

Application Note

BESTCOMSPPlus® Series – BE1-11 Step-By-Step Guide to Using BESTCOMSPPlus®, BESTspace™, and Preprogrammed Logic Schemes: *High Impedance Grounded Generator Protection with Sequential Trip*

Setting up a numeric relay has never been easier than with BESTCOMSPPlus BESTspace tool. A recent national study on electrical reliability has shown that the majority of numeric relay misoperations are caused by incorrect settings/design error. BESTspace combats the issue by clearly identifying relevant settings and adapting to your specific application - minimizing errors and time spent creating settings files. Although BESTspace files can be created and customized, the purpose of this guide is to assist you in using Basler Electric preconfigured BESTspace and preprogrammed logic files.

High Impedance Grounded Generator Protection with Sequential Trip

This guide is a walkthrough of the *High Impedance Grounded Generator Protection with Sequential Trip* BESTspace and logic scheme. The logic scheme provides protection for the system represented by the one line diagram shown in Figure 1. The logic scheme provides

for more elaborate protection for generators grounded through high neutral impedance. Compared to the basic high impedance logic, this scheme adds sequential trip logic for minimizing overspeed when decoupling and implements a more involved tripping scheme. It provides three trip output contacts: one each for main breaker, field, and prime mover tripping, with different logic for each. As in the basic high impedance logic, tripping function numbers include 24, 27 Phase, 27 Neutral (third harmonic), two 32 Reverse Power, 40Q, 40Z, 46, 47, 50P/50N Inadvertent Energizing, 51 Phase with Voltage Control, 51 Neutral (calculated 3I0), 51 Ground, 59 Phase, 59 Neutral, 59 Neutral (calculated 3V0), and two 81 Under, two 81 Over. There is selective and interlocked logic that discriminates on which output each function trips. It provides for sequential trip logic, but not synchronism check. Unneeded elements can be disabled without changing the logic.

The BESTspace feature was added to BESTCOMSPPlus recently. Opening a BESTspace file automatically formats the BESTCOMSPPlus environment to support specific activities. BESTspace files do not add or alter actual settings. The BESTspace discussed in this document is specially designed to work with the *High Impedance Grounded Generator Protection with Sequential Trip* logic scheme developed by Basler.

Opening the BESTspace

BESTCOMSPPlus refers to the software suite used to program BE1-11 relays. The BESTspace tool is only compatible with BESTCOMSPPlus v 2.11.01 or greater.

If not already installed on your computer, it is easy to download the latest version at www.basler.com. BESTCOMSPPlus requires an activation key for use without an active BE1-11 connection. Please email request for activation to info@basler.com.

The BESTspace file can be downloaded from www.basler.com/Product/BE1-11-Logic-Schemes.

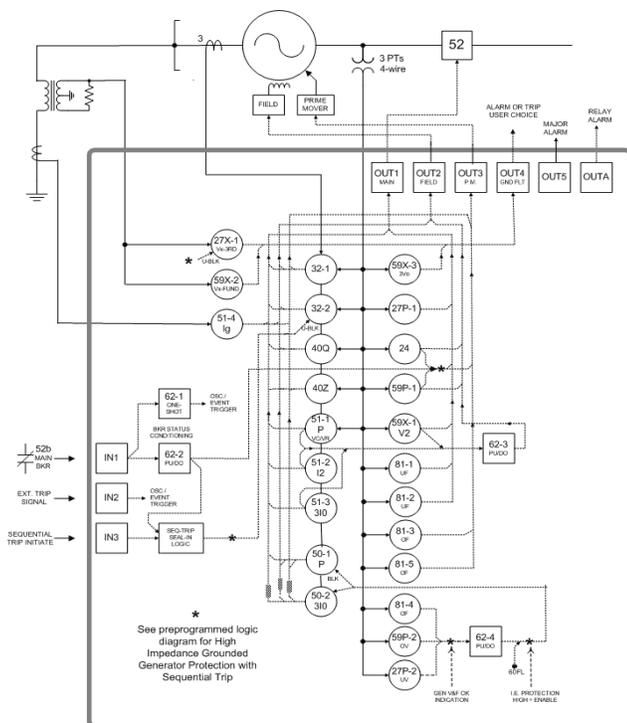


Figure 1 - One-Line Diagram of High Impedance Grounded Generator Protection with Sequential Trip

To begin, launch BESTCOMSPlus and click on the 'File' dropdown menu at the top left-hand corner of the window. Select to open a new BEI-11 file as shown in Figure 2.

BESTCOMSPlus will then open a default settings file. To open the BESTspace, click on 'View' directly below 'File' and select to open a new BESTspace file as shown in Figure 3.

Based on Figure 4, click 'Load' on the Load/Save Window BESTspace File window and browse for BESTspace file 'HighImpedanceGrounded GeneratorProtectionwithSequentialTrip.bswx'.

Click 'Apply' to open the BESTspace.

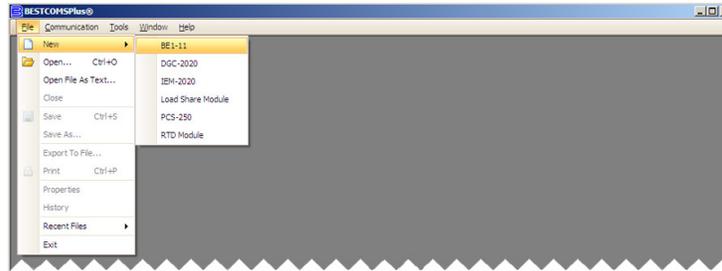


Figure 2 - Opening a File in BESTCOMSPlus

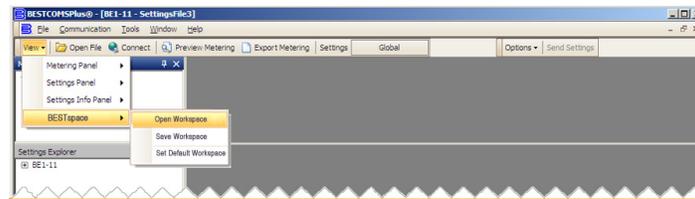


Figure 3 - Opening a New BESTspace in BESTCOMSPlus

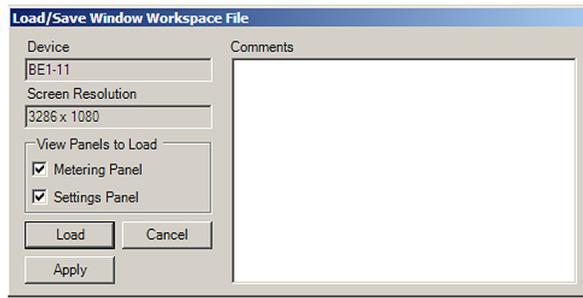


Figure 4 - Loading a BESTspace File

Establishing the Style Number

Figure 5 demonstrates how the BESTspace formats the working environment with the Style Number screen on top. The environment is tab-based, with tabs aligned across the top of the screen. Check the relay front faceplate for the style number and enter it on the style number screen using the dropdown selection boxes. The right-hand bottom portion of the viewable area contains settings information such as settings ranges and units. It can be closed at any time to increase viewing area. Tabs can be closed by clicking on the 'x' to the right of the right-most tab. Doing this will close the active tab. Close the style number screen when finished. Successive tabs should be closed once you are finished, except where noted.

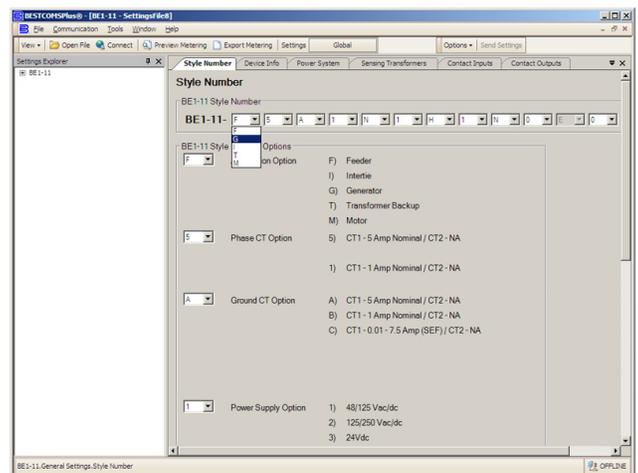


Figure 5 - The Style Number screen is on top when starting a BESTspace

Accessing Device Info

Closing the style number screen causes the next tab to the right, “Device Info”, to activate. The Device Info screen contains information about the embedded software in the connected BEI-II relay. 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.

Power System

The Power System screen contains information on your system that the relay uses to perform internal calculations. Starting under Nominal Settings, enter in the system frequency, nominal secondary voltage in terms of PN quantities, and nominal secondary current (this is the secondary rating of your CT). The auxiliary 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.

Although the power line parameters are useful, they are not necessary if the information is not available. MTA is necessary only if you plan to specify a directional overcurrent element. Additional details on the power line parameter and MTA settings can be found in the BEI-II instruction manual.

Sensing Transformers

The Sensing Transformers screen contains 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 auxiliary 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.

Contact Inputs and Outputs

Closing the previous screen will pull up two successive Contact Inputs and Outputs screens. These screens

allow you to customize the physical alarms and contact I/O with labels and energized state labels, which will appear on the BEI-II LCD screen.

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. Since the *High Impedance Grounded Generator Protection with Sequential Trip* scheme utilizes three contact inputs, it is helpful to label them.

- Input #1 is designated as a 52b breaker status input.
- Input #2 is an external fault trigger input for initiating oscillography.
- Input #3 is a sequential trip initiate.

The hold attribute serves several purposes for contact outputs. The main use for the BEI-II 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. Now label the contact outputs:

- Output #1 is tied to the tripping element for the main breaker.
- Output #2 is tied to the tripping element for the field.
- Output #3 is tied to the tripping element for the prime mover.
- Output #4 closes for ground fault.
- Output #5 is a major alarm output.
- Output A is for relay failure.

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.

Overexcitation (24)

The BEI-IIg detects overexcitation conditions in generators with a volts/hertz element that consists of one alarm setting, one integrating time characteristic with selectable exponents (3 sets of time curves), and two definite-time characteristics. This allows the user to individually select an inverse-time characteristic, a composite characteristic with inverse time, and one or two definite-time elements, or a dual-level, definite-time element. If you are unsure of which timing schemes to use or how to set the element, there is more information on generator overexcitation in the BEI-IIg instruction manual, *Overexcitation (24) Protection* chapter. You also can download Basler’s *Generator Protection Application Guide* at www.basler.com.

The single 24 is used for online and offline overexcitation, with the former being supervised with a timer initiated by a breaker close. The online element trips the prime mover and the main breaker, while the offline element trips only the field breaker.

By default, all protection elements are disabled. Choosing a mode of operation enables them. If used, enable it under the 'Mode' setting and then enter in your pickups, time dial, reset dial, and so on.

Under/Overvoltage (27P-1, 27P-2, 27X-1, 59P-1, 59P-2, 59X-1, 59X-2, 59X-3)

Use the 'Mode' setting to enable the elements you need. There are several modes of operation for the phase 27/59 elements:

- One of Three operates when the voltage on one phase rises above (59) or drops below (27) the pickup and times out.
- Two of Three operates when the voltage on two phases rises above or drops below the pickup and times out.
- Three of Three operates when all three phase voltages rise above or drop below the pickup and times out.

The voltage elements provided are as follows:

- 27P-1 phase undervoltage. Set pickup under nominal voltage. Picks up for low voltage on any one phase (Mode = One of Three). It is blocked when the breaker is open and trips the main breaker.
- 27P-2 phase undervoltage. Used for supervisory logic. Picks up for normal voltage on all 3 phases (typically set PU for $V < 110\%$ rated). Target should not be enabled for this function. (Mode = Three of Three)
- 27X-1 3rd harmonic undervoltage. Monitors 3rd harmonic at generator neutral for 100% stator ground detection. Blocked unless voltage and frequency are normal. (Mode = Vx Third Harmonic) One of three elements that provide a ground fault indication for tripping output #4.
- 59P-1 phase overvoltage. Set pickup above nominal voltage. Picks up for high voltage on any one phase (Mode = One of Three). Trips the field breaker.
- 59P-2 phase overvoltage. Used for supervisory logic. Picks up for normal voltage on all three phases (typically set PU for $V > 85\%$ rated). The target should not be enabled for this function. (Mode = Three of Three)
- 59X-1 negative sequence overvoltage. (Mode = V2) Trips the main breaker directly. If the condition persists for a specified time delay, trips the field and prime mover breakers also.
- 59X-2 measured neutral overvoltage (Mode=Vx-Fundamental). Monitors fundamental frequency overvoltage at generator neutral for ground fault detection. One of three elements that provide a ground fault indication for tripping output #4.
- 59X-3 calculated zero sequence overvoltage. Monitors fundamental frequency 3V0 on generator phase VTs for ground fault detection.

Requires 4-wire VT connection. If you do not have 4-wire VTs, leave disabled. (Mode = 3V0) One of three elements that provide a ground fault indication for tripping output #4.

Each phase voltage element can be set to your choice of inverse timing or definite timing. For an instantaneous response, set it for definite timing with a time delay of zero. In addition, the 27 has an inhibit threshold.

Following the 59X-3 tab is the Voltage Protection Summary tab. Review the enabled elements and modes of operation on this screen. If elements are disabled when you believe they should be enabled, it will appear on this screen. Each element will have a status color to the left and the mode of operation to the right. Green status indicates that the element is enabled, yellow indicates the setting is disabled by a setting other than the mode (i.e. the element has an invalid setting such as a pickup of 0.000 volts), blue indicates the setting is disabled by only the mode setting, and gray indicates the element has both an invalid setting and disabled mode.

You will see similar summary screens throughout the walkthrough. It is a good idea to leave these screens open and double check the protection elements you have set up once you are finished.

Frequency (81-1, 81-2, ... 81-5)

There are five total frequency elements. Set:

- 81-1 as level 1 underfrequency
- 81-2 as level 2 underfrequency
- 81-3 as level 1 overfrequency
- 81-5 as level 2 overfrequency

The 81-4 element is used for supervisory logic and picks up for normal frequency (typically set PU for $F > 85\%$ rated). The target should not be enabled for this function.

Both underfrequency elements are blocked when the breaker is open. Level 1 and Level 2 elements should be coordinated such that Level 2 is less sensitive and times out more quickly than Level 1. Under-frequency elements trip the main breaker while overfrequency elements trip the prime mover.

Select the Phase VT source for each element and set the pickups as needed. The under and overfrequency elements employ an inhibit setting when voltage is too low. Set appropriately, if desired.

Review the Frequency Protection Summary screen on the tab following 81-6.

Instantaneous Overcurrent (50-1, 50-2)

The next two tabs contain settings for the Instantaneous Overcurrent elements 50-1 and 50-2. There are several modes of operation for overcurrent elements on the BEI-11:

1. I_A, I_B, I_C operates only on the selected phase of current.
2. 3 Phase will monitor all three phases and operate on any one of them.
3. $3I_0$ operates on the calculated zero sequence current (calculated 50G).
4. I_2 operates on the calculated negative sequence current (46).
5. I_G operates on the ground CT input only (50G).
6. I_1 operates on the calculated positive sequence current.
7. Unbalance operates on calculated unbalanced current.

The *High Impedance Grounded Generator Protection with Sequential Trip* logic scheme utilizes two instantaneous overcurrent elements. The 50-1 is a phase overcurrent used to protect against inadvertent energization while the 50-2 is a neutral overcurrent used for the same purpose. Both elements are enabled only when abnormal system conditions are present and no fuses have been blown (60FL). They are configured in logic to trip all three breakers.

Enter the secondary current pickup and intentional time delay (if no intentional time delay is desired, leave at 0). Choose the directionality of the element (Non-Directional).

Inverse Overcurrent (51-1, 51-2, 51-3, 51-4)

The inverse overcurrent elements have the same mode selections as the instantaneous elements.

- 51-1 phase overcurrent, voltage controlled/restrained. (Mode = 3 Phase) Trips the main breaker directly. If the condition persists after a specified time delay, trips the field and prime mover breakers also.
- 51-2 negative sequence overcurrent. (Mode = I_2) Trips the main breaker directly. If the condition persists after a specified time delay, trips the field and prime mover breakers also.

- 51-3 calculated neutral overcurrent. (Mode = $3I_0$) Trips the main breaker directly. If the condition persists after a specified time delay, trips the field and prime mover breakers also.
- 51-4 measured neutral overcurrent. (Mode = I_G) Connect ground CT to relay ground current input. Trips all three breakers directly.

The element screen contains a setting for pickup, time dial, curve, direction, voltage restraint, and reset timing. If you wish to implement voltage control or restraint on the phase overcurrent element, choose 'Control' or 'Restraint' under 'Mode' along with an appropriate threshold.

There are many curves to choose from. However, if the curves do not fit your needs, you can program your own custom curve using the IEEE C37.112 equation or construct one of up to 40 custom points using a table curve.

The Table Curve feature adds points to the curve and uses a point and click interface to move points around once they are inserted. A separate screen under Protection > Current allows you to configure a table curve.

Be sure to set the directionality (Non-Directional) and reset type. An integrating reset mimics the behavior of an electromechanical reset. When used to provide high-speed overcurrent protection for the substation bus, it is recommended that all 51 function timing curves be set for instantaneous reset. Both the inverse timing curve and the reset time can be viewed by changing the selection below the graph.

Review the Current Protection Summary screen.

Power (32-1, 32-2)

The logic scheme incorporates two reverse overpower protection elements to detect the loss of the prime mover or function as part of the sequential tripping scheme. The 32-1 element trips the field and main breakers directly.

Sequential tripping is initiated and latched by an operator through contact input #3 as a means of gently decoupling the generator to prevent damaging overspeed conditions by tripping the prime mover breaker. The generator is then intentionally motored for a period of time defined by the 32-2 time delay, after which the field and main breakers are tripped. The 32-2 element is enabled only when sequential tripping is initiated by input #3. IEEE C32.102-2006 provides more information on setting this element.

Loss of Excitation (40Q, 40Z)

The BEI-11g offers loss of excitation protection via a reverse Var (40Q) or impedance based (40Z) element. The 40Q operates on Vars coming into the machine. Available settings are pickup and time delay and may be determined by analyzing the capability curve of the generator. Both elements trip all three breakers directly.

The 40Z is most often used for loss of excitation and is the alternative to the 40Q. It operates on mho characteristics identifying the minimum allowable impedance as seen from the terminals of the generator. Mho characteristic 1 defines the size and behavior of the inner circle most often used for more critical loss of sensing conditions. The diameter of this circle is typically set for 1.0 pu on the generator base impedance (the setting is in terms of ohms). Mho characteristic 2 defines the size and behavior of the outer circle, which is most often given a less sensitive setting to accommodate for power swings. The diameter of this circle is typically set for the direct axis reactance, X_d , while the offsets for both circles should be set in terms of the direct axis transient reactance, $X'_d/2$.

Although not used for some applications, the directional supervision angle (blinder angle) provides the ability to desensitize the 40Z for power swings by allowing it to neglect impedances above the line. Set the directional supervision angle appropriate to your application. It can be disabled by setting it to zero.

The voltage control feature allows the user to provide a faster trip when impedance measurements are supervised by a depressed level of voltage. It is not necessary and can be enabled or disabled based on the mode of operation you choose.

Review the Power Protection Summary screen.

Protection/Control Summary

The control and the more comprehensive protection summary screens allow you to view all elements that are enabled and the modes of operation.

It is a good idea to leave these screens open and double check the protection elements you have set up once you are finished.

Logic Timers (62)

Four logic timers are used in the *High Impedance Grounded Generator Protection with Sequential Trip* logic scheme.

The one-shot, non-retriggerable 62-1 is initiated when the breaker is closed to trigger an oscillography record. The output of a one-shot, non-retriggerable timer transitions to logic True after the duration of Time Delay 1 for the duration of Time Delay 2.

Sequential tripping uses the output of the 62-2 timer along with input #3. The 62-2 is a pickup/dropout style timer initiated by a breaker close.

- Upon receiving an initiate, the pickup/dropout timer will transition its output to logic True for the duration of Time Delay 1.
- Once the initiate input transitions to logic False, it must stay False for the duration of Time Delay 2 for the output to transition back to logic False. It delays unblocking/blocking 50 elements when sensed V and F become abnormal/normal.

The 62-2 timer should have Time Delay 1 = 0 while Time Delay 2 dictates the amount of time that the generator breaker must remain open before the online overexcitation (24) element is disabled.

The pickup/dropout 62-3 timer is initiated by the 59X-1 (47), 51-1 (51P), 51-2 (46), or 51-3 (51N) and is used to detect persistent faults after the main breaker has been tripped. The timer output trips the field and prime mover breakers directly.

The pickup/dropout 62-4 timer is initiated after abnormal frequency or voltage level. The timer output enables the 50-1 (50P) and 50-2 (50N) elements.

Enter desirable time delays based on the behavior of the timers.

BESTlogic™Plus

BESTlogicPlus 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.

Preprogrammed logic schemes make it easy to import a file for common applications. To download logic files, please visit www.basler.com/Product/BEI-11-Logic-Schemes and download the logic scheme 'High Impedance Gen with Sequence'.

Importing a file is easy; click on the 'Logic Library' dropdown menu as shown in Figure 6 and open 'HighImpedanceGroundedGenerator Protectionwith-SequentialTrip.bslx' to import file.

The BESTLogicPlus working environment is nested within BESTCOMSPPlus 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, physical I/O, logic gates, and elements. Items in the toolbox can be dragged and dropped onto any logic page. Logical I/O are conveyed between pages using custom labeled off-page inputs and outputs.

Preprogrammed logic is complete as downloaded. No changes are necessary to use it. Reviewing it is recommended as it provides useful detail on the operation and purpose of the logic. Below are the tabs present.

- *Input/Output* - You will find a brief description of the logic scheme on this page. Additionally you will find the physical output assignments with a description of their intended purpose and timers 62-1 and 62-2.
- *Voltage/Power* - This tab shows all protection elements related to voltage and power. Logic elements can be blocked by asserting Logic 1 at the 'Block' input. For example, the 27P-1 element is blocked by the 52b off-page input. Logic elements such as the 27P-1 generate 'Pickup' and 'Trip' signals used elsewhere in the logic scheme via off-page outputs to generate physical trips and oscillography.

- *Current* - All elements related to time and instantaneous overcurrent are located on this tab. Note that elements 50-1 and 50-2 are enabled through the 'IE Enabled' off-page input.
- *Misc. Logic* - The Misc. Logic tab shows the consolidation of the element off-page outputs using OR gates and four more off-page outputs, 'Trip Bus' and 'Pickup Bus'. It is useful to have a consolidated bit for performing other functions elsewhere in the logic scheme. Also on this tab are the protective elements used for supervisory purposes and the fault trigger element. Timer 62-3 is used to detect persistent faults. For full descriptions on the inputs and outputs of a logic element, consult the BE1-11g manual.

To use the logic scheme, click on the 'Save' button shown in Figure 7 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 finish, save the entire settings file by clicking on 'File' at the top left-hand corner of the BESTCOMSPPlus and select 'Save' or 'Save As...' from the dropdown menu.

For More Information

To get more information on BESTCOMSPPlus and the BE1-11 product line, including additional application notes, product bulletins, and instruction manuals, go to www.basler.com or contact Technical Support at 618-654-2341.

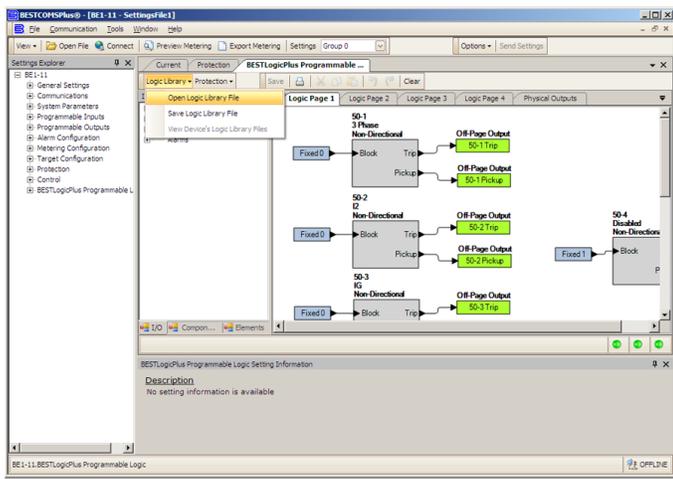


Figure 6 - Working with the Logic Library

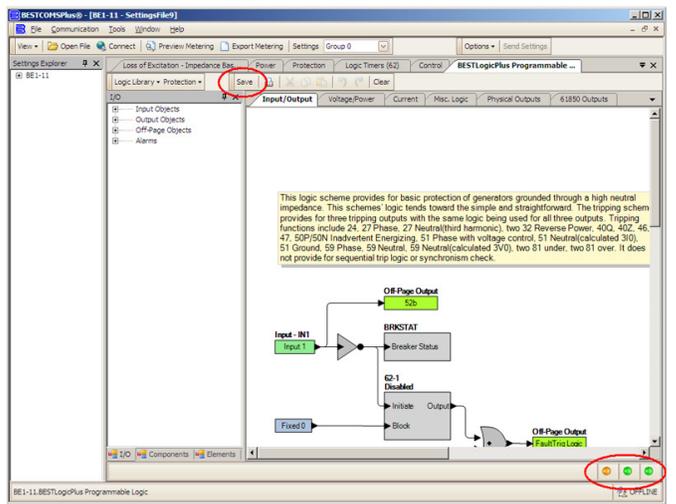


Figure 7 - Saving a Settings File with a Functional Logic Scheme

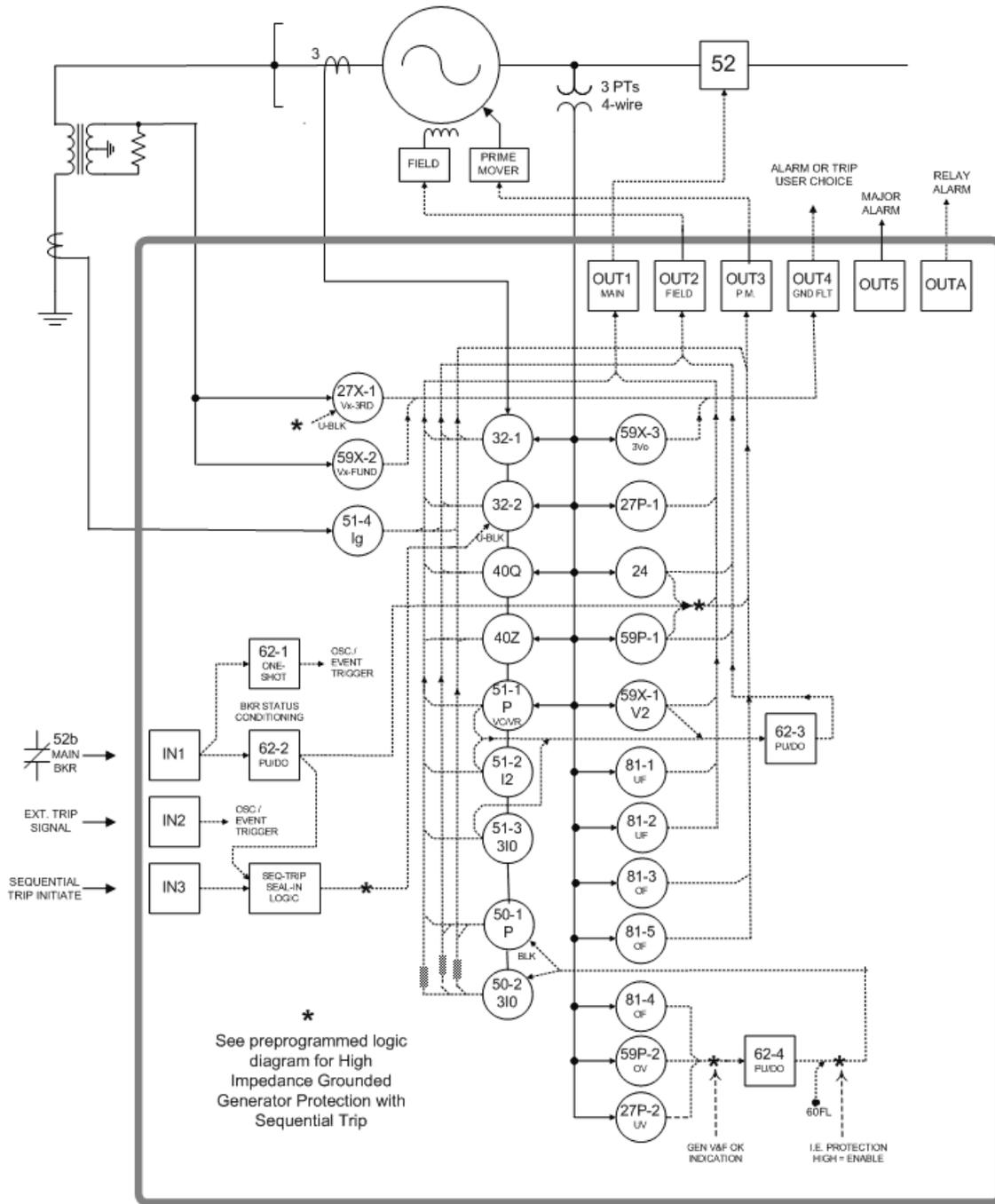


Figure 8 - Expanded version of Figure 1: One-Line Diagram of High Impedance Grounded Generator Protection with Sequential Trip