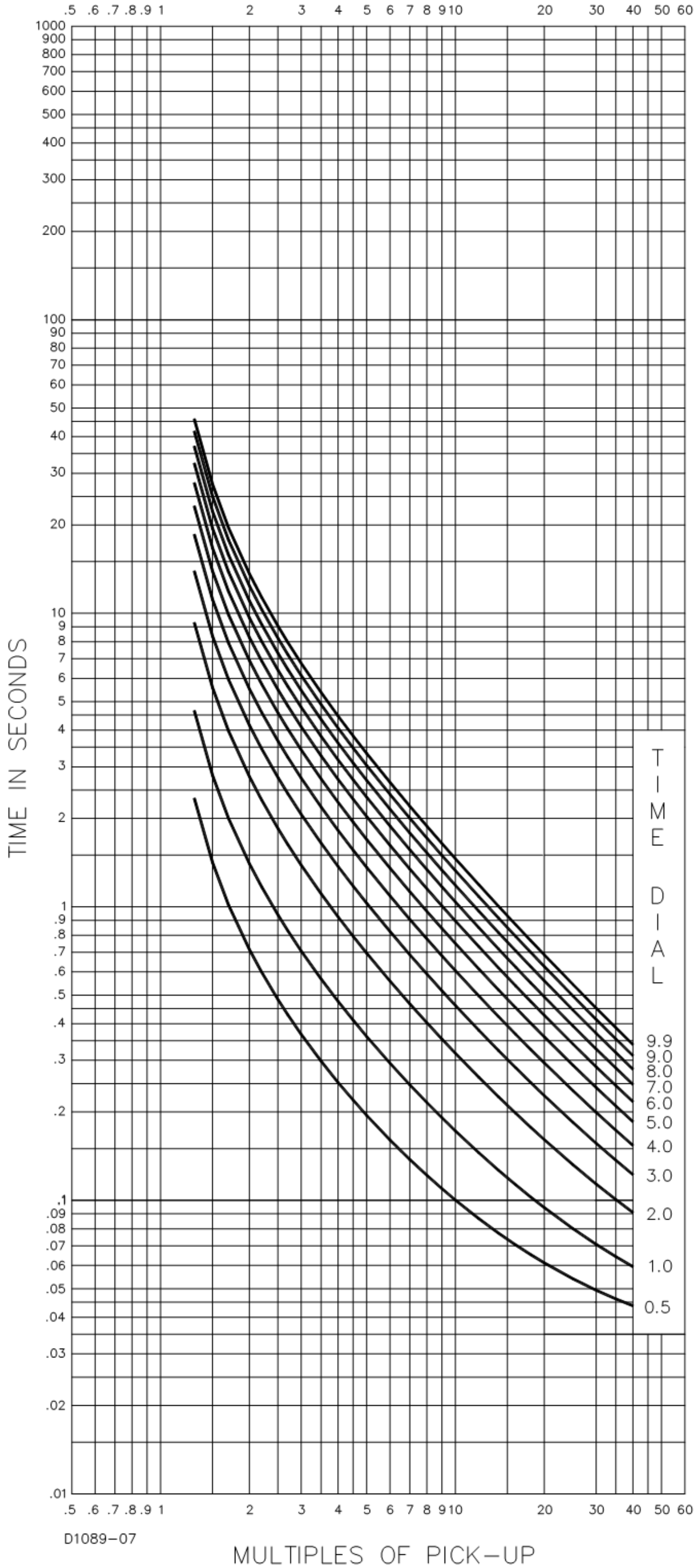


Figure 56-18. Time Characteristic Curve B, Very Inverse (BS 142)

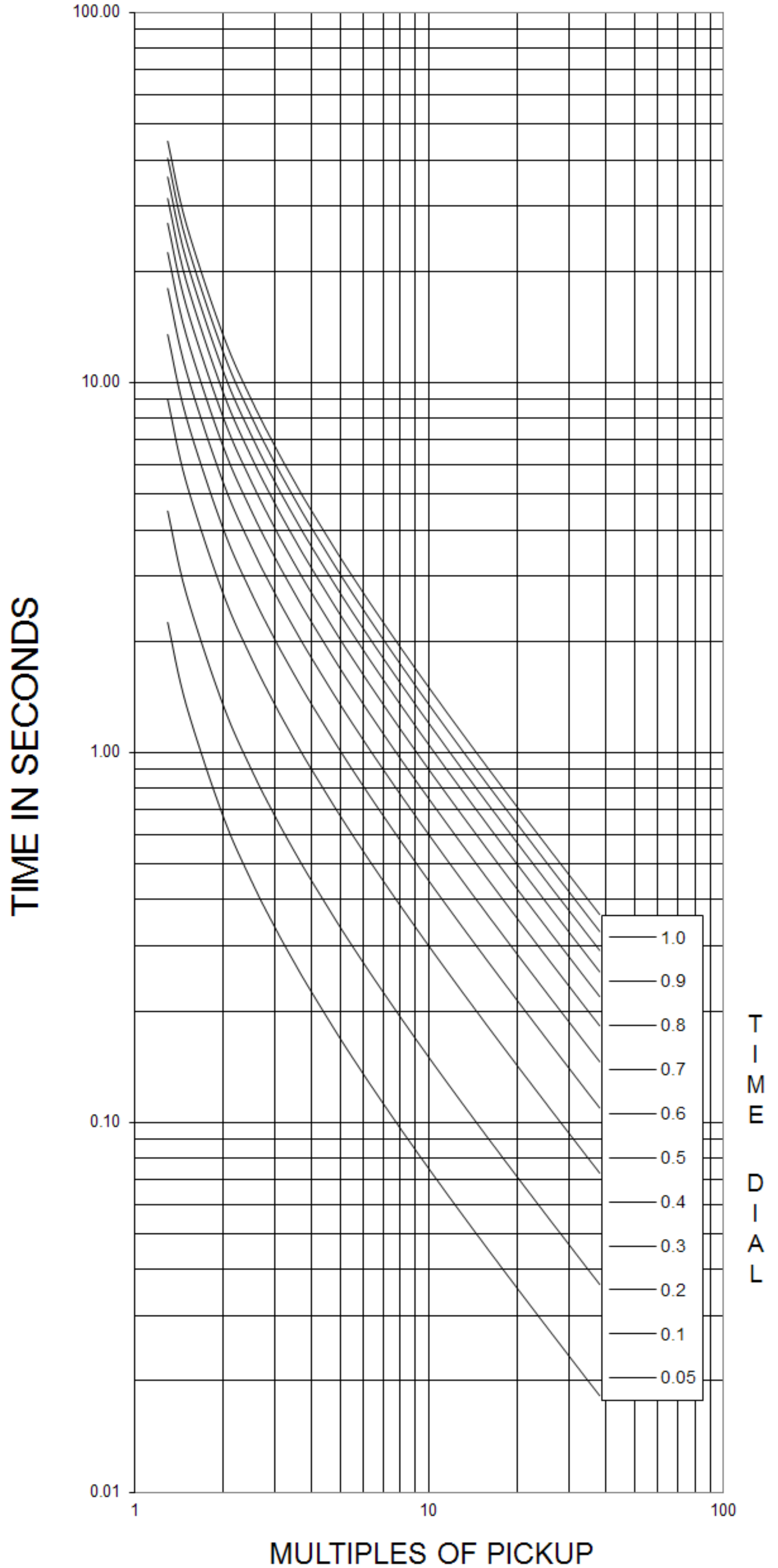


Figure 56-19. Time Characteristic Curve B1, Very Inverse (IEC 60255-151 Ed. 1)

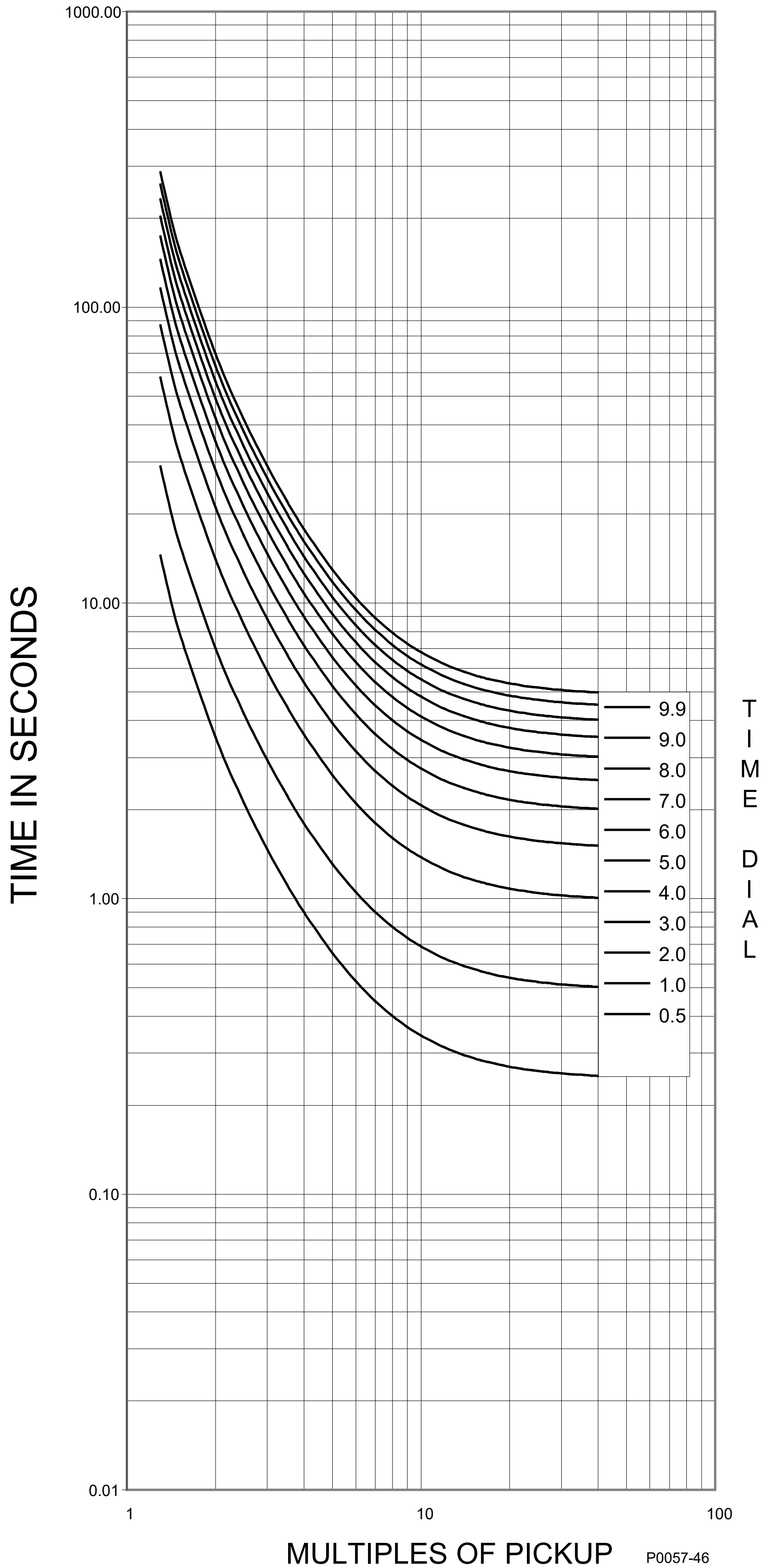


Figure 56-20. Time Characteristic Curve E3, Very Inverse (IEC 60255-151 Ed. 1)

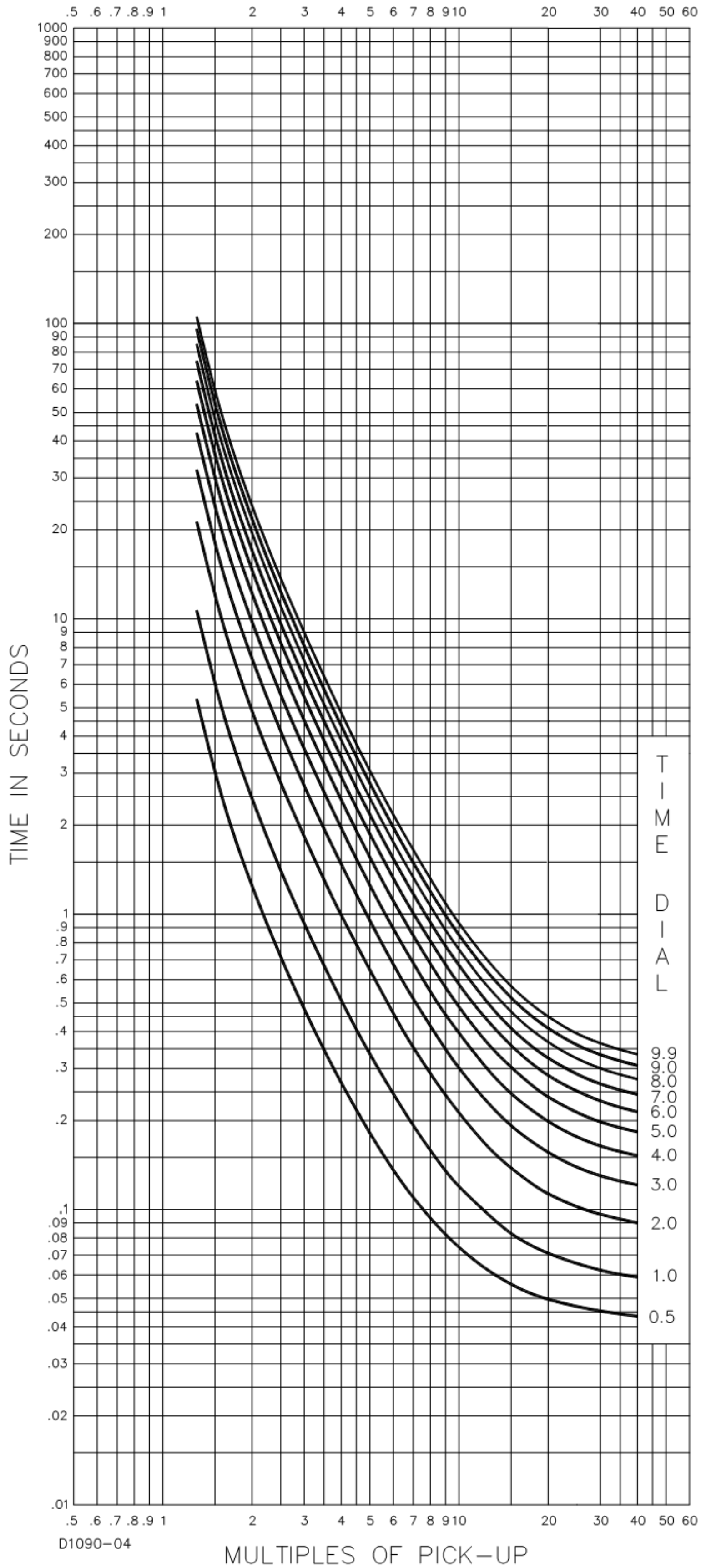


Figure 56-21. Time Characteristic Curve E1, Extremely Inverse (Similar to ABB CO-11)

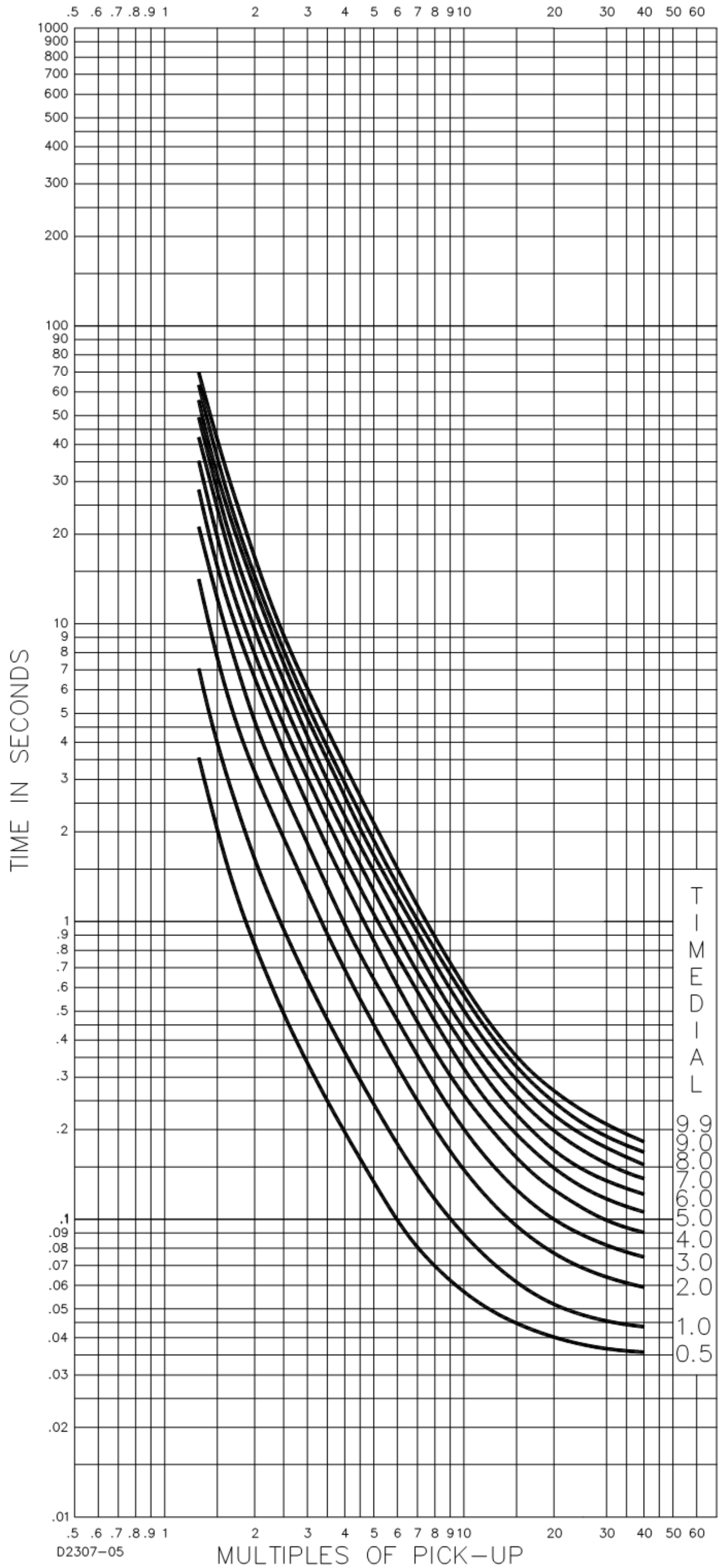


Figure 56-22. Time Characteristic Curve E2, Extremely Inverse (Similar to GE IAC-77)

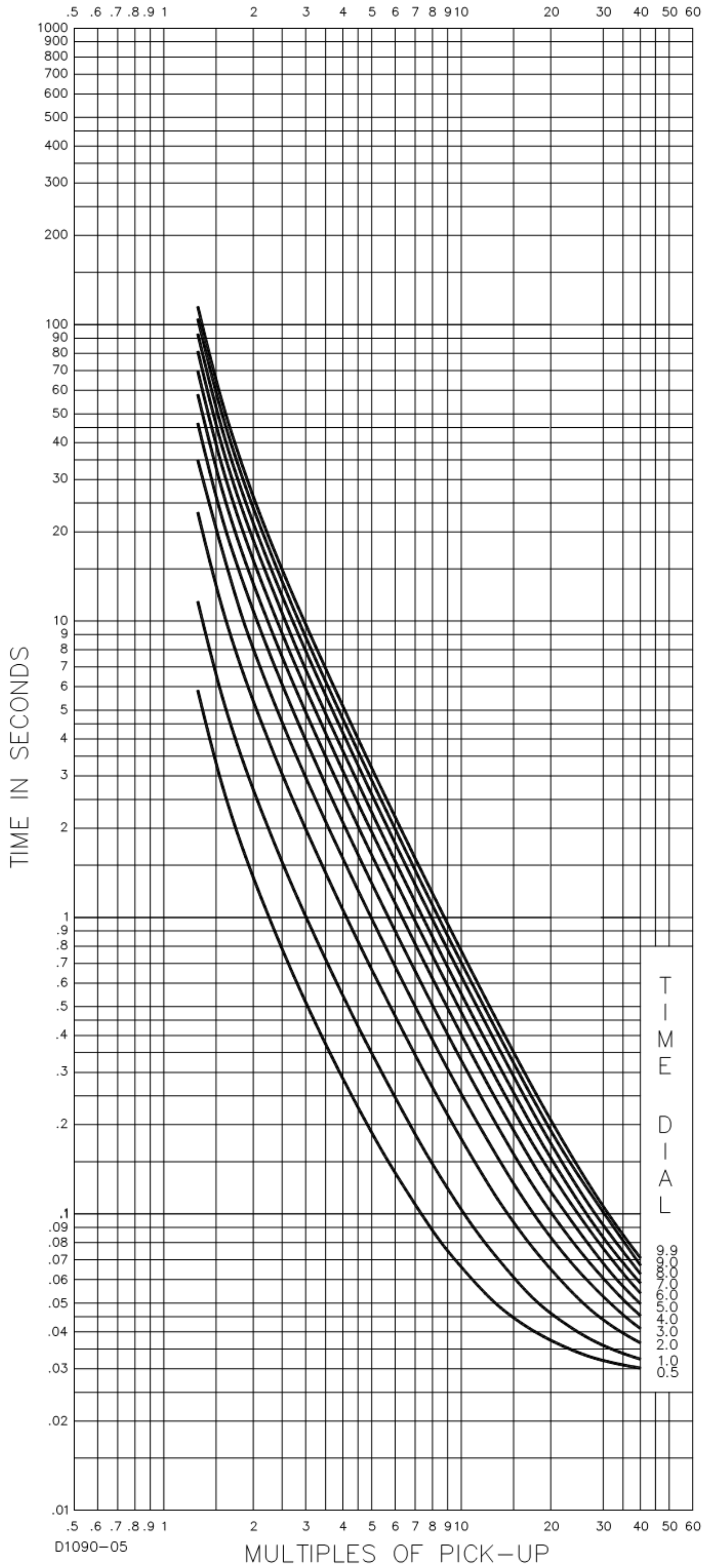


Figure 56-23. Time Characteristic Curve C, Extremely Inverse (BS 142)

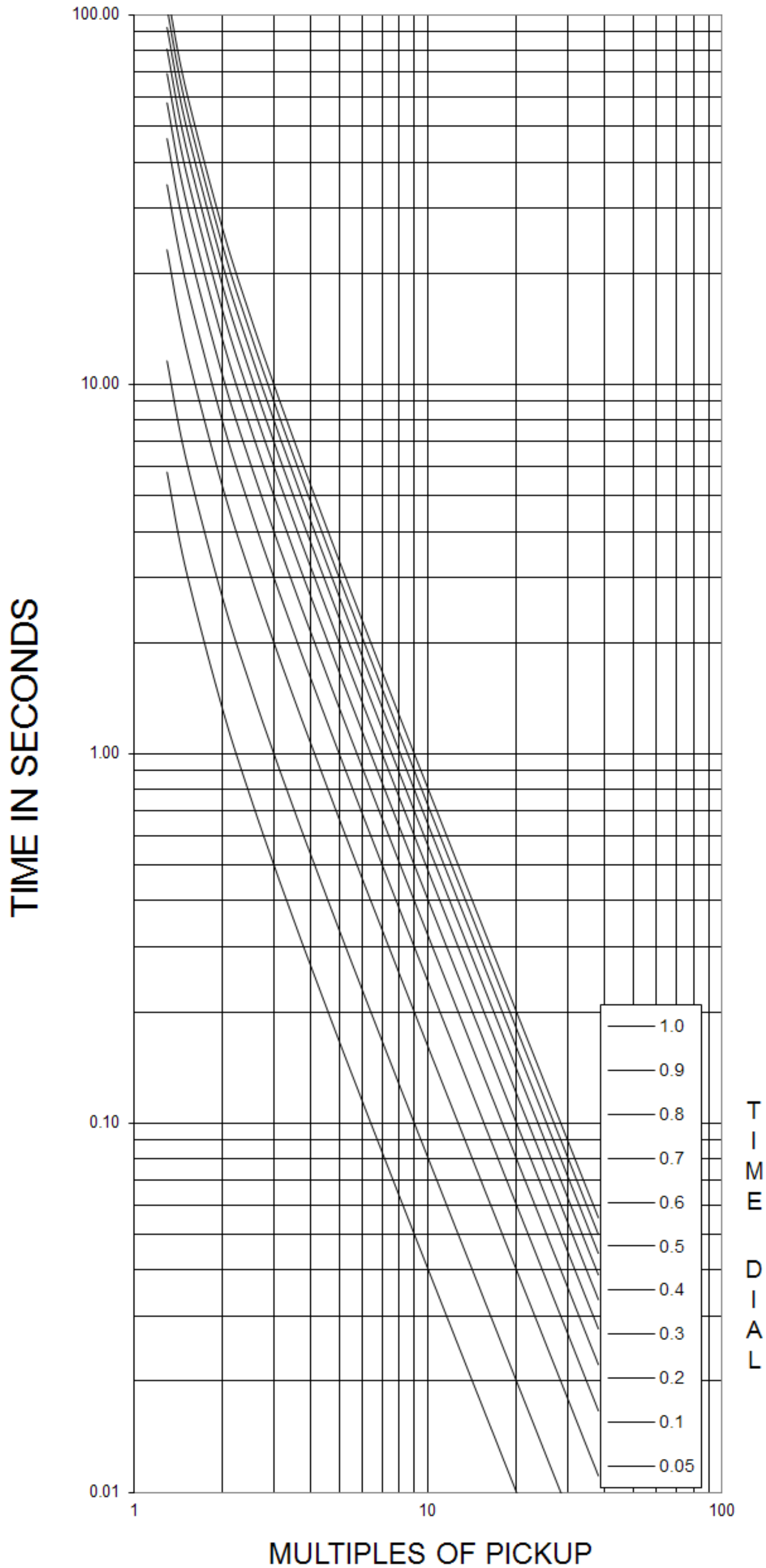


Figure 56-24. Time Characteristic Curve C1, Extremely Inverse (IEC 60255-151 Ed. 1)

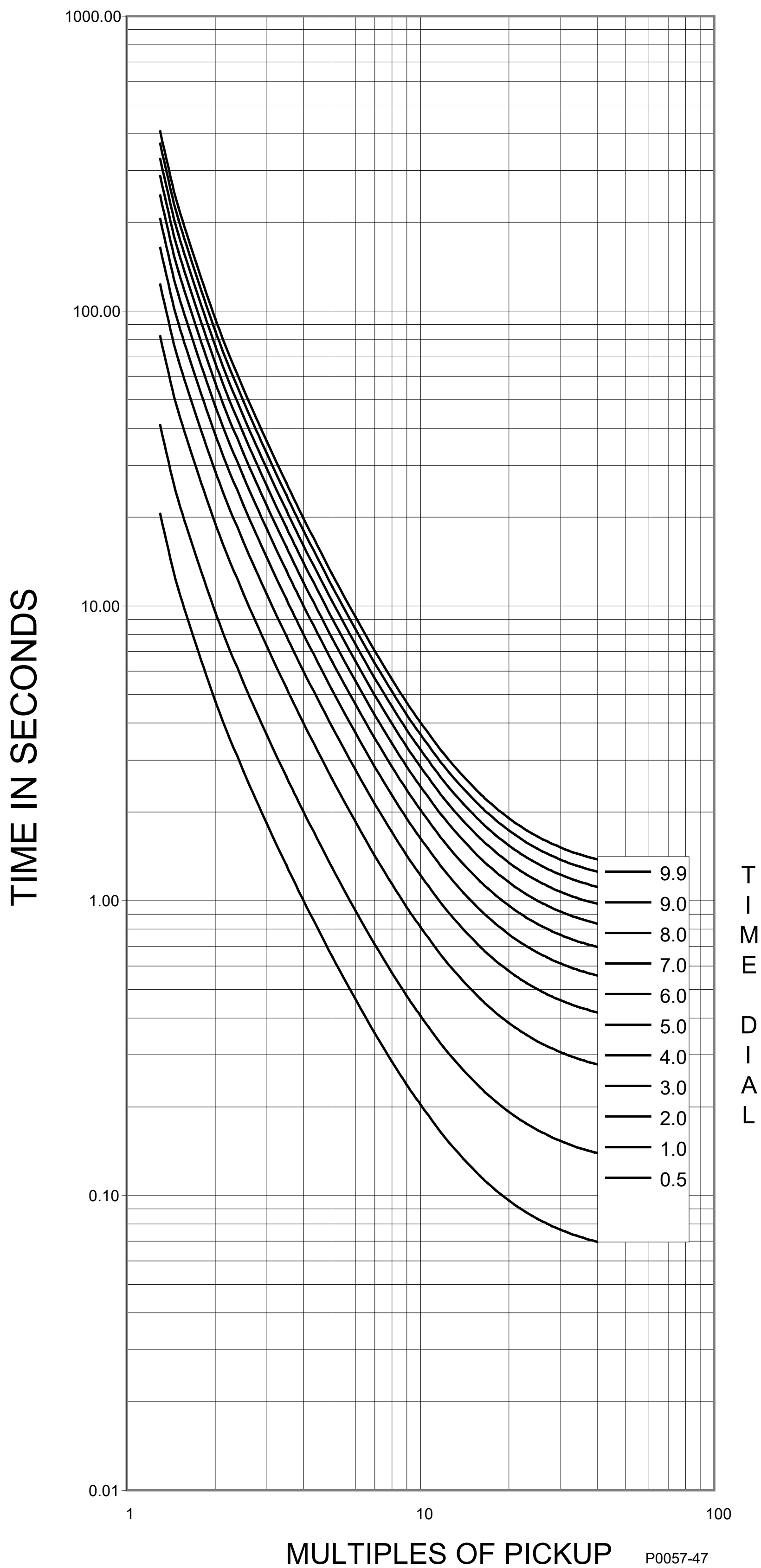


Figure 56-25. Time Characteristic Curve F1, Extremely Inverse (IEC 60255-151 Ed. 1)

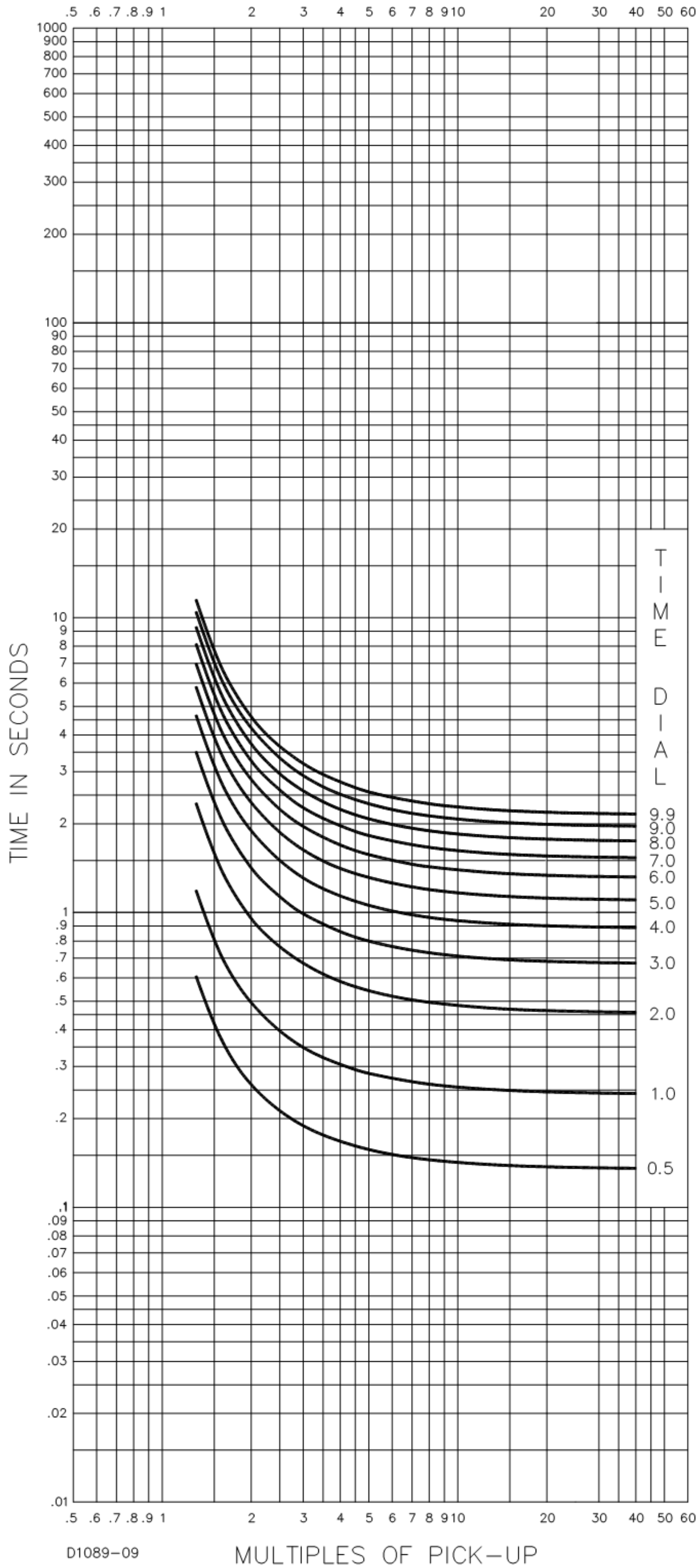
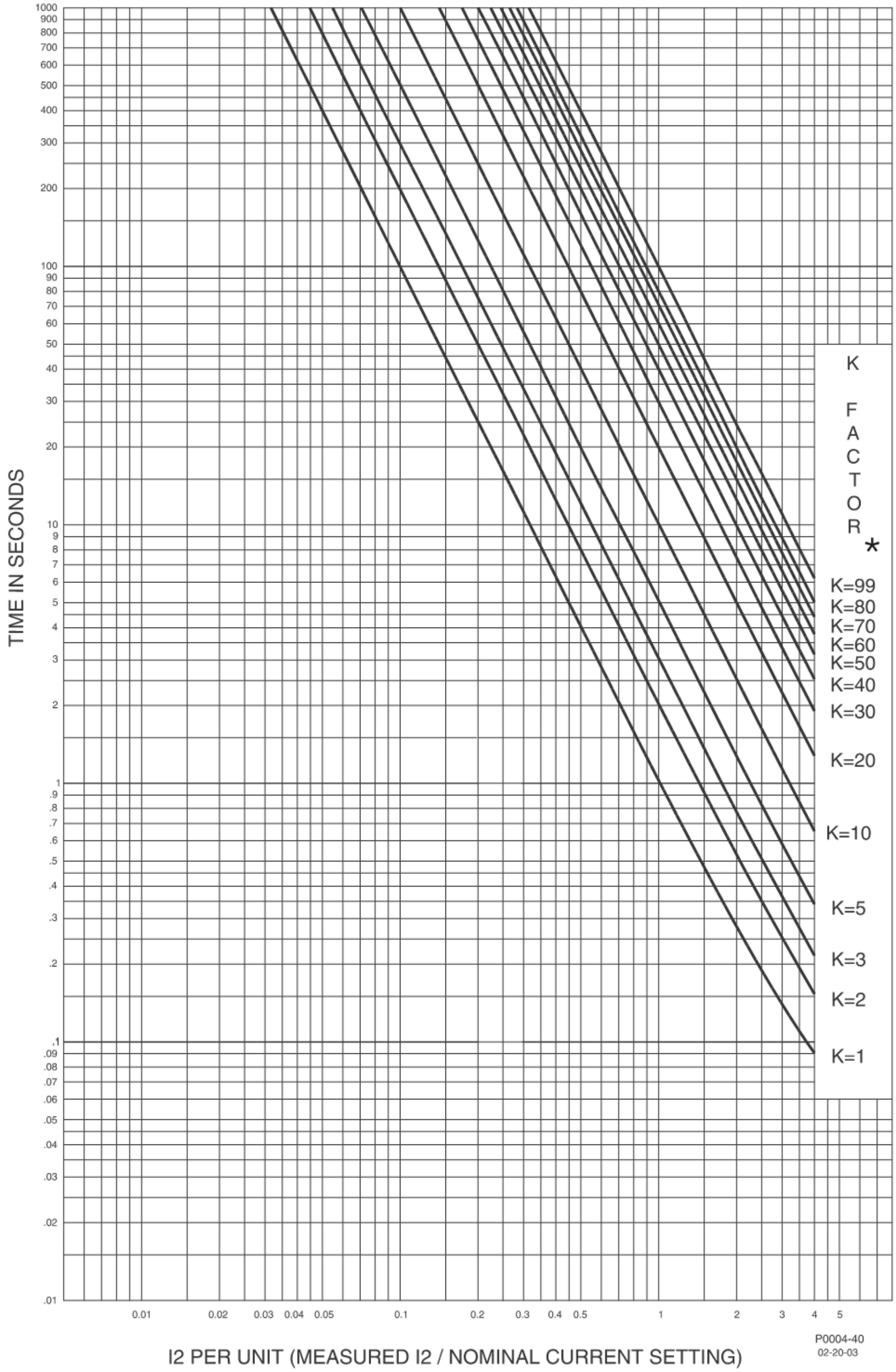


Figure 56-26. Time Characteristic Curve D, Definite Time (Similar To ABB CO-6)



* The K factor is the time that a generator can withstand 1 per-unit I2, where 1 pu is the user's setting for full-load current.

Figure 56-27. 46 Time Characteristic Curve

NOTE: Curves are shown as extending farther to the left than they will in practice. Curves stop at pickup level. For example, if the user sets Nominal Current to 5A and a 46 function pickup setting of 0.5A, the per-unit pickup is 0.1A. The BE1-FLEX will not pick up at less than 0.1 pu I2 for these settings.

Overexcitation (24)

General

The inverse time curves for the Overexcitation (24) element are defined below. Equation 56-10 and Equation 56-11 represent the trip time and reset time for constant volts per hertz level. Normally, the V/Hz pickup is set to a value greater than the V/Hz nominal. This ensures that V/Hz measured divided by V/Hz nominal is always greater than 1.000 throughout the pickup range.

Curve Specifications

If the pickup is set less than nominal, then measured values above pickup and below nominal will result in the maximum time delay. The maximum time delay is determined by Equation 56-11 with (V/Hz measured / V/Hz nominal) set equal to 1.001. The overall inverse time delay range is limited to 1,000 seconds maximum and 0.2 seconds minimum.

$$T_T = \frac{D_T}{\left(\frac{V/Hz\ \mathrm{Measured}}{V/Hz\ \mathrm{Nominal}} - 1\right)^n}$$

Equation 56-10. Time to Trip

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

Equation 56-11. Time to Reset

where:

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

When the measured V/Hz rises above a pickup threshold, the pickup element becomes true and an integrating or definite time timer starts. If the V/Hz remains above the pickup threshold and the integration continues for the required time interval as defined by the equations shown above and the set time dial, the trip output becomes true. If the measured V/Hz drops below pickup before timeout to trip, either an instantaneous or a time delayed integrating reset can be selected.

The following sets of curves are shown first with the time axis on the vertical and then on the horizontal for ease of use.

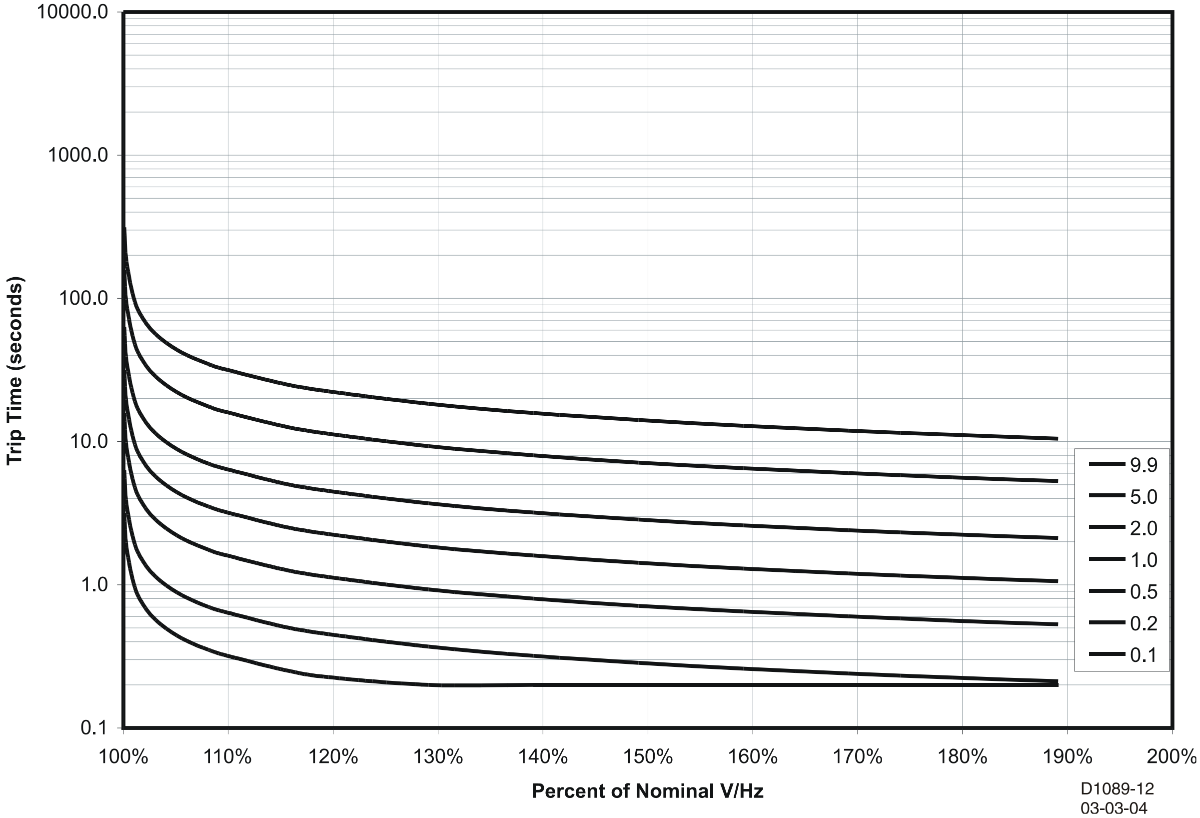


Figure 56-28. V/Hz Characteristic (M-1)^0.5 – Time on Vertical Axis

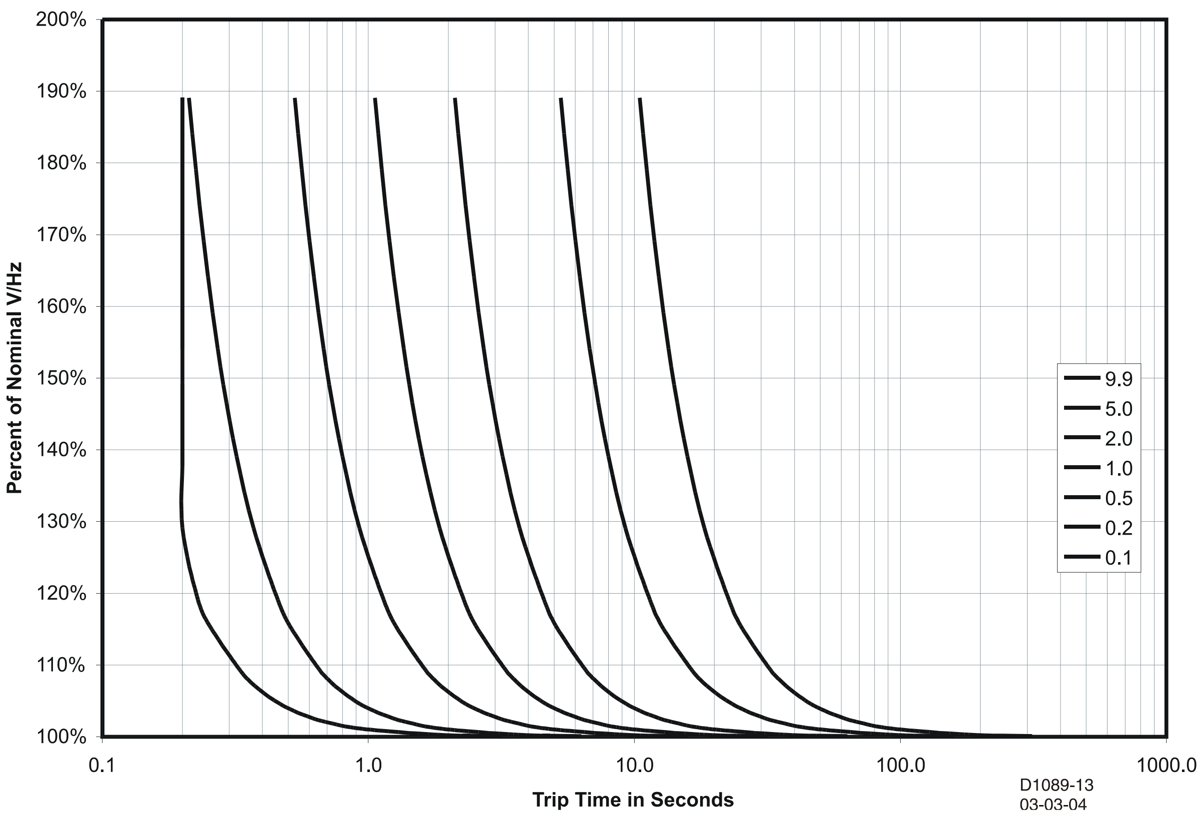


Figure 56-29. V/Hz Characteristic (M-1)^0.5 – Time on Horizontal Axis

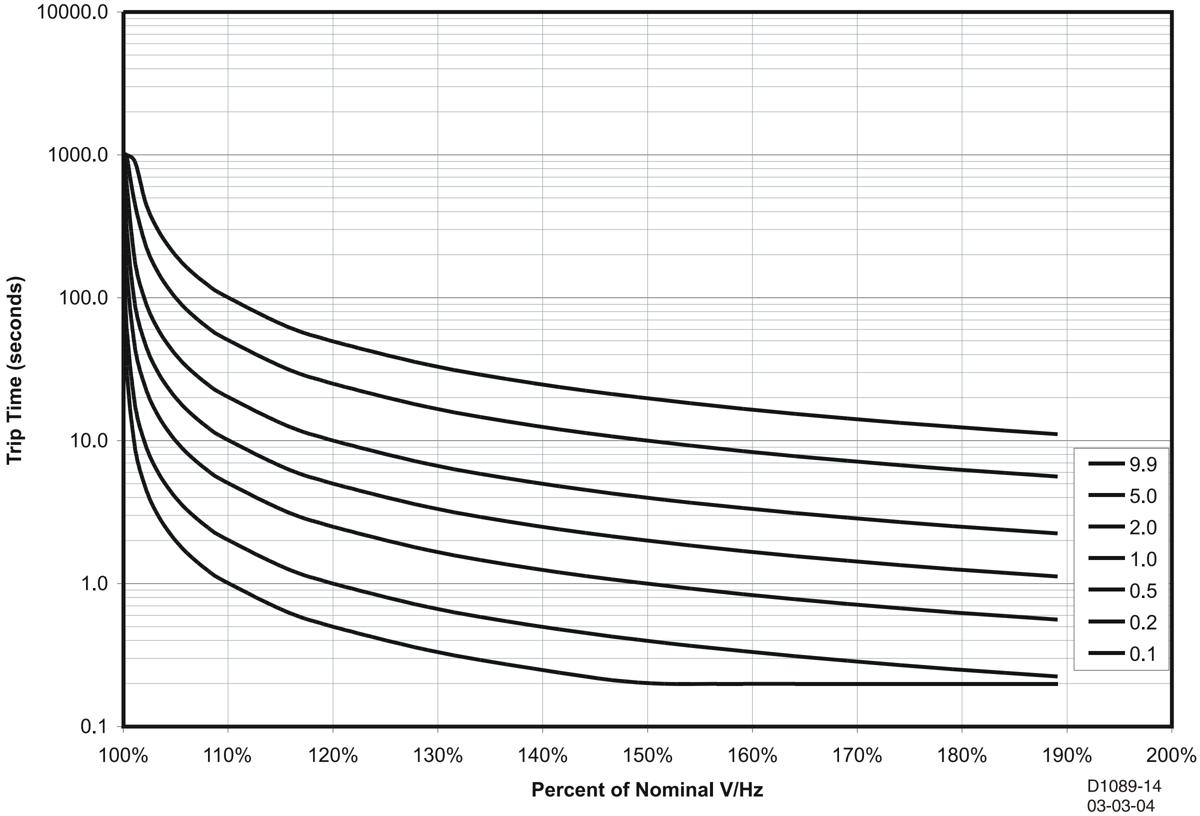


Figure 56-30. V/Hz Characteristic (M-1)^1 – Time on Vertical Axis

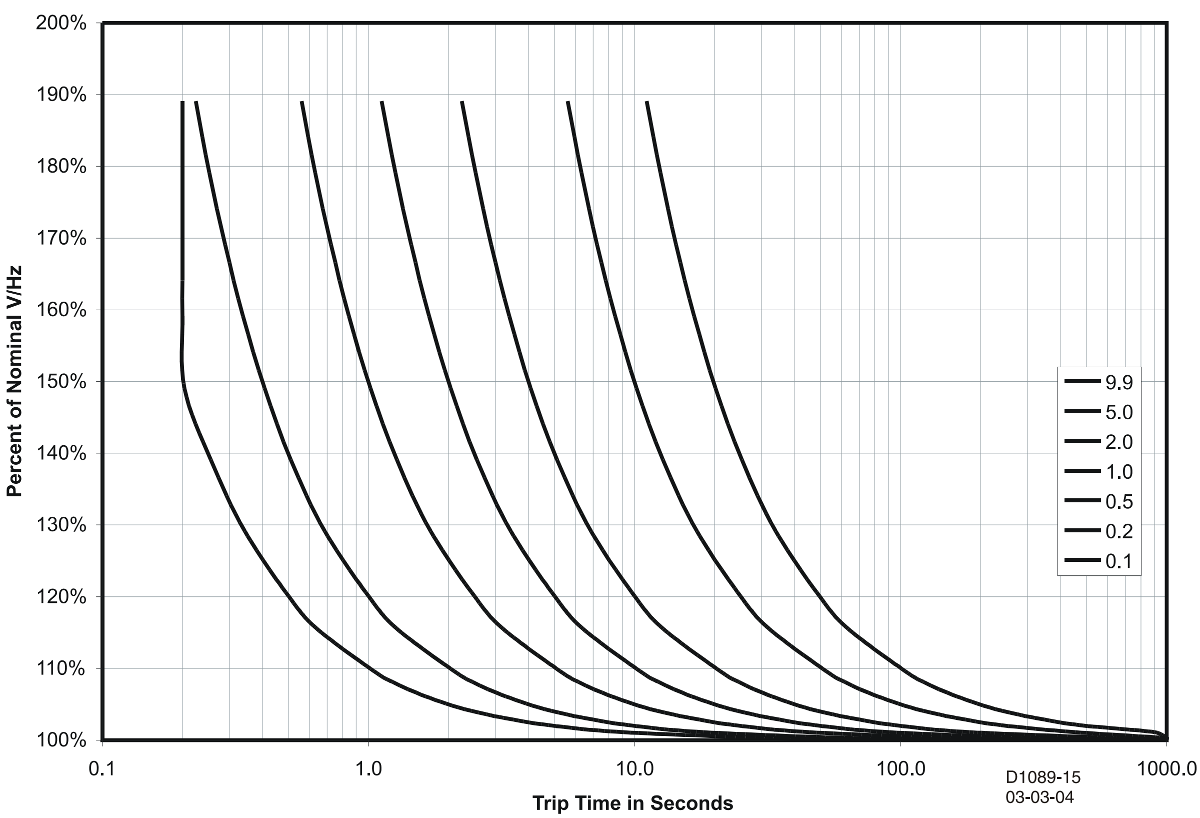


Figure 56-31. V/Hz Characteristic (M-1)^1 – Time on Horizontal Axis

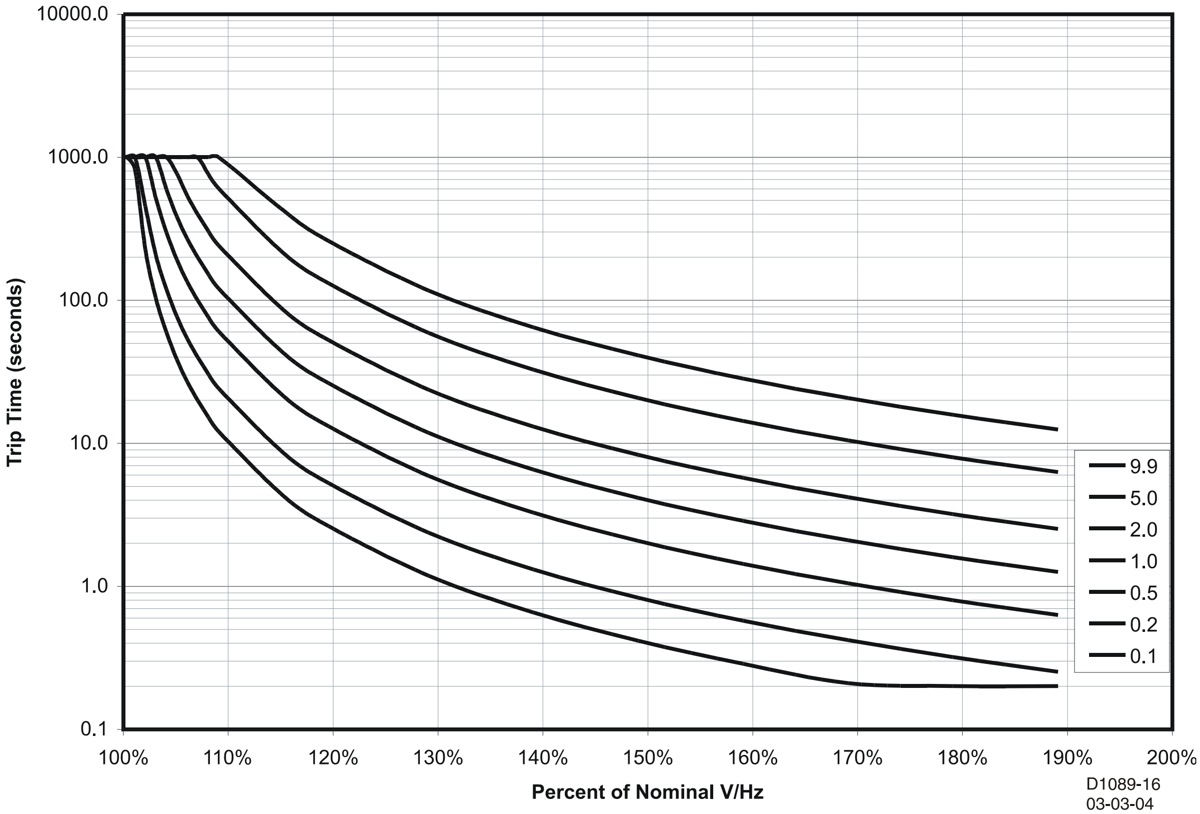


Figure 56-32. V/Hz Characteristic (M-1)^2 – Time on Vertical Axis

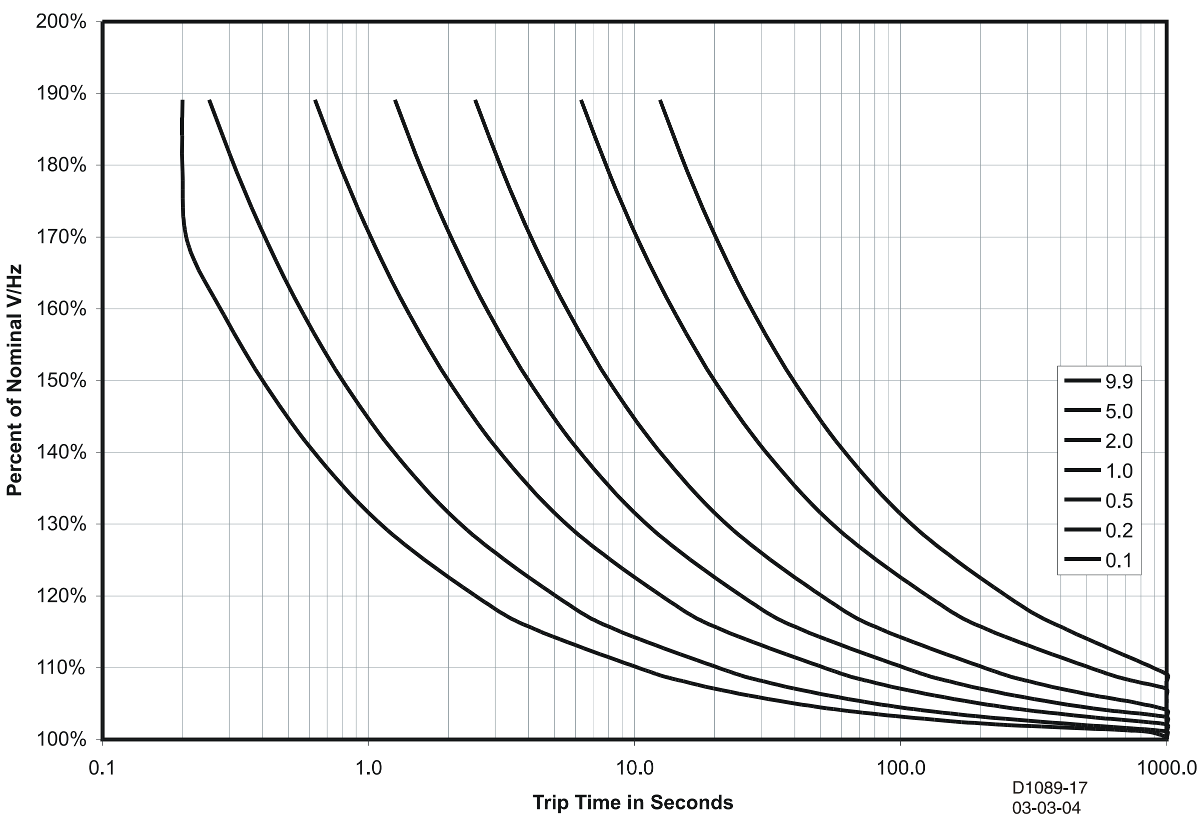


Figure 56-33. V/Hz Characteristic (M-1)^2 – Time on Horizontal Axis

57 • Introduction to Testing

The need to test protection systems to confirm performance as designed by manufacturers has always existed. However, digital system design is changing the industry testing paradigms that have been in use since the first protective relay was built. Each time a fault occurs, the digital protection system is tested, and because of its fault and event recording capability, the test is documented. In the unlikely event of a protection system problem, continuous monitoring along with remote communications capability provide for removing the affected device from service, auto switching to backup systems, and immediate notification of an attended facility. These features have virtually eliminated the need for periodic maintenance. Simple acceptance tests that verify the integrity of the BE1-FLEX measuring circuits and commissioning tests that verify the BE1-FLEX "electronic wiring" (control logic) are Basler Electric's recommended pre-installation tests.

The testing chapters provide guidelines for performing these tests and others. For assistance in conducting BE1-FLEX self-tests and troubleshooting using internal diagnostics, contact Basler Electric Technical Support Services.

Testing Philosophies

Testing is generally divided into the following categories:

- Acceptance
- Commissioning
- Periodic (user scheduled maintenance)
- Functional

While all types of tests can be performed, all users do not generally perform these tests. Likewise, the degree to which you will conduct each type of test depends on need, economics, and perceived system value.

Acceptance Testing

Acceptance testing confirms that a particular BE1-FLEX meets published specifications. Because this is a digital device whose characteristics are defined by software, Basler Electric does not require the user to test each operational setting in the BE1-FLEX. Successful completion of the Acceptance Test verifies proper response of the protection system's input and output circuits as well as its response to all external sensing input quantities (voltage, current, frequency).

Basler Electric performs detailed acceptance testing on all devices to verify all functions meet published specifications. All products are packaged and shipped with the strictest standards. The BE1-FLEX is a microprocessor-based device whose operating characteristics are digital and will not change over time or transit. The digital component of the device is validated continuously via the watchdog; however, it remains important that the user perform these acceptance tests to verify the device has not suffered any mechanical degradation in transit. Basler Electric provides warranty against any decay in performance outside of the published specified tolerances that result from problems created during transit.

Commissioning Testing

Commissioning testing verifies all physical connections and functional aspects of the BE1-FLEX for a new installation. This includes a thorough review and documentation of the operational settings to verify that the users calculated values match the actual values on each enabled protection element of the BE1-FLEX. All of the following connections or functions can be verified during commissioning tests:

- Proper connection and sensing of current and voltage signals as applicable
- Connections of I/O contacts
- I/O sensing versus virtual sensing
- Setting validation
- Proper operation of equipment (main or auxiliary)
- Proper alarming (to SCADA) and/or targeting

Periodic Testing

Periodic testing can be performed at regularly scheduled intervals or upon an indication of problems or questionable operations within the BE1-FLEX. Verifying the integrity of the protection system's performance, short of playback of recorded events, may be necessary by performing certain tests similar to those accomplished in the *Acceptance Testing* chapter. Verification that the BE1-FLEX is measuring signals faithfully, that BE1-FLEX logic is appropriate, and that protective elements and equipment (main or auxiliary) operate correctly are goals that can be achieved during this type of testing.

Basler Electric recommends that all captured fault records and sequence of event records be analyzed and kept on file as in-service periodic test results for this particular device. This is an indication that all protective elements and the associated equipment are operating satisfactorily.

It is not the intent of this manual to elaborate on every conceivable test possible because this would encroach on individual preferences, techniques, and philosophies. It is the intent to pursue relevant testing methods to verify this BE1-FLEX meets published design specifications and applicability.

Functional Testing

Functional (or application) testing is significantly more comprehensive in nature and tests suitability for a particular application. Functional testing also provides a means to familiarize the user with the logic and operation of this device. Test setups are generally more involved and often include ancillary equipment beyond voltage or current source type equipment. While economics may at times prohibit full functional testing, it is recommended that some functional testing be performed when published specifications lack appropriate detail to satisfy application testing requirements.

Testing and Troubleshooting Aids

Under test or in-service, the BE1-FLEX provides several ways to check operations, targets, or events. The status of the system is monitored by a continuous self-test. The most basic reporting function is targets. Targets can be viewed through BESTCOMS*Plus*® or the front-panel display. Fault Summary Reports, Sequence of Events Recorder (SoE) Reports, and Oscillographic Records yield more detail.

Each time a system disturbance occurs in or around this BE1-FLEX zone of protection, it is a test of the BE1-FLEX performance during the fault. If a questionable operation results in the need for troubleshooting, you have several ways in which to troubleshoot the BE1-FLEX, the installation, and overall application.

Performance Testing

Performance testing can be accomplished through the capture and playback of system fault records. In actual applications, this type of test realizes further confirmation of faithful BE1-FLEX responses during system disturbances. For specific power system disturbances, protection systems can be subjected to a re-creation of captured events with the aid of equipment capable of replicating COMTRADE record files. In these instances, there is significant merit in testing protection systems in this manner to assess BE1-FLEX performance. Correct response of BE1-FLEX action in a performance test is supplemental verification of the conclusions drawn from functional (or application) tests.

This type of testing verifies not only whether the device operated correctly for a particular system disturbance but also offers additional confirmation of your protection philosophy in this application. It is beyond the scope of this manual to develop performance tests for this device. For assistance in developing these types of tests, please consult Basler Electric and your test equipment documentation.

BE1-FLEX Self-Test

Internal circuitry and software that affect the BE1-FLEX core functionality are monitored by the continuous self-test diagnostics. If the self-test fails under certain conditions, it will force a reboot and try to correct the problem. The device cannot process new events for up to one minute during this reboot. For other self-testing failed conditions, the Relay Trouble LED on the front panel turns ON, all of the output relays are forced to their Normal powered-off state, and the logic Relay Trouble Alarm is set. For more information on self-test diagnostics and relay trouble alarms, see the *Alarms* chapter.

Status Reporting Features

Status reporting is available by using the Metering Explorer in BESTCOMS*Plus*. This report assembles all of the information required to determine the BE1-FLEX status.

Fault reporting and target data respectively is dependent on the element having it's Fault Recorder setting enabled or the proper setting of trip, pickup, and logic trigger expressions (via BESTlogic™*Plus* Programmable Logic) and the assignment of protective elements to be logged as targets (via BESTCOMS*Plus*).

While the design of the BE1-FLEX facilitates obtaining and verifying targets and event data, it is not always necessary to use the BE1-FLEX functions to determine if the device operated while testing. You can simply use an ohmmeter or continuity tester to monitor the output contact status.

The following is a summary of where target and event data can be viewed in BESTCOMS*Plus*:

- Fault records in memory - Metering Explorer/Reports/Fault Records
- Target data - Metering Explorer/Status/Targets
- Sequence of events (SoE) records - Metering Explorer/Reports/Sequence of Events

For more information on front-panel display, see the *Controls and Indicators* chapter.

Event Reporting Features

The SoE function of the BE1-FLEX records protective element output changes, overcurrent element pickup or dropout, input/output contact state changes, logic triggers, setting group changes, and setting changes. For more information on event reporting, see the *Sequence of Events* chapter.

The following summarizes the reporting capabilities of the BE1-FLEX through the front-panel display:

- Trip LED (Flashing): flashes during pickup of protective elements or when the pickup logic expression set in BESTlogic*Plus* Programmable Logic is true.
- Trip LED (Sealed-In): stays lit after an element with Fault Recording enabled trips or when Fault Recorder trip logic becomes true based on the trip logic expression set in BESTlogic*Plus* Programmable Logic.
- Targets: Reports > Targets & Alarms screen provides target data.
- Alarm: Reports > Targets & Alarms screen provides alarm data.
- Fault Reports: Reports > Fault Records screen indicates new fault reports.

58 • Acceptance Testing

Although Basler Electric performs detailed acceptance testing on all new BE1-FLEX systems, it is generally recommended that you perform each of the following acceptance test steps before installation. The following steps test functions of the BE1-FLEX to validate that it was manufactured properly and that no degradation of performance occurred because of shipping.

Test Equipment

Suitable test equipment is required with a current and voltage source for each circuit being tested and a contact wetting voltage. Test equipment should also have the capability of varying the frequency and the angle of the voltage and current sources. A PC with BESTCOMS*Plus*® installed and configured for communication with the BE1-FLEX is also required. Testing performed is commonly limited to functionality utilized by specific applications.

Power Up

Purpose: Verify that the BE1-FLEX performs the power-up sequence.

Step 1: Apply voltage to input power terminals (+) and (-). Table 58-1 shows the appropriate input voltage for each BE1-FLEX style.

Table 58-1. Input Voltages

Power Supply Option	Voltage Input	Connections
1	48/125 Vdc, 120 Vac	See Figure 4-2 in the *Hardware Configuration* chapter.
2	250 Vdc, 240 Vac	See Figure 4-3 in the *Hardware Configuration* chapter.
3	24 Vdc	See Figure 4-4 in the *Hardware Configuration* chapter.

Step 2: Verify that the Power LED is ON, and that the home screen is displayed on the front panel. Upon power-up, the BE1-FLEX will perform a brief self-test. Contact Basler Electric Technical Support Services if anything appears out of the ordinary or if an LCD error message appears.

Communications

Purpose: To verify that the BE1-FLEX communicates through the front USB and optional communication boards.

Use BESTCOMS*Plus* to connect to the BE1-FLEX through the front-panel USB port and through the optional rear panel Ethernet port. Refer to the *Communications* chapter.

Style Number and Serial Number Verification

Purpose: Verify that the BE1-FLEX style number matches expectation and serial number matches the unit and unit labels.

Step 1: Connect to the BE1-FLEX through BESTCOMS*Plus*. Style and Serial numbers are also available from the HMI on from the Menu, Device Information screen.

Step 2: Download Settings from the Communication pull-down menu.

Step 3: Use the Settings Explorer to open the Configuration, Style Configurator screen and verify that the style number matches the desired style number.

Step 4: Open the Configuration, Hardware Configuration, Hardware Info screen and verify that the serial number matches the unit labels.

IRIG Verification (if used)

Purpose: Verify that the BE1-FLEX acquires and updates IRIG time and date information.

Step 1: Connect a suitable IRIG source to BE1-FLEX terminals (+) and (–) on the Power Supply Board.

Step 2: Upon receiving the IRIG signal, the BE1-FLEX clock will update with the current time, day, and month. Verify this on the Metering, Status, Real Time Clock screen on the front-panel display.

Device Configuration (required for tests below)

Purpose: Configure the BE1-FLEX based upon the desired operation.

Step 1: Connect to the BE1-FLEX through BESTCOMS*Plus.* Download Settings from the Communication pull-down menu.

Step 2: If the device is not configured with the desired Circuits, Inputs and Outputs, do the following. In the Settings explorer, open Configuration, Style Configurator and select Auto-Generate Instance. Select the instances that are desired for the application or testing and click Ok.

Contact Sensing Inputs

Purpose: Verify that the BE1-FLEX senses hardware input status.

Step 1: Contact sense inputs are recognized as true when the voltage applied exceeds the Hardware Information, Card Setting for the sensing level as listed in Table 58-2. Note, each hardware slot can have a different setting.

Table 58-2. Contact Sensing Turn-On Voltages

Sensing Level	Contact Sensing Turn-On Voltage
24 V	4 to 9 Vdc
48 V	26 to 38 Vdc
125 V	69 to 100 Vdc 56 to 97 Vac
250 V	138 to 200 Vdc 112 to 194 Vac

Step 2: To test, apply an external voltage source within the range of the voltage Card Setting to contact sensing inputs IN1 (+/-), IN2 (+/-), IN3 (+/_), etc.

Step 3: To verify that all inputs have been detected, use the Metering Explorer in BESTCOMS*Plus* to open the Status, Inputs screen.

Control Outputs

Purpose: Verify that the BE1-FLEX senses hardware output status.

Step 1: Connect to the BE1-FLEX through BESTCOMS*Plus*.

Step 2: Use the Metering Explorer to open the Control, Output Override screen.

Step 3: Click the Disabled button for Output #1. The button changes to Enabled indicating that the output control override capability of the relay is enabled.

Step 4: Select Set to energize Output #1. Verify that the Output #1 Status LED, located on the Output Override screen of BESTCOMS*Plus*, turns on.

Step 5: Select Reset to de-energize Output #1. Verify that the Output #1 Status LED, located on the Output Override screen of BESTCOMS*Plus*, turns off.

Step 6: Use the Metering Explorer in BESTCOMS*Plus* to return to the Control, Output Override screen and click on the Enabled button for Output #1. The button changes to Disabled indicating that the output control override capability of the relay is disabled.

Step 7: Repeat Steps 3 through 6 for all desired output contacts.

Current Circuit Verification

Four- Channel Current Boards

Step 1: To verify 3I0, I1, and I2, connect an ac current source to Terminals I1 and I1•.

Step 2: Apply the appropriate current values in Table 58-3 to the BE1-FLEX. Measured 3I0 should correspond to values in Table 58-3 while I1 and I2 should be 1/3 the applied value ±1.5% (For example, if the applied value equals 2 amps, I2 = 2/3 = 0.667 amps ±1.5% or ±0.01 amps.) Verify current measuring accuracy by opening the Analog Metering, Circuit, Circuit 1, Secondary Current screen inside the Metering Explorer of BESTCOMS*Plus*. 3I0, I1, and I2 current measurements can also be verified from the Real Time Data tab of the front-panel display.

Table 58-3. Current Circuit Verification Values

Sensing Type	Applied Current	Measured Current (Sequence)		Measured Current (Phase and Ground)	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit
1A/5A	0.1 Aac	0.098 Aac	0.102 Aac	0.099 Aac	0.101 Aac
	1 Aac	0.985 Aac	1.015 Aac	0.990 Aac	1.010 Aac
	5 Aac	4.925 Aac	5.075 Aac	4.950 Aac	5.050 Aac
	10 Aac	9.850 Aac	10.15 Aac	9.900 Aac	10.10 Aac
	15 Aac	14.77 Aac	15.22 Aac	14.85 Aac	15.15 Aac
SEF	0.1 Aac	n/a	n/a	0.094 Aac	0.106 Aac
	2 Aac	n/a	n/a	1.976 Aac	2.025 Aac
	4 Aac	n/a	n/a	3.955 Aac	4.045 Aac
	6 Aac	n/a	n/a	5.935 Aac	6.065 Aac
	7.5 Aac	n/a	n/a	7.420 Aac	7.580 Aac

Table 58-4. Current Circuit IO Board Options

Option	Description	Connections
L6	Four-channel current (1 or 5 Aac phase and ground)	See Figure 4-11 in the *Hardware Configuration* chapter.
A9	Four-channel current (1 or 5 Aac phase and SEF ground)	See Figure 4-12 in the *Hardware Configuration* chapter.
X6	Seven-channel current (1 or 5 Aac phase and ground)	See Figure 4-13 in the *Hardware Configuration* chapter.
L2	Seven-channel current (1 or 5 Aac phase and SEF ground)	See Figure 4-14 in the *Hardware Configuration* chapter.
T3	Four-channel voltage (300 Vac max), four-channel current (1 or 5 Aac phase and ground)	See Figure 4-16 in the *Hardware Configuration* chapter.

Option	Description	Connections
M0	Four-channel voltage (300 Vac max), four-channel current (1 or 5 Aac phase and SEF ground)	See Figure 4-17 in the *Hardware Configuration* chapter.

Step 3: To verify IA, IB, IC and IG, connect the four current inputs in series by connecting suitably sized jumper wires between terminals I1• and I2, I2• and I3, and I3• and I4. Then connect an ac current source to terminals I1 and I4•.

NOTE: Four Current Input applies to Options L6, A9, T3 and M0. SEF Input is Input I4 on the four channel current boards and should be tested separately.

Step 4: Apply the appropriate current values in Table 58-3 to the BE1-FLEX. Verify current measuring accuracy on the Analog Metering, Circuit, Circuit 1, Secondary Current screen inside the Metering Explorer of BESTCOMS*Plus*. IA, IB, IC, and IG current measurements can also be verified from the Real Time Data tab of the front-panel display.

Step 5: Leave current circuit connected and de-energized. These test connections will be used later when verifying power readings.

Seven-Channel Current Boards

Step 1: Add Circuit 2 from the Settings, Configuration, Circuit Summary screen. Populate I4, I5 and I6 as IA, IB, and IC respectively. I1, I2, I3, and I7 will already be populated into Circuit 1 by the auto-generation step above.

Step 2: To verify 3I0, I1, and I2, connect one wire of an ac current source to Terminals I1 and jumper to I4 and the other return wire of the source to I1• and a jumper to I4•.

Step 2: Apply the appropriate current values in Table 58-3 to the BE1-FLEX. Measured 3I0 should correspond to values in Table 58-3 while I1 and I2 should be 1/3 the applied value ±1.5% (For example, if the applied value equals 2 amps, I2 = 2/3 = 0.667 amps ±1.5% or ±0.01 amps.) Verify current measuring accuracy by opening the Analog Metering, Circuit, Circuit 1, Secondary Current screen inside the Metering Explorer of BESTCOMS*Plus*. 3I0, I1, and I2 current measurements can also be verified from the Real Time Data tab of the front-panel display. Repeat validation for Circuit 2.

Step 3: To verify IA, IB, IC, IG of Circuit 1 and IA, IB, IC of Circuit 2, connect the seven current inputs in series by connecting suitably sized jumper wires between terminals I1• and I2, I2• and I3, and I3• and I4, I4• and I5, I6• and I7. Then connect an ac current source to terminals I1 and I7•.

NOTE: Seven Current Input applies to Options L2, and X6. SEF Input is I7 on the seven channel current boards and should be tested separately.

Step 4: Apply the appropriate current values in Table 58-3 to the BE1-FLEX. Verify current measuring accuracy on the Analog Metering, Circuit, Circuit 1, Secondary Current screen inside the Metering Explorer of BESTCOMS*Plus*. IA, IB, IC, and IG current measurements can also be verified from the Real Time Data tab of the front-panel display. Repeat validation for Circuit 2.

Step 5: Leave current circuit connected and de-energized. These test connections will be used later when verifying power readings.

Three-Phase Voltage Circuit Verification

Option	Description	Connections
X9	Four-channel voltage (300 Vac max, 3 phase, 4 wire plus auxiliary)	See Figure 4-15 in the *Hardware Configuration* chapter.
T3	Four-channel voltage (300 Vac max), Four-channel current (1 or 5 Aac phase and ground)	See Figure 4-16 in the *Hardware Configuration* chapter.
M0	Four-channel voltage (300 Vac max), four-channel current (1 or 5 Aac phase and SEF ground)	See Figure 4-17 in the *Hardware Configuration* chapter.

Step 1: Connect an ac voltage source at nominal frequency between BE1-FLEX terminals VA (A-phase) and VN (Neutral terminal). Apply 100 volts and verify voltage-measuring accuracy by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1 Secondary Voltage screen. Readings should be: VA = 100 volts ±0.5%, VAB = 100 volts ±0.5%, VCA = 100 volts ±0.5%, 3V0 = 100 volts ±0.75%, V1 = 33.4 volts ±0.75% (applied divided by 3), and V2 = 33.4 volts ±0.75% (applied divided by 3). Voltage measurements can also be verified from the Real Time Data tab of the front-panel display.

Step 2: Connect an ac voltage source at nominal frequency between BE1-FLEX terminals VB (B-phase) and VN (Neutral Terminal). Apply 100 volts and verify voltage-measuring accuracy by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1, Voltage, Secondary Voltage screen. Readings should be: VB = 100 volts ±0.5%, VAB = 100 volts ±0.5%, VBC = 100 volts ±0.5%, 3V0 = 100 volts ±0.75%, V1 = 33.4 volts ±0.75% (applied divided by 3), and V2 = 33.4 volts ±0.75% (applied divided by 3). Voltage measurements can also be verified from the Real Time Data tab of the front-panel display.

Step 3: Connect an ac voltage source at nominal frequency between BE1-FLEX terminals VC (C-phase) and VN (Neutral Terminal). Apply 100 volts and verify voltage-measuring accuracy by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1, Voltage, Secondary Voltage screen. Readings should be: VC = 100 volts ±0.5%, VBC = 100 volts ±0.5%, VCA = 100 volts ±0.5%, 3V0 = 100 volts ±0.75%, V1 = 33.4 volts ±0.75% (applied divided by 3), and V2 = 33.4 volts ±0.75% (applied divided by 3). Voltage measurements can also be verified from the Real Time Data tab of the front-panel display.

Step 4: Connect BE1-FLEX terminals VA (A-phase), VB (B-phase), and VC (C-phase) together. Connect an ac voltage source at nominal frequency to the three jumpered terminals and the Neutral Terminal (VN).

Step 5: Apply the voltage values listed in Table 58-5 and verify voltage-measuring accuracy by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1, Voltage, Secondary Voltage screen. Voltage measurements can also be verified from the Real Time Data tab of the front-panel display.

Table 58-5. Voltage Circuit Verification Values

Applied Voltage	Measured Voltage	
	Lower Limit	**Upper Limit**
80 Vac	79.6 Vac	80.4 Vac
100 Vac	99.5 Vac	100.5 Vac
120 Vac	119.4 Vac	120.6 Vac
140 Vac	139.3 Vac	140.7 Vac
160 Vac	159.2 Vac	160.8 Vac

Power Reading Verification

Step 1: Use the same voltage connections as in the previous test, polarity voltage jumpered to VA, VB, and VC, neutral tied to VN. Use the same current connection as in Steps 3 and 4 of *Current Circuit Verification;* that is, polarity current in I1 and out I3∙ with I1∙ and I2, I2∙ and I3, and I3∙ jumpered together.

Note

Power readings in this procedure are based on a 5 amp BE1-FLEX; for 1 amp values, divide by 5 if desired.

Step 2: Apply 100 Vac at angle 0 degrees and 5 Aac to the BE1-FLEX. Verify the accuracy of the power reading by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1, Power screen. Power should be 1.5 kW ±1.0% and reactive should read near 0 vars. The apparent power should be 1.5 kVA ±1.0% at unity power factor. Power measurements can also be verified from the Real Time Data tab of the front-panel display.

Step 3: Reverse the current polarity and apply the same values as in Step 2. Note that the power reading is –1.5 kW, which indicates "power in" to the zone being protected.

Step 4: Return the current polarity back to the Step 1 position. Apply 100 Vac at an angle of 0 degrees and 5 Aac at an angle of –90 degrees (I lags E by 90°) to the BE1-FLEX, and verify reactive power accuracy by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1, Power screen. Power should be nearly 0 kW, and the reactive power should read 1.5 kvar ±1.0%. Power measurements can also be verified from the Real Time Data tab of the front-panel display. Note power factor reads near 0 with a negative sign indicating a lagging power factor angle.

Step 5: Reverse the current polarity and apply the same values as in Step 4. Note that the reactive power reading is –1.5 kvar, which indicates reactive power in to the device being protected. Also note that the power factor angle is a positive value near zero. A positive power factor angle indicates leading power factor.

Step 6: Repeat Steps 2 and 4 for current values of 10 and 20 Aac. Corresponding power reading should be 3 kW/kvar and 6 kW/kvar ±1.0%.

VG Voltage Input Verification - (Fundamental and Third Harmonic)

Step 1: From the Settings, Configuration, Circuit Summary, select Circuit 1. Edit Circuit to add VX hardware to the configured VG.

Step 2: Connect BE1-FLEX terminals VX (polarity) and VX• to a 60 hertz ac voltage source.

Step 3: Apply the voltages listed in Table 58-6 and verify voltage-measuring accuracy by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1, Voltage, Secondary Voltage screen. Accuracy is ±0.5%.

Step 4: Connect BE1-FLEX terminals VX (polarity) and VX• to a 180 Hz (third harmonic) ac voltage source.

Step 5: Apply the voltages listed in Table 58-6 and verify voltage-measuring accuracy by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1, Voltage, Secondary Voltage screen. Voltage measurements can also be verified from the Real Time Data tab of the front-panel display. Accuracy is ±0.5%.

Table 58-6. VG Voltage Verification VG and VG 3rd Harmonic Values

Applied Voltage	Measured Voltage	
	Lower Limit	Upper Limit
30 Vac	29.85 Vac	30.15 Vac
50 Vac	49.75 Vac	50.25 Vac
70 Vac	69.65 Vac	70.35 Vac
90 Vac	89.55 Vac	90.45 Vac
110 Vac	109.45 Vac	110.55 Vac

Frequency Verification

Step 1: Connect BE1-FLEX terminals VA (polarity) and VN (A to Neutral of the three-phase voltage input) to a 60 hertz ac voltage source (line voltage).

Step 2: (Optional) For sync-check/auto-synchronizer applications: Configure Circuit 2 with Vx as Phase V. Connect BE1-FLEX terminals VX (polarity) and VX• to a second 60-hertz ac voltage source (bus voltage).

Step 3: Apply 115 Vac at 0 degrees and 60 hertz to one or (optional) both sources. Verify the measuring accuracy of the line and bus frequency by using the Metering Explorer in BESTCOMS*Plus* to open the Analog Metering, Circuit, Circuit 1 Frequency screen. Frequency measurements can also be verified from the Real Time Data tab of the front-panel display. (Optional) Repeat validation for Circuit 2.

59 • Commissioning Testing

Special precautions should be taken to ensure that all tests are performed with safety as the greatest concern. Any CT circuit signals routed through this device as part of a protection scheme, including discrete relays or as a stand-alone device, should be shorted and isolated from this BE1-FLEX during these tests.

If this BE1-FLEX is being installed in an existing installation, be aware of the equipment monitoring features of this device, especially if the monitoring logic will be utilized. Make note of any pretest operation levels, duty levels, etc. on existing equipment (e.g., breakers or transformers). As the user, you can make the determination of what values the BE1-FLEX should have as initial monitoring values when the BE1-FLEX is placed in service.

It may on occasion be necessary to temporarily disable some of the protective elements while testing the BE1-FLEX to isolate testing of individual functions. Always remember to enable these functions before placing the BE1-FLEX in service.

To assist you in the commissioning testing of this BE1-FLEX, you can refer to the related reporting and alarms chapters.

Please refer to the related protection and control chapters of the instruction manual for assistance on any particular functions of the BE1-FLEX. If you require further assistance, contact Basler Electric Technical Support.

Digital I/O Connection Verification

Contact Sensing Inputs

Purpose: Verify operation, labels, and logic settings of the contact sensing inputs.

Chapter Reference: *Hardware Configuration*

Step 1: Use the Settings Explorer in BESTCOMS*Plus*® to open the Configuration, Input Summary screen and verify the input's hardware slot and channel mapping, user-defined name, recognition time, debounce time, energized state label, and de-energized state label. Refer to the *Hardware Configuration* chapter for terminations and I/O options of each board type. Repeat for all Inputs.

Step 2: Use the Metering Explorer in BESTCOMS*Plus* to open the Status, Inputs screen. Verify the status of Input 1. From the actual field device, energize (or de-energize) the specific contact that supplies Input 1 of the BE1-FLEX. While maintaining contact position, verify that Input 1 has changed state on the Status, Inputs screen of BESTCOMS*Plus* or the front-panel display. Return the field contact to its original state and verify that Input 1 returns to its original state.

Step 3: Repeat Step 2 for each connected input.

Step 4: Use the Metering Explorer in BESTCOMS*Plus* to open the Reports, Sequence of Events screen. Click the Download button and review the events associated with the field contact changes.

Output Contacts

Purpose: Verify operation, verify labels, and logic settings of the output contacts.

Chapter Reference: *Hardware Configuration*

Step 1: Use the Settings Explorer in BESTCOMS*Plus* to open the Configuration, Output Summary Contacts screen and verify the output's hardware slot and channel mapping, energized state label, de-energized state label, and hold attribute. Repeat for all outputs. Refer to the *Hardware Configuration* chapter for the terminations of each board type. Note that some outputs are Form C and some outputs are Form A.

Step 2: Use the Metering Explorer in BESTCOMS*Plus* to open the Control, Output Override screen. Verify the status of all outputs. Use the procedure outlined in the *Acceptance Testing* chapter's *Control Outputs* section to actuate selected output contacts and actually trip or close the connected field device (circuit breaker, lockout, etc.). Verify that the selected output has changed state on the Control, Output Override screen in BESTCOMS*Plus*. Return the output to its original state and verify.

Step 3: Use the Metering Explorer in BESTCOMS*Plus* to open the Reports, Sequence of Events screen. Click the Download button and review the events associated with the output contact change.

Virtual Control Switches

Purpose: Verify operation, labels, and logic settings of the 43 switches.

Chapter Reference: *Virtual Control Switch (43)*

Step 1: Use the Settings Explorer in BESTCOMS*Plus* to open the Control, Virtual Control Switch (43) screen and select a Virtual Control Switch. Verify the mode, name label, on color, on label, off color, and off label.

Step 2: Use the Metering Explorer in BESTCOMS*Plus* to open the Control, Virtual Control Switch screen and obtain the position virtual switches. Alternately, the virtual control switch positions can be obtained on the Metering, Control, Virtual Control Switch screen on the front-panel display.

Step 3: For each virtual control switch enabled in your logic scheme, change the switch position by following the procedure described in the *Virtual Control Switch (43)* chapter.

Step 4: Verify each switch position change on the Control, Virtual Control Switch screen of BESTCOMS*Plus* or on the front-panel display.

Step 5: Return each virtual control switch to the original position.

Step 6: Use the Metering Explorer in BESTCOMS*Plus* to open the Reports, Sequence of Events screen. Click the Download button and review the events associated with the virtual control switch activities.

Breaker Control Switch

Purpose: Verify operation and logic setting for the 101 switch.

Chapter Reference: *Breaker Control Switch (101)*

Step 1: Use the Settings Explorer in BESTCOMS*Plus* to open the Control, Breaker Control Switch screen and select a Breaker Control Switch. Verify the mode, on color, and off color.

Step 2: Use the Metering Explorer in BESTCOMS*Plus* to open the Control, Breaker Control Switch screen and obtain the position of the breaker control switch. Alternately, the breaker control switch position can be obtained on the Metering, Control, Breaker Control Switch screen on the front-panel display.

Step 3: Change the switch position by following the procedure described in the *Breaker Control Switch (101)* chapter.

Step 4: Verify the switch position change on the Control, Breaker Control Switch screen of BESTCOMS*Plus* or on the front-panel display.

Step 5: Return the breaker control switch to the original position.

Step 6: Use the Metering Explorer in BESTCOMS*Plus* to open the Reports, Sequence of Events screen. Click the Download button and review the events associated with the breaker control switch.

Protection and Control Function Verification

Before placing the BE1-FLEX in service, ensure that all system ac and dc connections are correct, that the BE1-FLEX functions as intended with user settings applied, and that all equipment external to the BE1-FLEX operates as intended. All connected or monitored inputs and outputs, and polarity and phase rotation of ac connections should be tested. Verify that:

- Power supply voltages and contact wetting voltages are correct.
- User desired protection and control functions are enabled and connected to the correct CT and VT input circuits.
- The programmable logic settings (electronic wiring) provide the proper interconnection of these functions with the I/O of the BE1-FLEX.

Simple user-designed fault tests should be used to verify that the operational settings are correct, that the proper output relays are actuated and proper targeting occurs.

Use of the fault and event recording capability of the BE1-FLEX will aid in the verification of the protection and control logic. Use the Metering Explorer in BESTCOMS*Plus* to open the Reports, Sequence of Events screen. In addition, it is helpful to click on the Clear button prior to starting a test. This allows the user to review only those operations recorded since the Sequence of Events was last cleared. Refer to the *Sequence of Events* chapter for more detail.

It may be necessary to disable protection elements or change setting logic to verify a specific function. To guard against placing the BE1-FLEX in service with unwanted operational or logic settings, it is good practice to save a copy of the original setting file before the testing process begins. When testing is complete, compare the copy of the saved settings to the actual settings as a final verification from the Tools pull-down menu.

Use the settings compare feature in BESTCOMS*Plus* to compare setting files. Refer to the *BESTCOMSPlus* chapter for more information.

Verify Other Setpoints as Appropriate

Consult the *Specifications* chapter for performance guidelines on each protection and control function.

Reporting and Alarm Functions

Just prior to placing the BE1-FLEX in service, the following reporting and alarm functions should be reset and/or verified. Repeat for each instance configured.

Clock Display

Navigation Path: Metering, Status, Real Time Clock

Chapter Reference: *Timekeeping*

Set the real-time clock to the current date and time. If an IRIG signal or NTP server is used, day, time, and year are automatically synchronized with the source. Note that the time code signal from older IRIG time code generating equipment does not contain the current year information thus necessitating the entry of the year. The BE1-FLEX can be set to utilize either code type.

Energy Data and Demand

Navigation Path: Metering, Analog Metering, Circuit, Demand Metering

Chapter Reference: *Power System Configuration*

Read, change, or reset kWh and kvarh records. Reset the peak current, watt, and var demand registers to “0” or a pre-existing value.

Breaker Monitoring

Navigation Path: Metering, Analog Metering, Breaker, Breaker-1, Breaker Monitor

Chapter Reference: *Power System Configuration*

If the Breaker Monitoring features of the BE1-FLEX are enabled, reset the counter and the duty registers to "0" or a pre-existing value.

Relay Trouble Alarms

Navigation Path: Metering, Status, Alarms

Chapter Reference: *Alarms*

Reset and verify that the relay trouble alarm is not annunciated. If required, alarm information can be read by using the Metering Explorer in BESTCOMS*Plus* to open the Status, Alarms screen. To attempt clearing a Relay Trouble Alarm, click the Reset Relay Alarms in BESTCOMS*Plus* button or press the Alarm banner in the upper right corner of the HMI, then press the Reset Alarms button. The alarm banner does not display on the HMI if no Targets or Alarms are active. Refer to the *Alarms* chapter for settings details.

Major/Minor Programmable Alarms

Navigation Path: Metering, Status, Alarms

Chapter Reference: *Alarms*

Reset and verify that the programmable alarms, Major and Minor, as set to meet user needs, are not annunciated or asserted. If required, alarm information can be read by using the Metering Explorer in BESTCOMS*Plus* to open the Status, Alarms screen. To reset a Major/Minor alarm, press the Reset Major, Minor Alarms button or press the Alarm banner in the upper right corner of the HMI and press the Reset button. The alarm banner does not display on the HMI if no Targets or Alarms are active. Refer to the *Alarms* chapter for settings details.

Targets

Navigation Path: Metering Explorer, Status, Targets

Chapter Reference: *Fault Reporting*

Reset any active targets and verify that they clear. To reset targets, press the Alarm banner in the upper right corner of the HMI, then press the Reset button. Targets can also be cleared by using the Metering Explorer in BESTCOMS*Plus* to open the Status, Targets screen and clicking the Reset Targets button. The target banner does not display on the HMI if no Targets or Alarms are active.

Sequence of Events Recorder (SoE)

Navigation Path: Metering, Reports, Sequence of Events

Chapter Reference: *Sequence of Events*

Reset the "new" SoE records counter to "0" by using the Metering Explorer in BESTCOMS*Plus* to open the Reports, Sequence of Events screen and click the Clear button. Verify that the new records are "0" by clicking the Download button. Refer to the *Sequence of Events* chapter setting details.

Just Prior to Energizing - Report Documentation

After completing the previous steps, click Export Metering on the icon menu bar to capture and save the information for inputs, outputs, alarms, and targets. Include other measurements as desired. This report should be kept in a permanent record file of the device so the data can be used for status validation.

In addition, save the entire settings record for future reference by using BESTCOMS*Plus* and selecting Download from Device Information from the Communication pull-down menu. After settings and logic are downloaded into BESTCOMS*Plus* memory, select Save from the File pull-down menu. Use this record during the maintenance cycle or during the analysis of an operation to verify that the “as found” settings are exactly as left during the commissioning process.

Refer to the related reporting and alarms chapters and the *BESTCOMSPlus* chapter.

In-Service Readings

After energizing the equipment, use the Metering Explorer in BESTCOMS*Plus* to verify the following analog metering values:

- Secondary voltage and current to verify VT and CT ratios.
- Polarity of energy readings to verify polarity of VT and CT connections.
- I2 and V2 to verify proper phase-sequence connections.
- Anything else that the user may find helpful.

Save this record along with the status record mentioned earlier for future reference.

60 • Periodic Testing

Because the BE1-FLEX has extensive internal test capabilities, periodic testing of the protection system can be greatly reduced. BE1-FLEX operating characteristics are a function of programming instructions that do not drift over time. Thus, the user may wish to verify items that the protection system's self-testing features cannot completely determine. Periodic testing may consist of the following settings and function checks:

- Verify that the setpoints that were proven during commissioning have not been changed.
- Verify proper interfacing between the inputs and outputs and the rest of the protection and control system.
- Verify that the power system analog parameters used by the protection and control functions are measured accurately.

Settings, Logic and Device Information Verification

Verification of the BE1-FLEX settings is accomplished by utilizing the Settings Compare function of BESTCOMS*Plus* under the Tools pull-down menu. Comparing Download settings from the Unit (as found) to the Settings File on Disk (document of record) provides as found – as intended verification.

I/O Verification

Verification of the BE1-FLEX digital I/O connections can be accomplished in different ways. The method used depends on your preferences and practices. You may choose to use either of the following two methods:

- Repeat the digital I/O connection and label verification under commissioning tests.
- Monitor SoE, status, and fault reports for proper sensing of digital signals and proper output tripping during normal operation.

Note
In redundant protection systems where multiple relays will trip a given breaker or other device for a fault, fault record monitoring may not indicate a failed output contact. The BE1-FLEX may report that it energized an output when tripping was actually accomplished by the redundant relay. In this situation, testing the contact is recommended.

Analog Circuit Verification

Verification of BE1-FLEX analog measurement circuits can be accomplished in multiple ways and depends on your preferences and practices. Either of the two following methods may be used:

- Repeat the acceptance tests by injecting test quantities into the BE1-FLEX.
- Use the BE1-FLEX metering functions to compare the protection system's measurements with those made by similar devices that are measuring the same signals. Redundant protection systems or metering devices can provide this independent confirmation of measured signals. If the BE1-FLEX is connected to an integration system, this verification can even be automated and done on a semi-continuous basis.

Note

If verifying the analog measurement circuits by comparison to independent devices is used, attention should be given to the measurement algorithm variances. For example, the measurements of a fundamental sensing relay cannot be directly compared with the measurements of an rms sensing device.

Functional testing is NOT required for this device. It is necessary only when performing a comprehensive assessment to determine suitability for an application.

61 • Frequently Asked Questions (FAQ)

Electrical/Connections

Is the power supply polarity sensitive?

Yes, power supply options reference whether they will accept ac and dc or dc only voltage. Positive and negative references are shown on power supply terminals. Refer to the *Hardware Configuration* chapter.

Are the sensing contacts polarity sensitive?

Yes, positive and negative references are shown on all input terminals. Refer to the *Typical Connections* and *Hardware Configuration* chapters for more information.

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

Voltage level is dependent on the Sensing Level setting per board in the Hardware Configuration settings. For additional information, refer to the *Power System Configuration* chapter.

Can the IRIG signal be daisy-chained to multiple BE1-FLEX units?

Yes, multiple BE1-FLEX units can use the same IRIG-B input signal by daisy-chaining the BE1-FLEX inputs. The burden data is nonlinear, approximately 4 kΩ at 3.5 Vdc and 3 kΩ at 20 Vdc. See the *Specifications* chapter for additional information.

General Operation

Does the BE1-FLEX trip output contact latch after a fault?

The answer to the question is yes and no. In general, once the fault goes away the output contacts open. The BE1-FLEX does offer an option to ensure that the contact will stay closed for at least 200 milliseconds. See the *Power System Configuration* chapter for additional information on that function. Also, a Set Priority Latch in BESTlogic™*Plus* can keep the relay outputs closed as long as power is applied. Finally, style options are available with Form C outputs that include a Normally Open and Normally Closed contact.

Can logic settings be made at the front panel?

No, logic settings cannot be made at the front panel. Logic settings must be programmed using BESTCOMS*Plus*® communication software. Logic settings can be viewed from the HMI.

Since the BE1-FLEX is a programmable device, what are the factory defaults?

The BE1-FLEX does not contain any default logic. A logic scheme must be uploaded before placing the BE1-FLEX in service. BESTCOMS*Plus*® can be used to open a settings template that was previously saved as a file and upload it to the BE1-FLEX.

Does the BE1-FLEX have a battery installed as the backup power source for the internal clock on loss of power?

A ride-through capacitor, up to 24 hours, and a backup battery, greater than 5 years, are standard features of the BE1-FLEX. Refer to the *Timekeeping* chapter for more information on the backup battery including replacement.

How are reports and other information obtained from the BE1-FLEX saved in files for future use?

BESTCOMS*Plus* and web pages can be used to view and download device information, diagnostic log, sequence of events, fault records, security log, load profile, and real-time metering. Reports, excluding oscillography capture, can be viewed from the HMI. See the appropriate chapters for more information.

What is the version number of the BE1-FLEX?

The application version can be found on the Device Information screen of the front-panel display, in BESTCOMS*Plus*, and on the web pages.

Features

How many elements does the BE1-FLEX have available?

A BE1-FLEX has over 25 unique general protection, automation, and control element types. Configurable protection allows for protection and control of almost all metered parameters. A device can be configured for nearly any quantity and combination of any element. Hundreds of elements in a configuration are possible. Some elements types are limited by field upgradable style number.

Communications

Is the IRIG signal modulated or demodulated?

The BE1-FLEX accepts an IRIG-B signal that is demodulated (dc level-shifted digital signal). See the *Specifications* chapter for additional information.

62 • Troubleshooting

Basler microprocessor-based protection, automation, and control systems are similar in nature to a panel of electromechanical or solid-state component relays. Both must be wired together with inputs and outputs, and have operating settings applied. Logic settings determine which protection elements are electronically wired to the inputs and outputs of the device. Operating settings determine the pickup thresholds and time delays. The major variance across product types is where the wiring occurs. With electromechanical or solid-state, the connections are normally outside of the relay. With multi-function products, a single box commonly monitors numerous inputs and outputs and 'wires' them internally.

The logic and operating settings should be tested by applying actual inputs and operating quantities and verifying proper output response. For more details, refer to the testing chapters. All of the following connections and functions should be verified during commissioning tests:

- Proper connection and sensing of current and voltage signals
- Input and output contact connections
- Input and output sensing
- Settings validation
- Proper operation of equipment (main or auxiliary)
- Proper alarming (to SCADA) and/or targeting

If you do not get the results that you expect from the BE1-FLEX, first check the programmable settings for the appropriate function. Use the following troubleshooting procedures when difficulties are encountered in the operation of your BE1-FLEX.

Warning!
Troubleshooting of the BE1-FLEX should be performed only by qualified personnel. High voltage may be present on the rear terminals of the BE1-FLEX.

Communications

Ethernet Port Does Not Operate Properly

Step 1. The BE1-FLEX can be equipped with numerous Ethernet ports. Verify that the proper port of your computer is being used. For more information, refer to the *Communications* chapter.

Step 2. Ports have independent settings. Verify that the network configuration of the BE1-FLEX is set up properly. For more information, refer to the *Communications* chapter.

Step 3. Verify that the protocol and port are enabled in the Security settings. Default settings have most protocols disabled. For more information, refer to the *Security* chapter.

USB Port Does Not Operate Properly

Verify that the USB driver was installed properly. For more information, refer to the *BESTCOMSPlus Software* chapter.

USB Driver Did Not Install Properly (Windows® 10 used as example)

Step 1. Close all programs and restart the computer. Run the BESTCOMS*Plus* installer and select Modify to complete the installation. See Figure 62-1 and Figure 62-2.

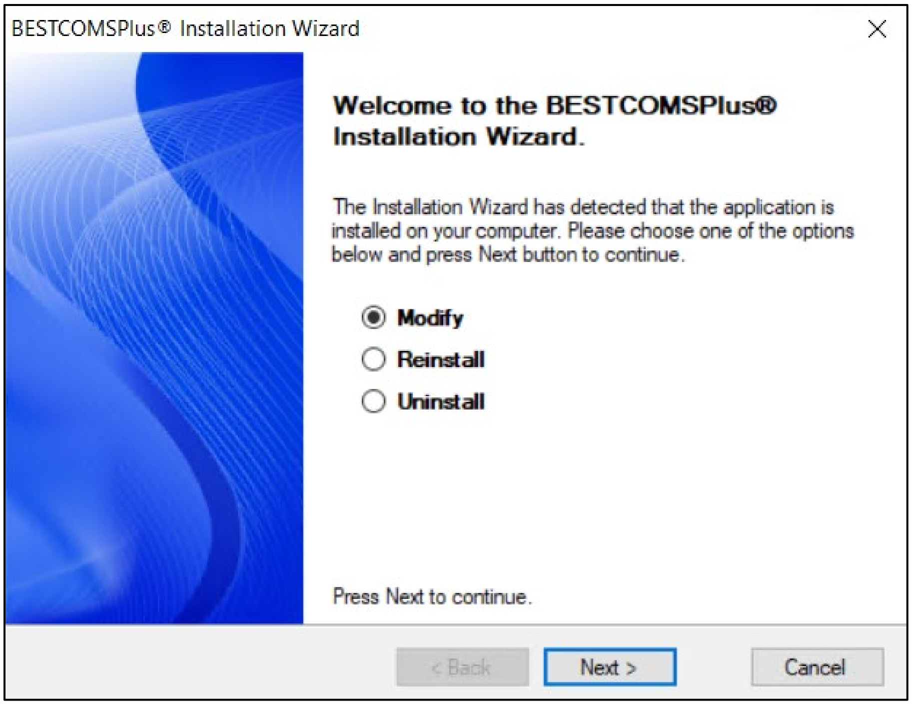


Figure 62-1. BESTCOMS*Plus* Installation Wizard

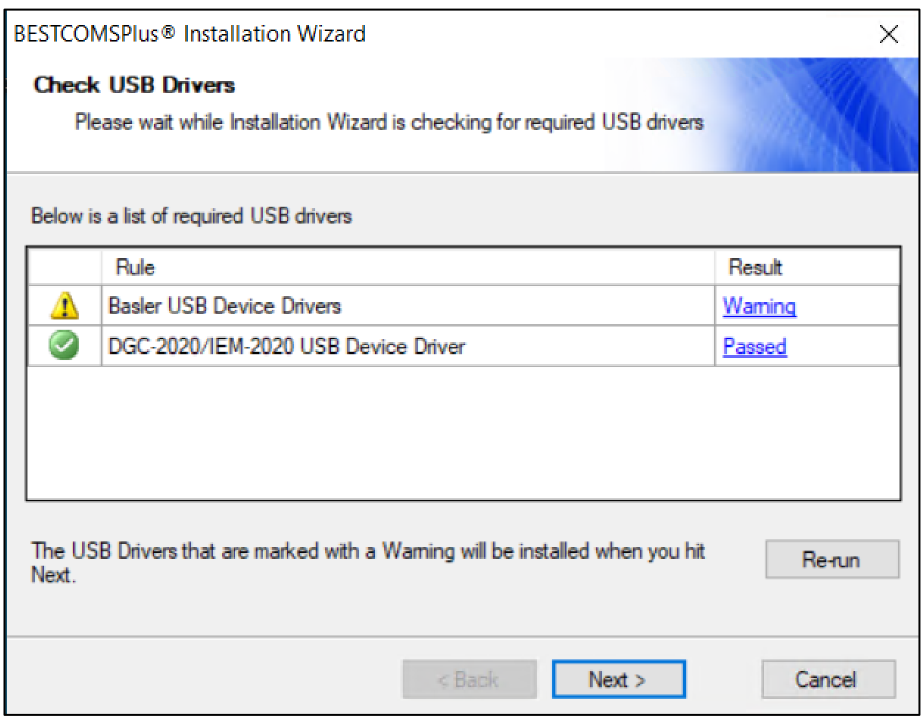


Figure 62-2. Check USB Drivers Screen

Step 2. Open the Windows® Device Manger as shown in Figure 62-3. Right-click on USB Serial Device (COM#) for the BESTCOMS*Plus* connection and select Update Driver.

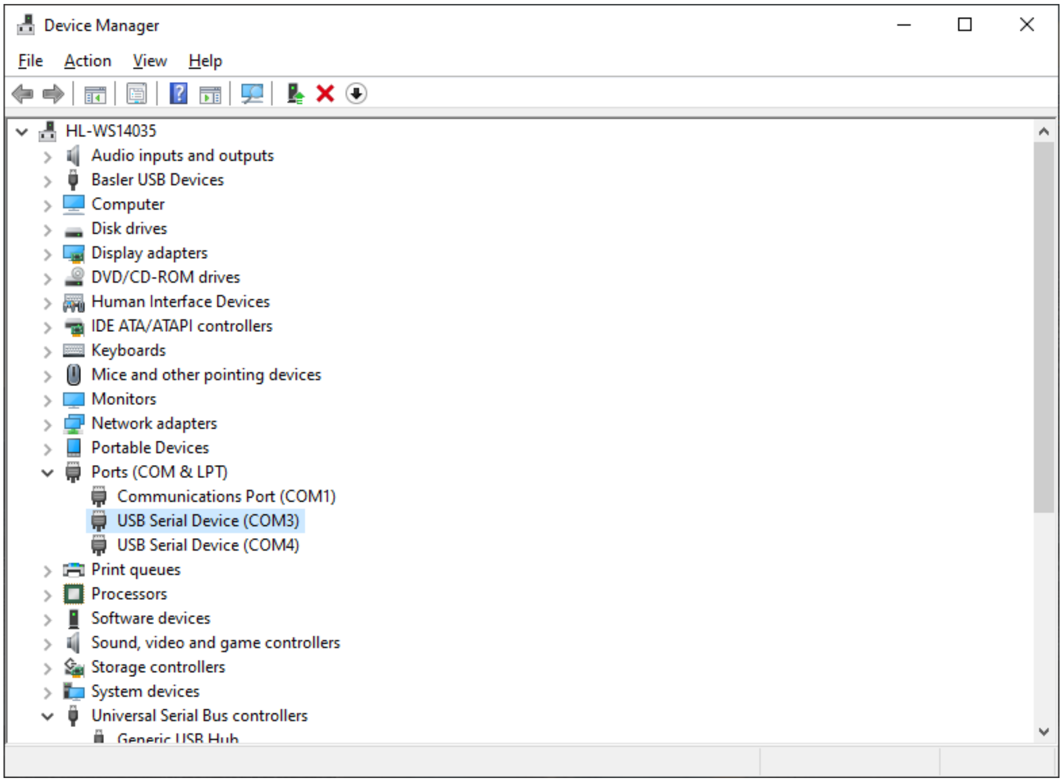


Figure 62-3. Device Manager

Step 3. In the Basler USB Connect Properties window (Figure 62-4), select the Details tab. Check to see if the Value contains **MI_00** or **MI_02** in the middle of the string. This value will be used later in Step 6.

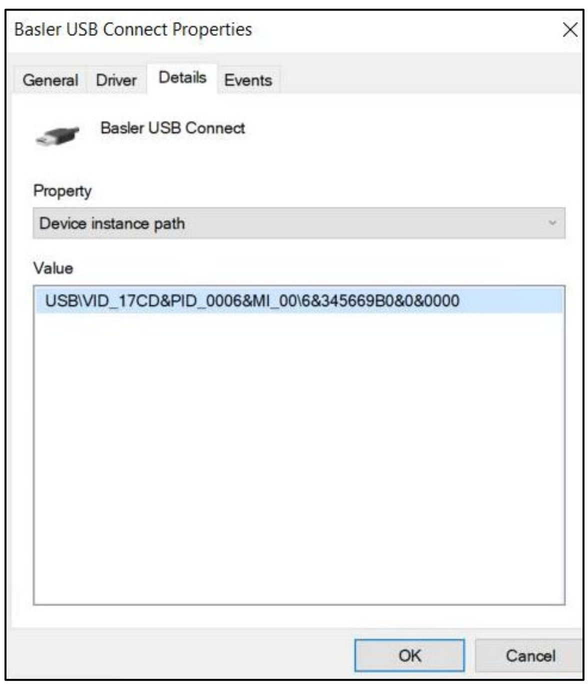


Figure 62-4. Basler USB Connect Properties

Step 4. In the USB Serial Device (COM#) Properties window, select the Driver tab and click Update Driver. See Figure 62-5.

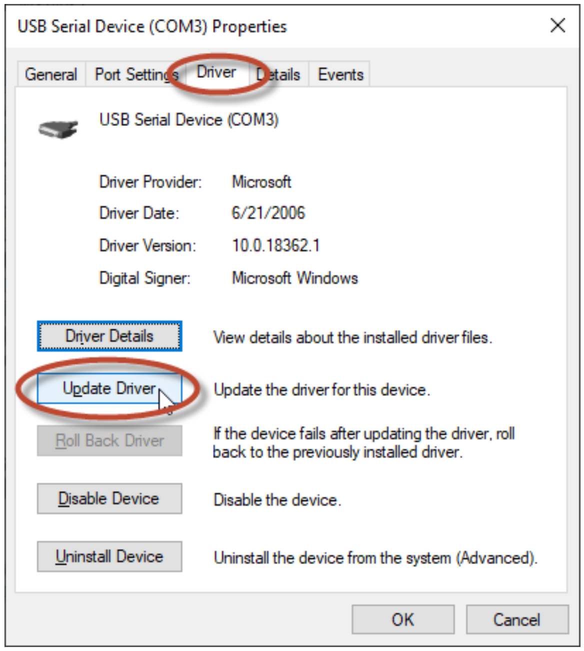


Figure 62-5. USB Serial Device Properties

Step 5. Select Browse My Computer for Driver Software as shown in Figure 62-6.

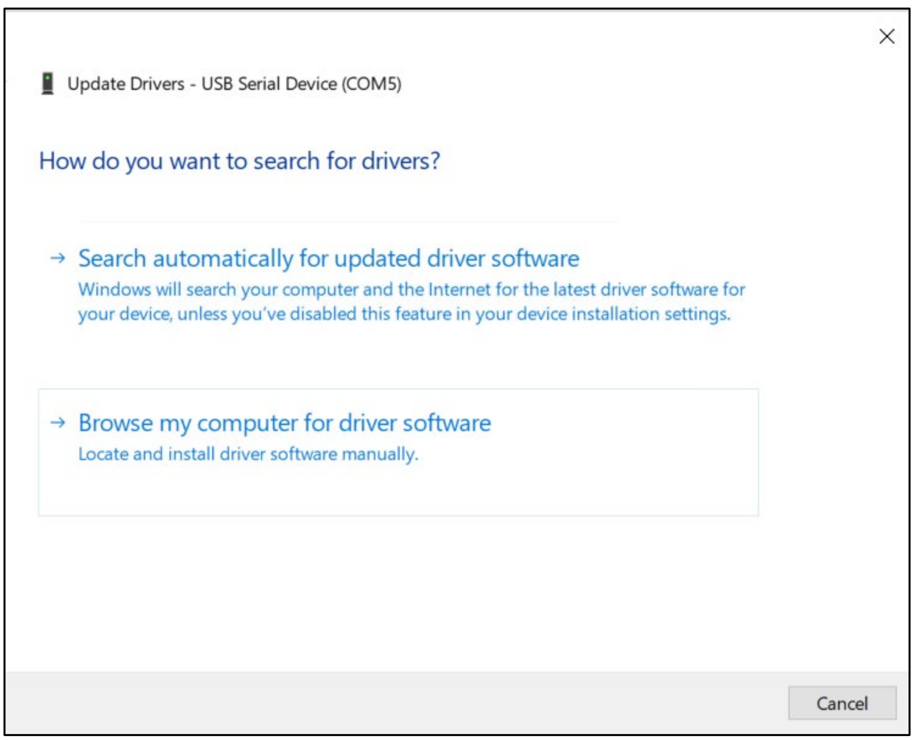


Figure 62-6. Browse Computer for Driver Software

Step 6. Click Browse and navigate to C:\Program Files\Basler Electric\USB Device Drivers\W10x64_USBIO. If the value in Step 3 contained **MI_02**, select W10x62_USBCOM instead. Click Next. See Figure 62-7.

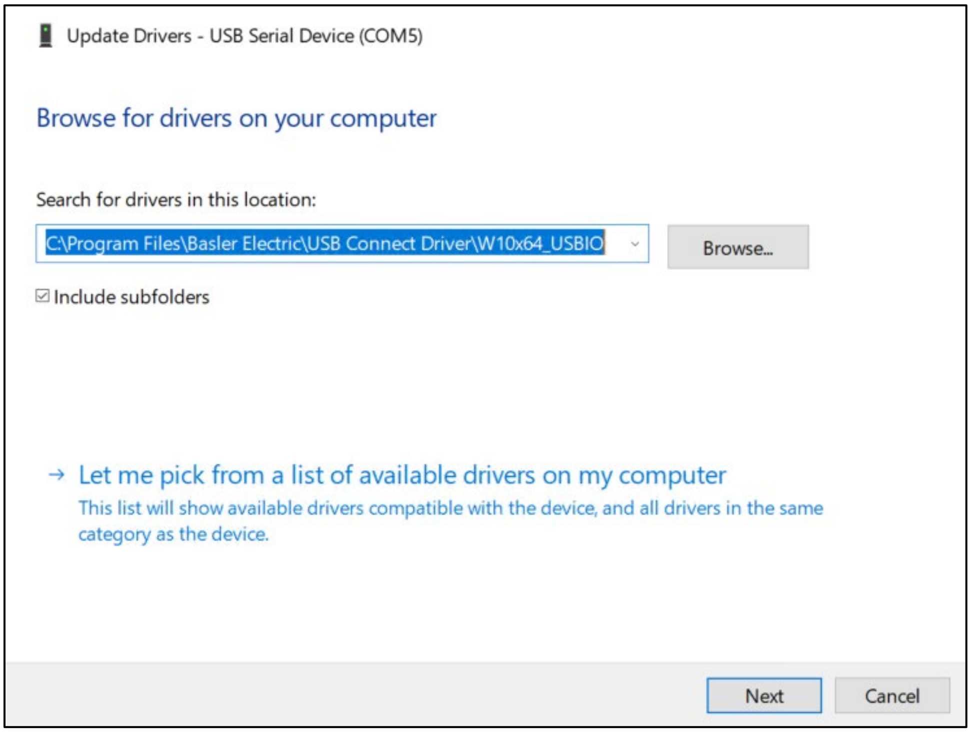


Figure 62-7. Update Drivers

Step 7. If a Windows Security window (Figure 62-8) appears, click Install.

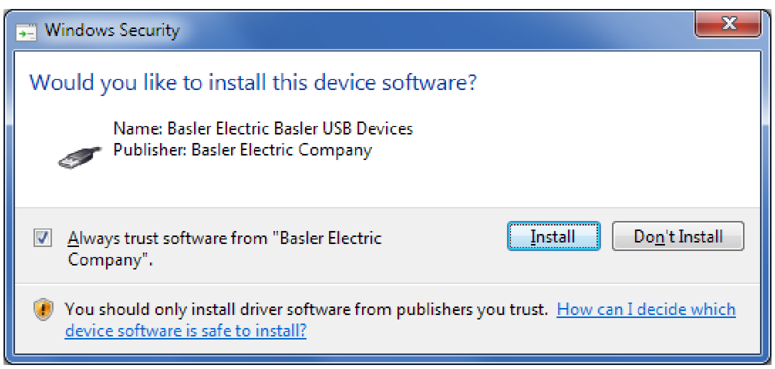


Figure 62-8. Windows Security

Step 8. The window in Figure 62-9 appears if driver installation was successful.

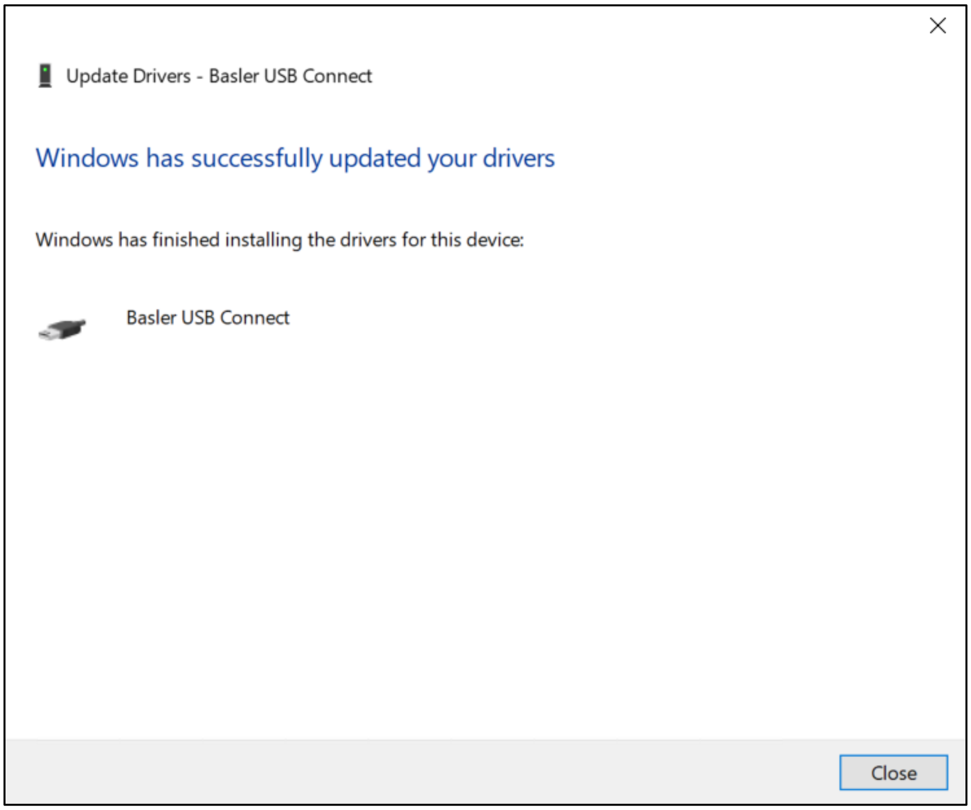


Figure 62-9. Driver Software Update Successful

In Modbus® TCP/IP, the client cannot communicate with the BE1-FLEX, but can communicate over Modbus TCP/IP with other devices on the same network.

Step 1. Verify that there is no IP address or Modbus server address conflict.

Step 2. For some devices on an Ethernet network, only the IP address is required to communicate over Modbus TCP/IP. This is because each device must have a different IP address. With BE1-FLEX systems, in addition to the correct IP address, the client must also use the correct server address.

The BE1-FLEX security parameters are not sent to the relay when I upload settings.

The security settings are included in with Settings, Logic, or Device information files. The Upload Security to Device box must be checked to send Security settings to the BE1-FLEX.

I upgraded BESTCOMSPlus and my desktop shortcuts no longer work.

BESTCOMS*Plus* desktop shortcuts may no longer link correctly. Use the shortcuts created with the latest install to open BESTCOMS*Plus*. Delete the original shortcuts as they link to software that is no longer present or active.

I moved an Ethernet connection from Port 1 to Port 2 and it does not communicate.

Cycle control power on the BE1-FLEX to establish communication on Port 2. This is used to reset network knowledge of the previous connection.

Communications cannot be established when using the USB-C port of the computer.

USB-C to USB-C communications is not directly supported in the BE1-FLEX. Some solutions are to utilize a different USB port type or USB-C to USB-A cable with USB-A to USB-C adapter or hub to communicate.

Inputs and Outputs

Programmable Inputs Do Not Operate as Expected

Step 1. Verify that all wiring is properly connected. Refer to the *Hardware Configuration* and *Typical Connections* chapters.

Step 2. Verify that the inputs are mapped to expected hardware from the Output Summary screen.

Step 3. Verify that the Sensing Level is set to the correct voltage on the Hardware Info (Slot #) screen in BESTCOMS*Plus*. Refer to the *Power System Configuration* chapter.

Programmable Outputs Do Not Operate as Expected

Step 1. Verify that all wiring is properly connected. Refer to the *Hardware Configuration* and *Typical Connections* chapters.

Step 2. Verify that the outputs are programmed properly.

Step 3. Verify that the output is not being set by other means. There can be more than one connection to an output (check the physical outputs tab in BESTlogic*Plus*). Also, check that the output override is not set for the output. Live Logic status can be viewed from BESTCOMS*Plus* metering to further diagnose logical conditions controlling the outputs.

Metering/Display

Incorrect Display of Current

Step 1. Verify that all wiring is properly connected. Refer to the *Hardware Configuration* and *Typical Connections* chapters.

Step 2. Verify that the Circuits are mapped to expected hardware via the Circuit Summary screen.

Step 3. Verify that the proper current is present at BE1-FLEX current sensing inputs. Refer to the *Hardware Configuration* chapter for input terminal locations.

Step 4. Verify that the current transformer ratio and sensing configuration is correct.

Step 5. Verify that the current sensing transformers are correct and properly installed.

Incorrect Display of Voltage

Step 1. Verify that all wiring is properly connected. Refer to the *Hardware Configuration* and *Typical Connections* chapters.

Step 2. Verify that the Circuits are mapped to expected hardware via the Circuit Summary screen.

Step 3. Verify that the proper voltage is present at BE1-FLEX voltage sensing inputs. Refer to the *Hardware Configuration* chapter for input terminal locations.

Step 4. Verify that the voltage transformer ratio and sensing configuration is correct.

Step 5. Verify that the voltage sensing transformers are correct and properly installed.

General Operation

How do I reset targets or alarms?

To reset the Trip LED, targets or alarms, navigate to Reports > Targets & Alarm and click the Reset button. The targets and alarms will not reset if the initiating trip or alarm condition still exists.

The 60FL alarm or target does not reset when I press the Target Reset.

The only way to reset the Fuse Loss alarm or target is to apply more than 85% of rated positive-sequence voltage. Refer to the *Fuse Loss (60FL)* chapter for more information.

Do I have to log in to reset the targets or alarms?

It depends on the security setup. You can reset the targets or alarms through a specific port without logging in if the Unsecured Access Level is set to Control on that port. Target and alarm reset can also be set outside of security control, allowing reset through the front-panel interface without logging in. Refer to the *Security* chapter for more information.

The targets or trip LED does not work properly.

If a protective element is tripping at the desired level, but the targets and Trip LED are not behaving as expected, use BESTCOMS*Plus* to verify that the targets are enabled for the protective function. Refer to the *Fault Reporting* chapter for detailed information about targets.

Trip LED behavior depends on the Pickup and Trip status of the Fault Recorder and presence of dropped (latched) targets. The Fault Recorder status can be driven both by within each protective element as well as within logic. When the Fault Recorder pickup value is true and the Fault Recorder trip value is false, the Trip LED flashes. When the Fault Recorder trip value is true, the Trip LED lights Solid. If Targets are active, the LED will remain Solid after the Fault Recorder Pickup and Trip return to false. The below logic drawing (Figure 62-10) defines how the LED illuminates.

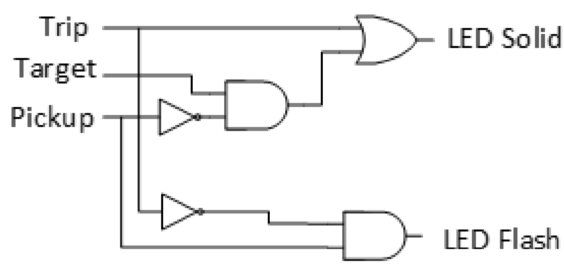


Figure 62-10. Trip LED Logic

Why are voltage dependent elements (21P, 24, 25, 25A, 27, 32, 40Q, 40Z, 51V, 55, 59, 78OOS, 78V) not operating as expected when testing by secondary injections?

The BE1-FLEX has the ability to distinguish a loss of fuse from a loss of voltage. Check the sequence of events for a Fuse Loss alarm. If a Fuse Loss alarm is active, voltage dependent elements will not operate when set to Block with 60FL. Refer to the *Fuse Loss (60FL)* chapter for information on applying voltage and current so the BE1-FLEX does not detect a fuse loss. Fuse Loss protection can also be disabled for the protection element being tested.

63 • Specifications

BE1-FLEX Protection, Automation, and Control Systems have the following features and capabilities for voltages and currents in the range of 40 to 70 Hz.

Metering Specifications

Metered Current Values and Accuracy

Phase and Ground Range ....0.15 to 15 Aac
SEF Range..0.01 to 3.0 Aac
Phase and Ground Current Accuracy.......................±0.5% of reading at nominal current
±1% of reading or ±0.15% of full range, whichever is greater at 77°F (25°C)
SEF Accuracy...±(1% + 4.5 mA) at 77°F (25°C)
I1, I2, I0* Accuracy...±0.8% of reading at nominal current
±1.5% of reading or ±0.25% of full range, whichever is greater at 77°F (25°C)
Temperature Dependence......................................≤ ±0.02% per °C
* 3I0 displayed

Metered Voltage Values and Accuracy

Range ....50 to 250 Vac
Accuracy ....±0.5% of reading or ±0.1% of full range whichever is greater at 77°F (25°C)
V1, V2, V0* Accuracy...±0.75% of reading or ±0.15% of full range whichever is greater at 77°F (25°C)
Temperature Dependence......................................≤ ±0.02% per °C
* 3V0 displayed

Metered Frequency Values and Accuracy

Range ....10 to 125 Hz
Accuracy ....±0.01 Hz, ±1 least significant digit at 77°F (25°C) from 10 to 79.99 Hz
±0.02 Hz, ±1 least significant digit at 77°F (25°C) from 80 to 125 Hz
Minimum Frequency Tracking Voltage.....................10 V rms

Calculated Values and Accuracy

Demand

Range ....0.1 to 7.5 times nominal
Type...Exponential smoothing
Accuracy ....±1% of reading, ±1 digit at 77°F (25°C)
Temperature Dependence......................................≤ ±0.02% per °C
Interval ....1 to 60 min

True Power

Range ....–8,500 W to +8,500 W
Accuracy ....±1% at unity power factor

Reactive Power

Range ....–8,500 var to +8,500 var
Accuracy ....±1% at zero power factor

Energy Data Reporting

Range (Rollover) ....100,000,000,000 kWh or 100,000,000,000 kvarh
Units of Measure ....kWh or kvarh
Accuracy ....±1% at unity power factor

Protection Specifications

For the protection elements listed in this section, Pickup Time is the delay between onset of the event until pickup is acknowledged by the relay. Times listed are valid for 50 to 60 Hz systems. Time Delay and Time Dial accuracies relate to timing between pickup and trip, when set to a non-zero value.

Current ranges and accuracies listed do not apply to SEF hardware unless otherwise noted.

21N - Neutral Distance Protection

X and R Axis Reach
Setting Range..0 to 500 Ω
Accuracy ....±3% or ±0.2 Ω, whichever is greater from 0 to 500 Ω

Time Delay
Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....8 to 28 ms

Tilt Angle
Setting Range..–20 to 20°
Accuracy ....±1°

21P - Phase Distance Protection

Diameter
Setting Range..0 to 500 Ω
Accuracy ....±3% or ±0.2 Ω, whichever is greater from 0 to 500 Ω

Time Delay
Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....8 to 28 ms

Offset
Setting Range..–500 to 500 Ω
Accuracy ....±3% or ±0.2 Ω, whichever is greater from –500 to 500 Ω

24 - Overexcitation Protection

Inverse Time
Curve Exponent...0.5, 1, or 2

Pickup
Setting Range..0, 0.5 to 6 V/Hz
Accuracy ....±2% or ±0.05 V/Hz, whichever is greater
Dropout/Pickup Ratio..1 to 3% of actual pickup value

Time Dial
Setting Range..0.0 to 9.9
Accuracy ....±5% or ±3 cycles, whichever is greater
Pickup Time ....0 to 20 ms

Reset Dial
Setting Range..0.0 to 9.9
Accuracy ....±5% or ±3 cycles, whichever is greater

Definite Time 1 and 2

Pickup
Setting Range..0, 0.5 to 6 V/Hz
Accuracy ....±2% or ±0.05 V/Hz, whichever is greater

Time Delay
Setting Range..50 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

Alarm

Pickup
Setting Range..0, 0.5 to 6 V/Hz
Accuracy ....±2% or ±0.05 V/Hz, whichever is greater
Reset/Alarm Ratio ....1 to 3% of actual pickup value

Time Delay
Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

25 - Sync-Check Protection

Settings

Voltage Difference
Setting Range..0 to 50% of nominal
Accuracy ....±2% or ±1 V, whichever is greater

Slip Angle
Setting Range..1 to 99°
Accuracy ....±1°

Slip Frequency
Setting Range..0.01 to 0.50 Hz
Accuracy ....±0.01 Hz

Sensing

Angle Compensation Setting Range ....0 to 359.9°

Voltage Monitoring

Live/Dead Voltage
Setting Range..0, 10 to 90%
Accuracy ....±2%

Drop Out Delay
Setting Range..0, 50 to 60,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater

25A - Synchronizer

Settings

Voltage Difference
Setting Range..0, 2 to 15% of nominal
Accuracy ....±2% or ±1 V, whichever is greater

Slip Frequency
Setting Range..0 to 0.5 Hz
Accuracy ....±0.01 Hz

Minimum/Maximum Slip Frequency
Setting Range..0 to 2 Hz
Accuracy ....±0.01 Hz

Breaker Close Angle
Setting Range..0, 3 to 20°
Accuracy ....±1°

Breaker Close Time
Setting Range..0 to 1,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater

Breaker Close Pulse Time
Setting Range..10 to 10,000 ms

Breaker Close Attempts
Range ....0 to 5

Sync Fail Activation Delay
Setting Range..0 to 600 s
Accuracy ....±0.5% or ±8 ms, whichever is greater

Voltage Controller

Volt Pulse Width
Setting Range..0, 0.1 to 5 s
Accuracy ....±0.5% or ±16 ms, whichever is greater

Volt Pulse Interval
Setting Range..0, 0.2 to 10 s
Accuracy ....±0.5% or ±16 ms, whichever is greater

Frequency Controller

Frequency Pulse Width
Setting Range..0 to 99.9 s
Accuracy ....±0.5% or ±16 ms, whichever is greater

Frequency Pulse Interval
Setting Range..0 to 99.9 s
Accuracy ....±0.5% or ±16 ms, whichever is greater

Sensing Setup

Angle Compensation Setting Range ....0 to 359.9°

Voltage Monitoring

Live/Dead Voltage
Setting Range..0, 10 to 90%
Accuracy ....±2%

Drop Out Delay
Setting Range..0, 50 to 60,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater

27 - Undervoltage Protection

Pickup

Setting Range..0, 1 to 300 V
Accuracy ....±2% or ±1 V, whichever is greater
Reset/Pickup Ratio ....1 to 3%

Inhibit Level

Setting Range..0, 1 to 300 V
Accuracy ....±2% or ±1 V, whichever is greater
Reset/Inhibit Ratio ....1 to 3%

Timing Mode

Definite Timing (Time Delay)

Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time*...0 to 20 ms

Inverse Timing (Time Dial)

Setting Range..0 to 9.9
Accuracy ....±5% or ±2 cycles, whichever is greater
Pickup Time*...0 to 20 ms

*If Inhibit voltage is non-zero, add 12 ms at 60 Hz and 16 ms at 50 Hz to the pickup time.

32 - Power Protection

Pickup

Setting Range..0, 1 to 6,000 W, three-phase
Accuracy ....±3% of setting or ±2 watts, whichever is greater, at unity power factor. (Accuracy of phase relationship measurement between V and I is accurate to within 0.5 degrees when I is greater than 0.1 Aac and V is greater than 5 Vac. The power and var measurements at power factor other than 1.0 are affected accordingly.)
Dropout ....1 to 5% of the actual pickup value

Time Delay

Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

37 - Instantaneous Undercurrent Protection

Pickup

Setting Range..0 to 100 A
Reset ....1 to 7% of the actual pickup value
Accuracy ....±2% or ±10 mA, whichever is greater

Inhibit Level

Setting Range..0 to 100 A
Reset ....1 to 7% of the actual pickup value
Accuracy ....±2% or ±10 mA, whichever is greater

Time Delay

Setting Range...0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time*..0 to 20 ms

*If Inhibit is non-zero, add 12 ms at 60 Hz and 16 ms at 50 Hz to the pickup time.

40Q - Loss of Excitation Protection - Reverse Var Based

Pickup

Setting Range...0, 1 to 6,000 var
Accuracy ....±3% or ±2 var, whichever is greater
Dropout ....1 to 7% of the actual pickup value

Time Delay

Setting Range...0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

40Z - Loss of Excitation Protection - Impedance Based

Directional Supervision Angle (Blinder Angle)

Setting Range...–90 to 0°

Diameter

Setting Range...0.1 to 500 Ω
Accuracy ....±3% or ±0.2 Ω, whichever is greater from 0 to 500 Ω

Offset

Setting Range...0 to 550 Ω
Accuracy ....±3% or ±0.2 Ω, whichever is greater from 0 to 550 Ω

Time Delay

Setting Range...0 to 300,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

Voltage Pickup

Setting Range...0, 5 to 180 V
Accuracy ....±2% or ±1 V, whichever is greater

Voltage Time Delay

Setting Range...0 to 60,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

46 - Negative-Sequence Current Protection

Negative-sequence current protection is available when a 50 or 51 element is configured in I2 mode. Refer to *Instantaneous Overcurrent (50)* or *Inverse Overcurrent (51)* for operational specifications.

47 - Negative-Sequence Voltage Protection

Negative-sequence voltage protection is available when a 27 or 59 element is configured in V2 mode. Refer to *Overvoltage (59)* or *Undervoltage (27)* for operational specifications.

49RTD - Resistance Temperature Device Protection

Pickup

Setting Range..32 to 482°F (0 to 250°C)
Accuracy ....±2% or ±3.6°F (±2°C), whichever is greater
Reset/Pickup Ratio ....±6% (over/under) or 41°F (5°C) minimum

Voting

Setting Range..1 to 14

Time Delay

Setting Range..0 to 600,000 ms
Accuracy ....±1 s

50 - Instantaneous Overcurrent Protection

Pickup

Setting Range..0 to 150 A
Unbalanced Setting Range ....0 to 100%
Dropout ....1 to 7% of the actual pickup value

3 Phase, IA, IB, IC, IG Accuracy

Phase and Ground ....±2% or ±10 mA, whichever is greater
SEF...±(2% + 6 mA)

3I0, I1, I2 Accuracy

Accuracy ....±3% or ±15 mA, whichever is greater

Unbalanced Accuracy

Accuracy ....±2% of pickup setting

2nd and 5th Harmonic Inhibit

Setting Range..0, 5 to 75%

Time and Reset Delay

Setting Range..0 to 600,000 ms

Accuracy

Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time (Fundamental)*...................................0 to 20 ms
Pickup Time (Peak Detect) ....0 to 12 ms

*If directional supervision is selected, add 8 ms to the pickup time (Fundamental only).

50BF - Breaker Failure Protection

Phase & Ground Pickup

Setting Range..0 to 10 A

Accuracy

Phase and Ground ....±2% or ±10 mA, whichever is greater from 0.1 to 10 A
SEF...±(2% + 6 mA)

Time Delay & Control Time

Setting Range..0, 50 to 999 ms
Accuracy ....±0.5 or (0 to ¾ cycle), whichever is greater
Pickup Time ....0 to 20 ms

51 - Inverse Overcurrent Protection

Pickup

Setting Range..0 to 16 A
Unbalanced Setting Range.....................................0 to 100%
Dropout ....1 to 7% of the actual pickup value

3 Phase, IA, IB, IC, IG Accuracy

Phase and Ground ....±2% or ±10 mA, whichever is greater
SEF...±(2% + 6 mA)

3I0, I1, I2 Accuracy

Accuracy ....±3% or ±15 mA, whichever is greater

Unbalanced Accuracy

Accuracy ....±2% of pickup setting

Time Current Characteristic Curves

Time Dial...0 to 9.9
Timing Accuracy..±5% or ±1½ cycles, whichever is greater, between 2-40 multiples of pickup for time dial settings greater than 0.1
Refer to the *Timing Characteristics* chapter for information on available timing curves.
Pickup Time* ....0 to 20 ms

*If directional supervision is selected, add 8 ms to the pickup time.

Voltage Restraint

Control/Restraint Range ....0, 30 to 250 V
Accuracy ....±2% or ±1 V, whichever is greater

51TF - Transformer Monitor

Base Current

Setting Range..0 to 16 A
Accuracy ....±2% or ±10 mA, whichever is greater

Alarm Count

Setting Range..1 to 99

Curves

Thresholds

Setting Range..0, 1 to 40 A
Accuracy ....±2% or ±10 mA, whichever is greater

N Constants

Setting Range..0.5 to 3

K Constants

Setting Range..1 to 3,000

Timing

Pickup Time ....0 to 20 ms

55 - Power Factor Protection

Lagging/Leading Pickup

Setting Range..0, ±0.05 to ±0.99
Accuracy ....±0.01

Time Delay

Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

59 - Overvoltage Protection

Pickup

Setting Range..0, 1 to 300 V
Accuracy ....±2% or ±1 V, whichever is greater
Dropout/Pickup Ratio..1 to 3%

Timing Mode

Definite Timing (Time Delay)

Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

Inverse Timing (Time Dial)

Setting Range..0 to 9.9
Accuracy ....±5% or ±2 cycles, whichever is greater
Pickup Time ....0 to 20 ms

60FL - Fuse Loss

Time Delay...Fixed at 50 ms

62 - Logic Timers

Modes ....Pickup/Dropout, One-Shot/Non-Retriggerable, One-Shot/Retriggerable, Oscillator, Integrating Timer, Latched
Setting Range..0 to 9,999,000 ms
Accuracy ....±0.5% or ±12 ms, whichever is greater

67/67N - Directional Current and Polarization Protection

Directional current and polarization protection is available when a 50 or 51 element is configured with the direction set to either the Forward or Reverse mode. Refer to *Instantaneous Overcurrent (50)* or *Inverse Overcurrent (51)* for operational specifications.

50/51 Direction Modes..Forward, Reverse, Non-directional

76 DC - Overcurrent

Pickup

Setting Range..0 to 200 mV
Accuracy ....±2% or ±0.1 mV, whichever is greater

Timing Mode

Definite Timing (Time Delay)

Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

Inverse Timing (Time Dial)

Setting Range..0 to 9.9
Accuracy ....±5% or ±2 cycles, whichever is greater
Pickup Time ....0 to 20 ms

78OOS - Out of Step Protection

Reverse/Forward Reach

Setting Range...0 to 500 Ω
Accuracy ....±3% or ±0.2 Ω, whichever is greater from –500 to 500 Ω

Blinder A/Blinder B Offset

Setting Range...0 to 500 Ω
Accuracy ....±3% or ±0.2 Ω, whichever is greater from –500 to 500 Ω

Blinder Angle

Setting Range...1 to 90°
Accuracy ....±1°

Blinder Traverse Time Delay

Setting Range...0 to 10,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater

Trip Delay

Setting Range...0 to 5,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

Min I1

Setting Range...5 to 600%
Accuracy ....±2%

I2/I1 Ratio

Setting Range...10 to 200%
Accuracy ....±1%

78V - Vector Jump Protection

Pickup Setting Range ....0, 2 to 90°
Pickup Accuracy...±1°
Hold Time Setting Range..0 to 60,000 ms
Pickup Time ....0 to 20 ms

79 - Recloser Protection

Reclose (1st, 2nd, 3rd, 4th), Reset (79R), Max Cycle (79M), Reclose Fail (79F), Pilot Time

Setting Range...0, 100 to 600,000 ms
Accuracy ....±0.5 or (0 to ¾ cycle), whichever is greater

81 - Frequency Protection

O/U

Pickup

Setting Range...0, 15 to 110 Hz
Accuracy ....±0.01 Hz
Dropout ....±0.01 to 0.03 Hz of the actual pickup value

Time Delay

Setting Range...0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....2 to 3 cycles

ROC

Pickup
Setting Range..0, 0.2 to 20 Hz/sec (positive, negative, or either)
Accuracy ....±2% or ±0.1 Hz/sec, whichever is greater
Dropout ....±3% of the actual pickup value

Over/Underfrequency Inhibit
Setting Range..15 to 110 Hz
Increment ....0.01 Hz
Accuracy ....±0.01 Hz

Negative-Sequence Inhibit
Setting Range..0 to 99% of nominal voltage
Accuracy ....±0.5% or ±1 V, whichever is greater

Time Delay
Setting Range..0 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....1 to 2 cycles for 0.57 > pickup,
3 to 4 cycles for 0.24 > pickup,
7 to 8 cycles for 0.08 > pickup,
15 to 16 cycles at pickup

O/U/ROC Voltage Inhibit
Setting Range..0, 15 to 250 V
Accuracy ....±2% or ±1 V, whichever is greater

87 - Phase Differential

Restrained Differential
Accuracy ....±4% or ±25 mA, whichever is greater
Response Time ....<2 cycles at 5 times pickup
<3 cycles at 1.5 times pickup

Tap
Setting Range..0.40 to 20.0

Minimum Restraint Pickup (Iop)
Setting Range..0, 0.1 to 1.00 multiples of tap

2nd Slope Pickup (Ires)
Setting Range..0, 0.1 to 20.0 multiples of tap

Restraint Slopes 1 & 2
Setting Range..5 to 140%
Accuracy ....±1%

Alarm Slope
Setting Range..0, 50 to 100%
Accuracy ....±1%

Unrestrained Pickup
Setting Range..0 to 21 multiples of tap
Accuracy ....±4% or ±25 mA, whichever is greater

2nd and 5th Harmonic
Setting Range..0, 5 to 75%
Accuracy ....±2%

Transient Monitor Operate & Delay Time

Setting Range...0 to 10,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

87 - Flux Balance

Pickup

Range ....0, 0.1 to 5 A
Accuracy ....±4% or ±25 mA, whichever is greater

Alarm

Range ....0, 0.1 to 5 A
Accuracy ....±4% or ±25 mA, whichever is greater

Time Delay

Setting Range...0 to 60,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

87N - Neutral Differential

I_{op} Minimum Pickup

Range ....0, 0.02 to 5 A
Accuracy ....±4% or ±15 mA, whichever is greater

Overcorrection Coefficient

Setting Range...1 to 1.3

Time Delay

Setting Range...0 to 60,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

Transient Time Delay

Setting Range...0 to 10,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

Control Power Monitor

Pickup

Setting Range...0, 1 to 300 V
Accuracy ....±4% or ±2 V, whichever is greater

Time Delay

Setting Range...0, 1 to 600,000 ms
Accuracy ....±0.5% or ±8 ms, whichever is greater
Pickup Time ....0 to 20 ms

Automatic Setting Group Characteristics

Number of Setting Groups 4

Control Modes

Monitored Setting ....Ground Current, Max Phase Current, Neutral Current, Negative Sequence Current, or Fuse Loss
External...Discrete Input Logic, Binary Input Logic

Switch & Return Thresholds
Setting Range..0 to 25 A

3 Phase, IA, IB, IC, IG Accuracy
Phase and Ground ....±2% or ±10 mA, whichever is greater
SEF...±(2% + 6 mA)

3I0, I1, I2 Accuracy
Phase and Ground ....±3% or ±15 mA, whichever is greater

Switch Time
Range ....0 to 60 min with 1 min increments where 0 = disabled
Accuracy ....±0.5% or ±2 s, whichever is greater

BESTlogic™*Plus*
Update Rate..¼ cycle

General Specifications

AC Current Inputs

1A/5A CT
Continuous Rating..20 A
One Second Rating ....500 A

For other current levels, use the formula: I= (K/t) ½ where t = time in seconds, K = 160,000.
Burden ....<10 mΩ

SEF
Continuous Rating..4 A
One Second Rating ....80 A
Burden ....<22 mΩ

Voltage Inputs
Nominal Voltage...50 to 300 V, Line to Line
Continuous Rating..600 V, Line to Line
One Second Rating ....1200 V, Line to Neutral
Burden ....<1 VA at 300 Vac

Analog to Digital Converter
Type..24-bit
Sampling Rate..32 kHz base sampling rate, adjusted to input frequency
(10 to 125 Hz)

Power Supply

PS-1 (48/125 Vdc, 120 Vac)
DC Operating Range ....35 to 150 Vdc
AC Operating Range ....55 to 135 Vac

PS-2 (250 Vdc, 240 Vac)
DC Operating Range ....90 to 300 Vdc
AC Operating Range ....90 to 270 Vac

PS-3 (24 Vdc)
Operating Range ....17 to 32 Vdc (down to 8 Vdc momentarily)

Frequency Range (Options 1 and 2 only)
40 to 70 Hz

Burden (Options 1, 2, and 3)
15 W nominal, 20 W with 23 outputs energized

Output Contacts

Make and Carry for Tripping Duty ....30 A, 250 Vdc for 0.2 seconds per IEEE Std C37.90-2005 - *IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus*; 7 A continuous AC or DC
Break Resistive or Inductive....................................0.3 A at 125 or 250 Vdc (L/R = 0.04 maximum)

Contact-Sensing Inputs

The ranges for the each configuration of the circuit are given in Table 63-1.

Table 63-1. Contact-Sensing Ranges

Nominal Voltage	Card Sensing Level Setting	Turn-On Voltage Range	Minimum Burden
24 Vdc	24V	4 to 9 Vdc	20 kΩ
48 Vac/Vdc	48V	26 to 38 Vdc	47 kΩ
125 Vac/Vdc	125V	69 to 100 Vdc	94 kΩ
250 Vac/Vdc	250V	137.5 to 200 Vdc	185 kΩ

IRIG Interface

Standard ....200-98, Format B002, and 200-04, Format B006
Input Signal ....Demodulated (dc level-shifted signal)
Logic High Level..3.5 Vdc, minimum
Logic Low Level...0.5 Vdc, maximum
Input Voltage Range ....–10 to +10 Vdc
Input Resistance..Nonlinear, approximately 4 kΩ at 3.5 Vdc, 3 kΩ at 10 Vdc
Response Time ....<1 cycle

Real-Time Clock

Clock has leap year and selectable daylight saving time correction. Backup capacitor and standard backup battery sustain timekeeping during losses of BE1-FLEX operating power.
Accuracy ....±1.73 s/d at 77°F (25°C)

Clock Holdup
Capacitor Holdup Time ....At least 8 hours at 70ºC
Battery Holdup Time..Greater than 5 years depending on conditions
Battery Type..BR2032 or CR2032, coin-type, 3 Vdc, 195 mAh Basler Electric P/N 38526

Caution

Replacement of the backup battery for the real-time clock should be performed only by qualified personnel.
Observe polarity markings on the battery socket while inserting a new battery. The battery polarity must be correct in order to provide backup for the real-time clock.

Note

Failure to replace the battery with Basler Electric P/N 38526 may void the warranty.

Communication Ports

Communication ports consist of USB, serial, and Ethernet connections.

USB

A front-panel C-type USB connector provides local communication with a PC operating BESTCOMS*Plus*® software. Compatible with USB 2.0 specification.
Data Transfer Speed ....480 Mb/s (High Speed)

RS-485

Rear-panel RS-485 port that supports Modbus® and DNP3.
Port Speed (Baud)..Up to 115,200

Ethernet

RJ45 and Fiber Optic Ethernet ports are available. These connectors provide dynamic addressing (DHCP), fixed addressing, web pages (HTTP), e-mail alerts (SMTP), network time protocol (NTP) to synchronize the real-time clock, as well as communication with devices running BESTCOMS*Plus*, Modbus®, DNP3 and IEC 61850 software.

Copper Type (RJ45 Connector)
Version..10/100/1000BASE-T*
Maximum Length (One Network Segment)...............328 ft (100 m)
* 10Base-T only applies to copper Ethernet port 1. All copper ports support 100/1000 Base-T communications.

Fiber Optic Type (LC Connector)
Version..100BASE-FX, multimode
Maximum Length (Half-Duplex)...............................1,310 ft (399 m)
Maximum Length (Full-Duplex)...............................6,600 ft (2,011 m)

BESTnet™*Plus* Webpage Interface

Supported in the following browsers:

- Android – Chrome (Android and Chrome are trademarks of GOOGLE LLC.)
- Apple® iPhone® and iPadOS® – Safari®
- Linux® – Chromium and Firefox® (Chromium is a trademark of GOOGLE LLC.)
- Mac® – Safari® on macOS®
- Windows® – Chromium-based Edge, Chrome, and Firefox® (Chromium and Chrome are Trademarks of GOOGLE LLC.)

Panel Display

Seven-inch, high-contrast, color touchscreen LCD.

Environment

Operating Temperature Range ....–40 to 158°F (–40 to 70°C) surrounding air*
Storage Temperature Range ....–40 to 158°F (–40 to 70°C)
* Display is impaired below –20°C (–4°F)
For use in Pollution Degree 2 Environment.
For use on a Flat Surface of a Type 1 Enclosure.

Isolation

Meets IEC 255-5 and exceeds IEEE C37.90 one-minute dielectric test as follows:

- Power Supply, Current Sensing,
  Voltage Sensing, Contact Inputs,
  Contact Outputs, Shunt Inputs.....................2,000 Vac or 2,828 Vdc
- Auxiliary Inputs (0 to 10 V, 4 to 20 mA),
  IRIG-B, RS-485..500 Vac or 707 Vdc
- RJ45 Ethernet Port.....................................1,500 Vdc

Standards

IEC Standards:

- IEC 60068-1 – *Environmental Testing Part 1: General and Guidance. Temperature Test*
- IEC 60068-2-1 – *Basic Environmental Testing Procedures, Part 2: Tests - Test Ad: Cold (Type Test)*
- IEC 60068-2-2 – *Basic Environmental Testing Procedures, Part 2: Tests - Test Bd: Dry Heat (Type Test)*
- IEC 60068-2-30 – *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h +12 h cycle)*
- IEC 60068-3-4 – *Environmental testing - Part 3-4: Supporting documentation and guidance - Damp heat tests*
- IEC 60255-1 – *Measuring Relays and Protection Equipment-Part 1: Common Requirements*
- IEC 60255-21-1 – *Vibration, Shock, Bump, and Seismic Tests on Measuring Relays and Protective Equipment (Section 1 - Vibration Test - Sinusoidal). Class 1*
- IEC 60255-21-2 – *Vibration, Shock, Bump, and Seismic Tests on Measuring Relays and Protective Equipment (Section 2 - Shock and Bump Test - Sinusoidal). Class 1*
- IEC 60255-21-3 – *Vibration, Shock, Bump, and Seismic Tests on Measuring Relays and Protective Equipment (Seismic) Class 2*
- IEC 60255-27 – *Measuring relays and Protection Equipment - Part 27: Product safety requirements*
- IEC 60255-127 – *Over/Under Voltage Protection (Functional Requirements)*
- IEC 60255-151 – *Over/Undercurrent Protection (Functional Requirements)*
- IEC 60255-181– *Over/Under/Rate of Change Frequency Protection (Functional Requirements)*
- IEC 61810-2 – *Electromechanical Elementary Relays - Part 2: Reliability*

IEEE Standards:

- IEEE Std C37.90.1-2012 – *IEEE Standard Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus*
- IEEE Std C37.90.2-2004 – *IEEE Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers*
- IEEE Std C37.90.3-2001 – *IEEE Standard Electrostatic Discharge Test for Protective Relays*
- IEEE Std C37.118.2-2011 – *IEEE Standard for Synchro Phasor Data Transfer for Power Systems*
- IEEE 1613 – *Environmental and Testing for Communications Networking Devices in Electric Power Substations*

CE and UKCA Compliance

This product has been evaluated and complies with the relevant essential requirements set forth by the EU legislation and UK Parliament.

EC Directives:

- LVD 2014/35/EU
- EMC 2014/30/EU
- RoHS 2 2011/65/EU as amended by (EU) 2015/863

Harmonized standards used for evaluation:

- IEC 60255-1
- IEC 60255-26
- IEC 60255-27
- IEC 61000-4-2
- IEC 61000-4-3
- IEC 61000-4-4
- IEC 61000-4-5
- IEC 61000-4-6
- IEC 61000-4-8
- IEC 61000-4-9
- IEC 61000-4-10
- IEC 61000-4-11
- IEC 61000-4-13
- IEC 61000-4-16
- IEC 61000-4-17
- IEC 61000-4-18
- IEC 61000-4-29
- IEC 61000-6-4
- IEC 63000:2016

UL Recognition

This product is cULus listed per the applicable U.S. and Canadian safety standards and requirements by UL.

Standard used for evaluation:

- UL 508
- UL 94 V-0
- CSA C22.2 No. 0
- CSA C22.2 No. 14

Maritime Recognition

European Union Recognized Organization (EU RO) Mutual Recognition Design Evaluation in accordance with Article 10.1 of EU Regulation 391/2009.

American Bureau of Shipping (ABS)

EU RO Mutual Recognition Technical Requirements for Electrical/Electronic Relays, Version 0.6, 2023.

FCC Requirements

This product complies with FCC 47 CFR Part 15.

China RoHS

The following table serves as the declaration of hazardous substances for China in accordance with PRC standard SJ/T 11364-2014. The EFUP (Environment Friendly Use Period) for this product is 40 years.

PRODUCT:	BE1-FLEX									
	有害物质 Hazardous Substances									
零件名称 Part Name	铅 Lead (Pb)	汞 Mercury (Hg)	镉 Cadmium (Cd)	六价铬 Hexavalent Chromium (Cr^{6+})	多溴联苯 Polybrominated Biphenyls (PBB)	多溴二苯醚 Polybrominated Diphenyl Ethers (PBDE)	邻苯二甲酸二丁酯 Dibutyl Phthalate (DBP)	邻苯二甲酸丁苄酯 Benzyl butyl phthalate (BBP)	邻苯二甲酸二酯 Bis(2-ethylhexyl) phthalate (BEHP)	邻苯二甲酸二异丁酯 Diisobutyl phthalate (DIBP)
金属零件 Metal parts	O	O	O	O	O	O	O	O	O	O
聚合物 Polymers	O	O	O	O	O	O	O	O	O	O
电子产品 Electronics	X	O	O	O	O	O	O	O	O	O
电缆和互连配件 Cables & interconnect accessories	X	O	O	O	O	O	O	O	O	O
绝缘材料 Insulation material	O	O	O	O	O	O	O	O	O	O

本表格依据 SJ/T11364 的规定编制。

O: 表示该有害物质在该部件所有均质材料中的含量均在 GB/T 26572 规定的限量要求以下。

X: 表示该有害物质至少在该部件的某一均质材料中的含量超出 GB/T 26572 规定的限量要求。

This form was prepared according to the provisions of standard SJ/T11364.

O: Indicates that the hazardous substance content in all homogenous materials of this part is below the limit specified in standard GB/T 26252.

X: Indicates that the hazardous substance content in at least one of the homogenous materials of this part exceeds the limit specified in standard GB/T 26572.

HALT (Highly Accelerated Life Testing)

Basler Electric uses HALT to prove that our products will provide the user with many years of reliable service. HALT subjects the device to extremes in temperature, shock, and vibration to simulate years of operation, but in a much shorter period span. HALT allows Basler Electric to evaluate all possible design elements that will add to the life of this device. As an example of some of the extreme testing conditions, the BE1-FLEX was subjected to temperature extremes of –90°C to +120°C, vibration extremes of 0 to 50 g at +20°C, and temperature/vibration extremes of 50 g over a temperature range of –85°C to +110°C. Combined temperature and vibration testing at these extremes proves that the BE1-FLEX is expected to provide long-term operation in a rugged environment. Note that the vibration and temperature extremes listed in this paragraph are specific to HALT and do not reflect recommended operation levels. These operational ratings are listed under *Temperature*.

Physical

IP Class..IP54 (from the front when installed and USB plug is in place)
ISTA...Pre-shipment Testing Procedures and Projects, Test Procedures 1A and 2A
Case Size..Refer to the *Mounting* chapter.
Weight...7 lb (3.2 kg) maximum
Shipping Weight ....10 lb (4.5 kg) maximum

Basler Electric®
www.basler.com

Highland, Illinois USA
Tel: +1 618.654.2341
Fax: +1 618.654.2351
email: info@basler.com

Suzhou, P.R. China
Tel: +86 512.8227.2888
Fax: +86 512.8227.2887
email: chinainfo@basler.com