

Application Note

DGC-2020 and DGC-2020HD Control and Protection for Configurable Machines

In the portable power industry, it is common for generators to be moved from one site and installed at another.

This is very common in rental power applications, where generator power is provided as a service, typically at entertainment venues and construction sites. This practice is also common in military applications. Often times, generators are taken from inventory and added to a fleet of units in service. In such applications, quick disassembly, mobilization, and reinstallation of multiple generators at a temporary site is critical to operational success.

Power requirements vary from site to site. Voltage requirements typically range from 480 Vac to 120 Vac, while the frequency may be 60 Hz or 50 Hz. Some sites may require three-phase power while others require single phase. For this reason, generator manufacturers have developed clever ways of reconfiguring 12 lead machines easily with a selector switch.

Alternate Voltages

In 60 Hz systems, common voltage configurations are:

- Series (high) wye: $480 V_{L-L} / 277 V_{L-N}$
- Parallel (low) wye: $240 V_{L-L} / 139 V_{L-N}$
- Various configurations of delta: $240 V_{L-L} / 120 V_{L-N}$
- Series (high) zig zag: $480 V_{L-L} / 240 V_{L-N}$
- Parallel (low) zig zag: $240 V_{L-L} / 120 V_{L-N}$

It is important for a genset controller to be adaptable to each of these various configurations. Because portable machines need to be plug-and-play, site operators cannot afford to spend time adjusting settings in genset controllers for every configuration change. As mobile generators are often deployed in high urgency situations, delays in on-site power generation could result in loss of life, loss of equipment, loss of revenue, and loss of reputation. Due to the time sensitive nature of such mission critical operations, it is of paramount importance for a genset controller to automatically adapt to various operating configurations for control and protection purposes.

High Wye 480/277 Vac, Three Phase

The DGC-2020 family of genset controllers is capable of being configured to effectively control gensets operating at various voltages and frequencies. To have a machine operate within the list of configurations stated above, the genset controller must be setup for 480 Vac, three-phase wye in the rated data settings of the BESTCOMSPPlus® settings explorer as shown in Figure 1. This setting covers the high-wye configuration.

Gen	
PT - Primary Volts (V)	480.00
PT - Secondary Volts (V)	480.00
CT - Primary Amps (A)	200.00
Low Line Scale Factor	1.000
Rated Volts (V L-L)	480
Rated Secondary Volts (V L-L)	480
Rated Phase Amps	150
Rated Secondary Phase Amps	3.75
Rated Secondary Ground Amps	3.75
Rated Power Factor (PF)	0.80
Rated kW	100.00
Rated kVA	125.00
Rated kvar	75.00
Rated Volts Low Line Scale Factor	0.430
Phase Rotation	ABC
Voltage Sensing	Wye
CT Phase Connection	CT ABC

Figure 1 - Machine Setup for 480 Vac Three-Phase, Wye with 0.43 Low-Line Scale Factor

Low Wye 240/139 Vac, Three Phase

When the machine is configured for low wye, the controller needs to determine that the machine is now operating as a 240/139 Vac machine. This can be achieved by mapping a contact input to the **low-line override programmable function**. See Figure 2. When the machine is switched over for 240/139 Vac operation,

the low-line override contact closes. Once the contact input is closed, the DGC controller determines that that machine is in a low-line configuration. The low-line voltage is defined by the rated volts low-line scale factor as shown in Figure 1. The low-line scale factor is the ratio of the low-line voltage to the high line voltage. For the 240 Vac low-line voltage case, the low-line scale factor is $(240/480 = 0.5)$. Note that it is common practice to tune voltage regulator operating setpoint to $208 V_{L-L}/120 V_{L-N}$ in this configuration. In this case, the rated volts low-line scale factor is $208/480 = 0.43$. Once the controller receives a low-line override status, it scales the machine rated voltage by the low-line scale factor.

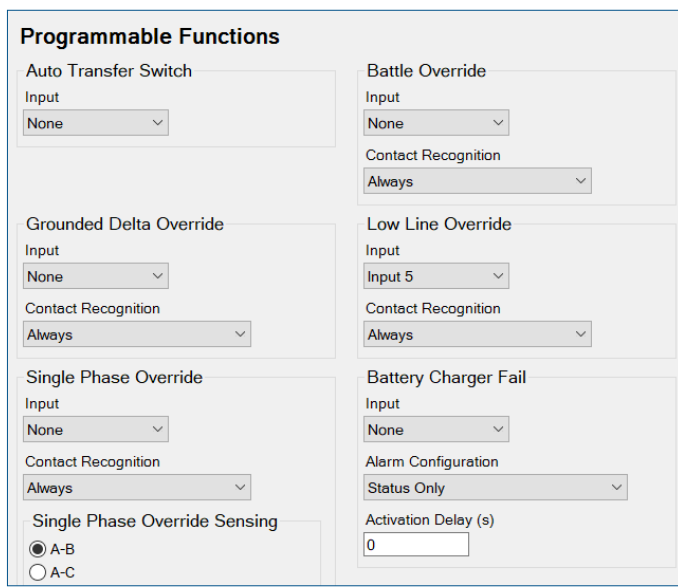


Figure 2 - Low-Line Programmable Function Mapped to Input 5

Alternatively, in the DGC-2020HD only, a contact input can be mapped to the **LOWLINEOVER logic element** in BESTlogic™ Plus programmable logic to set the controller in a low-line configuration. Setting the LOWLINEOVER logic element achieves the same results as closing a contact input that is mapped to the LOWLINEOVER programmable function.

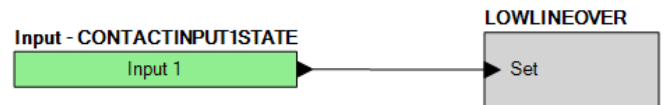


Figure 3 - Low-Line Programmable Function Mapped to Input 5

Delta 240 Vac, Three Phase

When the machine is configured for delta, the controller needs to determine that the machine is now operating as a 240 VAC delta connected machine. For any desired delta configuration, this can be achieved by mapping a contact input to the grounded delta programmable function. When that contact closes, the DGC controller will determine that the machine is in grounded delta override mode.

Zig-Zag 120/240 Vac, Single Phase

When the machine is configured for zig – zag 120/240 VAC 1phase, the controller needs to determine that the machine is operating as a 120/240 VAC 1phase machine. This can be achieved by mapping a contact input to the **single-phase override programmable function**. See Figure 4. When the machine is switched over for 120/240 VAC single phase operation, the single phase override contact closes to give the controller a single phase override status.

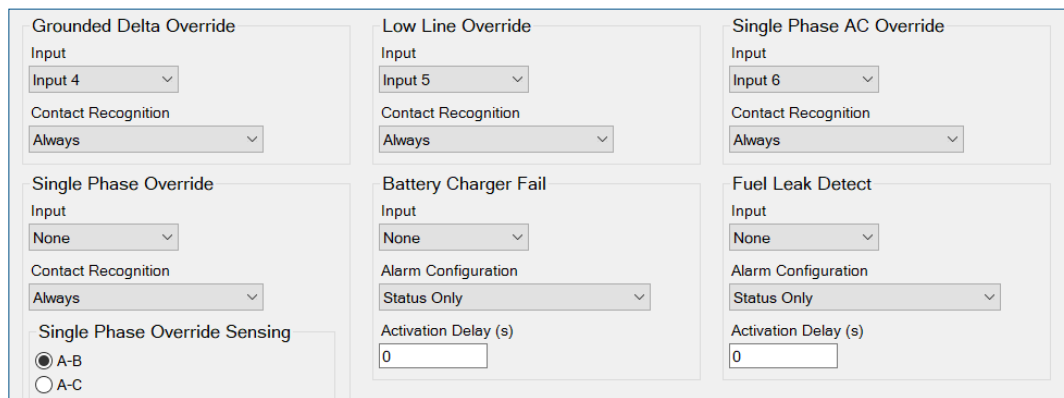


Figure 4 - Grounded Delta Override Mapped to Input 4 and Single-Phase AC Override Mapped to Input 6

Alternatively, in the DGC-2020HD only, a contact input can be mapped to the **1PHASEOVR logic element** in Bestlogic™ Plus programmable logic. See Figure 5. Whenever the contact input closes, the controller determines that the machine is in a single-phase configuration.

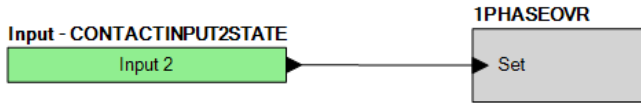


Figure 5 - Single-Phase Override Logic Element Set in BESTlogic™ Plus for a Zig-Zag Connection

Automatic Configuration Detection

All DGC controllers can be configured to automatically sense a low-line override condition instead of closing a contact input to detect a change of status. This feature allows easy detection of a machine's configuration without the need for additional wiring. The controller detects a low-line voltage condition by sensing whether the machine output voltage has dropped below a set threshold. If the average of the valid line-to-line voltages fall below the threshold, the machine is determined to be in a low-line configuration. Auto configuration detection must be enabled in order to use this feature. See Figure 6 below for an example.

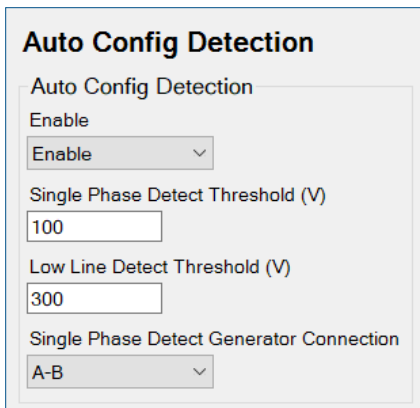


Figure 6 - Using Auto-Configuration Detection to Determine the Machine Configuration

All DGC controllers can also be configured to automatically detect a single phase condition. The controller detects a single-phase override condition by sensing whether the difference between the maximum and minimum line-to-line voltages exceeds a set threshold. If the threshold is exceeded, the unit is determined to be in single-phase configuration. In the example shown in Figure 7, if the difference between the maximum and minimum line-to-line voltages exceeds 100 Vac, the generator is determined to be operating in single-phase mode.

Automatic configuration detection cannot be used to detect a delta configuration or an alternate frequency configuration. When Automatic configuration detection is in use, if the machine stops and is then restarted with a new configuration, the controller assumes it is in the same configuration that it was in when the machine was stopped. This configuration remains in effect for a second or two until the automatic configuration detection detects the new configuration.

Inhibiting Automatic Configuration Detection

Auto configuration detection is inhibited in the following cases:

1. *Machine voltage is below the 81U Inhibit Voltage setting.*
For example, in a 480 Vac system, if the 81U inhibit setting is greater than 240 Vac, when the machine is configured for the low-wye configuration, the controller's voltage sensing inputs will detect that the machine is running at 240 Vac, but none of the automatic configuration detections will work.
2. *Machine frequency is below the 27 Inhibit Frequency Hz setting.*
Similarly, if a 60 Hz machine is running at an alternate frequency of 50 Hz and the inhibit frequency setting is greater than the machine frequency, none of the automatic configuration detections will work.

Configurable Voltage Status Inputs

Various configurable machine statuses (Figure 7) can be used as inputs to drive logic to perform additional functions as desired by users.

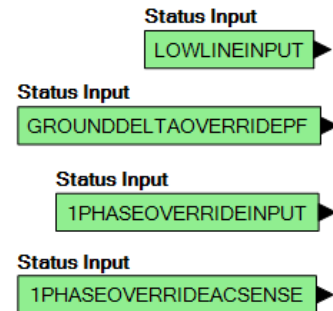


Figure 7 - Machine Configuration Status Inputs

Generator and Bus Condition Detection

Low-line voltage operation also impacts generator and bus stability detection conditions. A generator is defined as stable when the generator voltage and frequency stay within the defined thresholds for the duration of the Gen Stable Activation Delay. Similarly, a bus is defined as stable when the bus voltage and frequency stay within the defined thresholds for the duration of the Bus Stable Activation Delay. The low-line scale factor setting in the generator and bus condition detection settings allow the pickup and drop out settings to be automatically scaled when the controller receives a low-line override status. BESTCOMSPPlus® settings are shown in Figure 8.

Without this adjustment of the pickup and dropout settings, the generator and bus would not be detected as stable while in low-line override mode. The auto-synchronizer is prevented from running when generator and bus stability conditions are not detected. Automatic updating of the generator and bus stability thresholds allows the auto synchronizer to operate as it normally would regardless of the machine operating voltage.

Overvoltage Settings Pickup (V L-L) <input type="text" value="520"/> V <input type="text" value="1.083333"/> Per Unit		Dropout <input type="text" value="512"/> V <input type="text" value="1.066667"/> Per Unit	
Overfrequency Settings Pickup <input type="text" value="62.00"/> Hz <input type="text" value="1.0333"/> Per Unit		Dropout <input type="text" value="61.80"/> Hz <input type="text" value="1.0300"/> Per Unit	
Gen Stable Activation Delay (s) <input type="text" value="0.1"/>		Undervoltage Settings Pickup (V L-L) <input type="text" value="320"/> V <input type="text" value="0.666667"/> Per Unit	
		Dropout <input type="text" value="340"/> V <input type="text" value="0.708333"/> Per Unit	
		Underfrequency Settings Pickup <input type="text" value="58.00"/> Hz <input type="text" value="0.9667"/> Per Unit	
		Dropout <input type="text" value="58.20"/> Hz <input type="text" value="0.9700"/> Per Unit	
		Low Line Scale Factor <input type="text" value="0.430"/>	Alternate Frequency Scale Factor <input type="text" value="1.000"/>

Figure 8 - Low-Line Scale Factor Setting Allows Generator Condition Detection Settings to Update Automatically

Alternate Frequencies

60 Hz and 50 Hz frequencies are typically used in on-site power systems. DGC controllers can support machines which operate at different frequencies. The controller needs to determine the frequency at which a machine is running during a run session. This can be achieved by mapping a contact input to the ALTFREQOVER logic element. On the Rated Data settings page, settings need to be entered for the machine rated frequency and the machine alternate frequency.

Rated Data

Current Sensing Input Type

Frequency
 Rated frequency of the unit

Alternate Frequency (Hz)

Battery Volts
 12V
 24V

Rated Engine RPM

Ground Current
 Primary Amps

Figure 9 - Rated and Alternate Frequency Settings

In the example shown in Figure 9, this machine is rated for and will operate at 60 Hz during normal operation. However, when it is desired to operate the machine at 50 Hz, the ALTFREQOVER logic element will be set so that the controller assumes protection, and control settings for 50 Hz operation.

A contact input can be mapped to the ALTFREQOVER logic element to set it when the contact input closes. See Figure 10.



Figure 10 - Contact Input Mapping

Generator and Bus Condition Detection

Alternate frequency operation also impacts generator and bus stability detection conditions. Since frequency is one of the parameters that determines whether a generator or bus is stable or not, the frequency pickup and drop out settings are automatically adjusted when a DGC controller determines that a machine is operating at an alternate frequency. This feature enables the auto-synchronizer to operate whenever the generator and the bus are stable, regardless of the machine operating frequency.

Protection

In the past, it has been difficult to establish generator voltage protection schemes which protect the machine in its various configurations. One of the ways in which the DGC-2020 and the DGC-2020HD can provide voltage and frequency protection for such machines is by utilizing multiple sets of generator protection elements in conjunction with programmable logic.

Voltage Protection

Three-Phase Operation

Consider a reconfigurable machine capable of operating at multiple voltages. Very common operating voltages include 480 Vac, 240 Vac, 208 Vac, and 120 Vac. $208 V_{L-L} / 120 V_{L-N}$ can be achieved by configuring the machine to operate in a low-*wye* configuration at $240 V_{L-L} / 139 V_{LN}$, and using the voltage regulator to trim the generator's voltage down to $208 V_{L-L} / 120 V_{L-N}$.

Hence, voltage protection can be achieved for most configurable machine operating voltages by using one set of voltage protection elements for the high-*Wye* configuration, and another for the low-*Wye* configuration.

The DGC-2020 and the DGC-2020HD have multiple Overvoltage (59) protection elements and multiple Undervoltage (27) protection elements available. Each 59 and 27 element has a three-phase pickup level, a three-phase dropout level, a single-phase pickup level, a single-phase dropout level, and a low-line scale factor setting. If the machine is in a three-phase configuration, the three-phase settings are used. If it is in a single-phase configuration, the single-phase settings are used. The low-line scale factor is applied to the settings when the controller determines that the machine is operating in a low-line configuration.

The following procedure can be implemented to automatically adjust protection settings for various machine voltage configurations. In this example, the machine high-*Wye* voltage is assumed to be 480 Vac_{L-L} / 277 Vac_{L-N}. Please note that the protection settings stated in the examples included in this application note are for illustration purposes only.

Enter the desired pickup voltage for the 59-1 element. In this example we will use 528 Vac for the three-phase

pickup. Set the alarm configuration to alarm. If the voltage exceeds 528 Vac and is sustained beyond the activation delay, the generator breaker will open and the genset will shutdown.

Enter the desired pickup voltage for the 27-1 element. In this example, we will use 432 Vac for the three-phase pickup. Set the alarm configuration to alarm. If the voltage remains below 432 Vac beyond the activation delay, the generator breaker will open and the genset will shutdown.

In the 59-2 element settings, enter an appropriate overvoltage pickup for the low-*Wye* configuration. In this example, we will use 229 Vac for the three-phase pickup. Set the alarm configuration to alarm. If the voltage exceeds 229 Vac beyond the activation delay, the generator breaker will open and the genset will shutdown.

In the 27-2 element, enter an appropriate undervoltage pickup setting for the low-*Wye* configuration. In this example we will use 187 Vac for the three-phase pickup. Set the alarm configuration to alarm. If the voltage remains below 187 Vac beyond the activation delay, the generator breaker will open and the genset will shutdown.

The Overvoltage settings screen is shown in Figure 11.

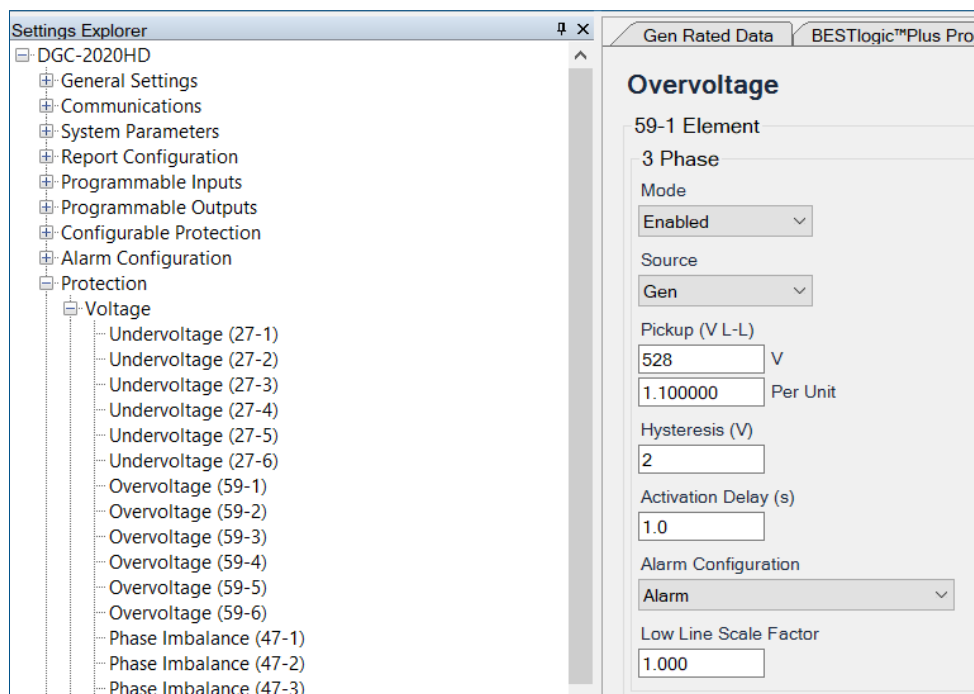


Figure 11 - Entering Voltage Protection Settings

In BESTlogic™ Plus programmable logic, implement the following algorithm (Figure 12):

- IF A high-wye configuration is detected
- THEN Block protection settings that apply to the low-wye configuration.
- ELSE Block the protection settings that apply to the high-wye configuration.

This logic will ensure that only the applicable protection elements for each machine configuration will pick up and trip.

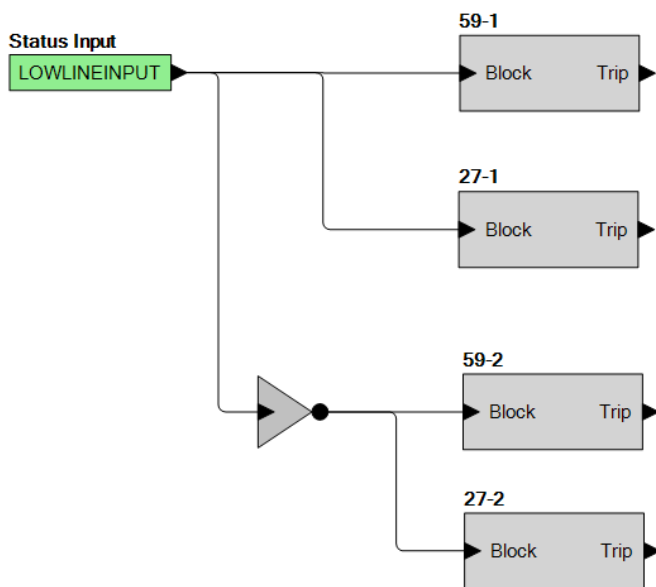


Figure 12 - Logic Scheme for Updating Protection Settings to Align with Machine Configuration

Another way of implementing voltage protection for multiple voltage configurations is to use the low-line scale factor setting. Once the controller determines that the machine is operating in a low-line configuration, the low-line scale factor will be applied to the protection algorithm. Hence, with one protection element, a protection scheme can easily be developed which applies to high-wye and low-wye configurations. For example, in Figure 13, the pickup for the 59-1 element is 528 V_{L-L} when the machine is operating at its rated voltage of 480 V_{L-L}. However, when the controller determines the machine is in a low-line configuration, it will scale the protection pickup setting by the low-line scale factor. So, the pickup for 208 V_{L-L} operation will be 227 V_{L-L}.

Overvoltage

59-1 Element

3 Phase

Mode:

Source:

Pickup (V L-L): V

Per Unit

Hysteresis (V):

Activation Delay (s):

Alarm Configuration:

Low Line Scale Factor:

Figure 13 - High-Wye and Low-Wye Voltage Protection Scheme with One Element

Single-Phase Operation

For single-phase operation, a voltage protection scheme can be built by simply entering a pickup value that is applicable to single-phase series operating voltage. The single-phase protection settings will take effect once the controller determines that the machine is operating in a single-phase configuration. For single-phase parallel operation, the controller needs to be given low-line override and single-phase override statuses simultaneously.

In this example, a machine rated for 480 Vac, three phase needs to operate at 240 Vac, single phase. Occasionally, the machine will also operate at 120 Vac single phase. Overvoltage protection for the 240 Vac case and the 120 Vac case can be achieved as shown in Figure 14.

Single Phase

Mode

Source

Pickup (V L-L)
 V
 Per Unit

Hysteresis (V)

Activation Delay (s)

Alarm Configuration

Low Line Scale Factor

Figure 14 - Protection Settings for Single-Phase Operation

Frequency Protection

Consider the same machine discussed in the examples given so far. This machine also needs to be capable of operating at 60 Hz or 50 Hz.

The DGC-2020 and the DGC-2020HD have multiple Overfrequency (81) protection elements available. In the DGC2020's protection settings, there is an 81O and an 81U element, with an alternate frequency scale factor that applies to both elements. In the DGC2020HD, there are eight (8) frequency elements, each of which can be set to 81O, 81U, Rate-of-Change of Frequency (ROCOF), positive ROCOF, or negative ROCOF.

Each of the DGC-2020HD's elements also has an Alternate Frequency Scale Factor setting. The alternate frequency scale factor is applied to the protection settings when the controller determines that the machine is operating in an alternate frequency configuration. Since the DGC-2020 only has one 81O setting and one 81U setting, using the Alternate Frequency Scale Factor setting is recommended for switching between frequency configurations. For example, if a machine is rated at 60 Hz and the alternate frequency is 50 Hz, then the alternate frequency scale factor is 0.833. Once the controller determines that the machine is operating in an alternate frequency configuration, it scales the associated protection and control functions by the magnitude of the alternate frequency scale factor.

Settings Explorer

- DGC-2020HD
 - General Settings
 - Communications
 - System Parameters
 - Report Configuration
 - Programmable Inputs
 - Programmable Outputs
 - Configurable Protection
 - Alarm Configuration
 - Protection
 - Voltage
 - Frequency
 - Frequency (81-1)
 - Frequency (81-2)
 - Frequency (81-3)
 - Frequency (81-4)
 - Frequency (81-5)
 - Frequency (81-6)
 - Frequency (81-7)
 - Frequency (81-8)
 - Current
 - Power
 - Loss of MAINS Protection
 - Field Protection
 - Breaker Management
 - Bias Control Settings
 - VRM Settings
 - Multigen Management
 - Programmable Senders
 - BESTlogic™Plus Programmable Logic

Frequency

81-1 Element

Mode

Enable

Source

Pickup
 Hz
 Per Unit

Hysteresis (Hz)

Activation Delay (s)

Inhibit Volts (%)

Alternate Frequency Scale Factor

Alarm Configuration

Figure 15 - Frequency Protection Settings are Automatically Adjusted by Alternate Frequency Scale Factor

Conclusion

In summary, the DGC-2020 and DGC-2020HD are very versatile controllers with extensive flexibility that can be utilized to setup protection and control schemes for configurable generators. These features allow generator fleet operators to run their generators with the correct settings for each operating configuration. In addition, operators can save time and improve reliability by eliminating the need for making settings adjustments as power requirements change.

For More Information

For more information on the DGC family of genset controllers, download the product bulletins or instruction manuals at www.basler.com. For assistance with product orders or questions, visit www.basler.com/support, contact your Application Engineer, or contact Technical Support at +1 618.654.2341.



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