Integration Guide: OutBack Power

PHI 3.8™, PHI 2.9™, PHI 1.4™ & PHI 730™ Battery Models

SimpliPhi Your Energy Security and Independence

and gain control of your own power.

SimpliPhi Power helps you manage your power as a personal resource. Anytime. Anywhere. SimpliPhi energy storage optimizes integration of any power generation source – solar, wind, generator – on or off grid, and protects your home and mission-critical business functions from power outages and intermittency. SimpliPhi storage technology reduces operating temperature constraints, toxic coolants and the risk of thermal runaway. Safe lithium ferrous phosphate (LFP). No cobalt. No toxic hazards.

SimpliPhi's battery technology utilizes the industry's most environmentally benign chemistry (LFP) combined with proprietary architecture and power electronics (BMS) to create a portfolio of high performance, scalable and enduring energy storage solutions that provide power security, resilience and daily cycling for savings on your utility bill – all with a 98% efficiency rate.

SimpliPhi Power offers proprietary, commercially available energy storage and management systems that are safe, non-toxic, reliable, durable, efficient, highly scalable, and economical over the lifetime of the PHI Battery.

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1.0 – Introduction

1.1 – Product Information & Online Resources

This Integration Guide covers the recommended set up and configuration of Outback Power equipment for optimizing performance with SimpliPhi PHI batteries. More information on SimpliPhi products can be found on our website: https://simpliphipower.com/.

Specifically, the Product Documentation section of SimpliPhi's web site (https://simpliphipower.com/product-documentation/) includes Specification Sheets, Warranties, Installation & Operator's Manuals, and Integration Guides for all SimpliPhi's current and legacy products.

Outback Power offers many products which are too numerous to be covered here. This Guide does *not* substitute literature from OutBack Power. The Outback products covered in this guide include, but are not limited to:

- SkyBox Hybrid Energy Systems (http://www.outbackpower.com/products/true-hybrid-energy-system/skybox)
- Radian Series Inverter/Chargers (http://www.outbackpower.com/products/inverter-chargers/radian-series) & Radian Series GS Load Centers (http://www.outbackpower.com/products/inverter-chargers/radian-gs-load-centers)
- FXR/VFXR Series Inverter/Chargers (http://www.outbackpower.com/products/inverter-chargers/fxr-vfxr-series)
- FLEXmax 100 / AFCI Charge Controllers (http://www.outbackpower.com/products/charge-controllers/flexmax-100 & http://www.outbackpower.com/products/charge-controllers/flexmax-100-afci)
- MATE3s System Display & Controller (http://www.outbackpower.com/products/system-management/mate3s)
- OPTICS RE Remote System Monitoring & Control (http://www.outbackpower.com/products/system-management/optics-re)
- FLEXnet DC System Monitoring Device (http://www.outbackpower.com/products/system-management/flexnet-dc)
- SystemEdge Pre-Bundled Solutions
    - Energy Management Series (http://www.outbackpower.com/products/prebundled-solutions/systemedge-energy-management-series)
        - SystemEdge 415PHI-300AFCI
        - SystemEdge 822PHI-300AFCI
        - SystemEdge 514PHI
        - SystemEdge 521PHI
        - SystemEdge 511PHI
- FLEXpower Integrated Systems
    - FLEXpower ONE FXR Series (http://www.outbackpower.com/products/integrated-systems/flexpower-one-fxr)
    - FLEXpower TWO FXR Series (http://www.outbackpower.com/products/integrated-systems/flexpower-two-fxr)
    - FLEXpower THREE FXR Series (http://www.outbackpower.com/products/integrated-systems/flexpower-three-fxr)
    - FLEXpower FOUR FXR Series (http://www.outbackpower.com/products/integrated-systems/flexpower-four-fxr)
    - FLEXpower Radian Series (http://www.outbackpower.com/products/integrated-systems/flexpower-radian)

OutBack Power has instructional videos showing various steps of the battery commissioning and system programming process: http://www.outbackpower.com/resources/technical-support/videos.

1.2 – Technical Support

SimpliPhi Technical Support (805-640-6700 x 1, techsupport@simpliphipower.com) is available to take any questions regarding this manual or general installation questions. For assistance with battery system commissioning, SimpliPhi asks that a commissioning call be **scheduled ahead of time** with Technical Support.

We encourage you or your installer to contact SimpliPhi with any questions. We are committed to working with you and your installation team to achieve a safe, reliable storage system that will provide years of maintenance-free service that is covered by our Warranty terms & conditions.

CAUTION: Although each PHI Battery contains an internal BMS with circuitry that protects the PHI Battery cells from over-charge, over-discharge and extreme load amperage, the PHI Batteries must always be installed with appropriate inverter and/or charge controller settings to protect the PHI Battery from open PV voltage and other high voltage charging sources. Exposure to higher voltage than the PHI battery rating (12, 24 &48V) will destroy the PHI batteries and Void the Warranty.

2.0 – Testing

SimpliPhi Power and EnerSys / Outback Power have performed qualification testing of the PHI Battery with OutBack equipment. Settings and instruction outlined in this Integration Guide have been validated per these testing procedures.

2.1 – Equipment Interoperability

According to the PHI Battery Warranty, SimpliPhi does not warrant PHI batteries damaged by "Incidental or Consequential Damage Caused by Other Components of the Power System Including but not Limited to Inverters, Charge Controllers, Breakers, Bypass Switches, Fuses, etc." Many PHI battery models include built-in over-current protection, but to mitigate risk of potential over-voltage damage from Balance of System equipment, additional over-voltage protection may be installed between the system's charge controller(s) and the PHI battery bank.

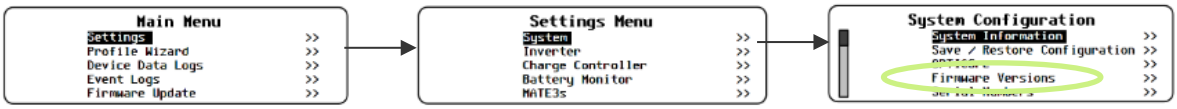
2.2 – OutBack Firmware Version

OutBack's pre-SA firmware inverters with firmware versions preceding **001.006.063** do not allow for Low Battery Cut Out (LBCO) programming to the level recommended for maintaining the PHI Batteries at a maximum 80% Depth of Discharge (DoD). Therefore, OutBack equipment paired with PHI Batteries should use firmware version 001.006.063 or greater. In situations where this is not possible (in inverter models without an "A" suffix, for instance), please consult OutBack Power to achieve the appropriate LBCO parameter: Support@OutBackPower.com.

2.2.1 – Verifying OutBack Firmware Version

To verify the firmware version of the equipment at hand, access the *Main Menu* in the MATE3s. "Access to the Main Menu" instructions are detailed on page 2 of this MATE3s Programming Guide: http://www.outbackpower.com/downloads/documents/system_management/mate3s/mate3s_programmingguide_web.pdf.

From the *Main Menu*, select *Settings*, then *System*, then *Firmware Versions*.



2.2.2 –OutBack Firmware Updates

If needed, firmware updates for OutBack equipment can be downloaded at this link: http://www.outbackpower.com/resources-mobile/technical-support/firmware-updates.

OutBack's instructional video showing a firmware update in the MATE3 is posted here: https://www.youtube.com/watch?v=Cu81s-QFabY.

2.3 – Eliminating Battery Temperature Compensation

The PHI Batteries' charging regimen does not include any temperature compensation. To achieve this, remove the Remote Temperature Sensor (RTS) from the system entirely.

3.0 – PHI Battery Bank Sizing

PHI Batteries are designed to operate at the continuous ratings listed on the relevant PHI Battery model's Specification Sheet. Therefore, a properly sized PHI Battery bank must be sized to handle both the inverter's "load rate" as well as the maximum potential charge rate from the solar photovoltaic (PV) array. Take care to consider not only the energy (kWh) requirement of the battery bank, but also all other power-related sizing parameters, as outlined in Sections 3.1, 3.2 or 3.3 and 3.4. Failure to do so will Void the Warranty.

CAUTION: PHI Battery bank sizing not in accordance with the following sections will damage the PHI batteries and Void the Warranty

3.1 – Sizing for Maximum Instantaneous Discharge (Load Rate)

The load rate is the amount of power that is discharged from the battery bank to the loads. This may include both alternating current (AC) and/or direct current (DC) loads. PHI Battery banks are sized so that the batteries' combined maximum continuous discharge rate meets or exceeds the load rate.

$$PHI\ Battery\ Bank\ MAX\ continuous\ discharge\ rate\ kW\ DC \geq (Inverter\ DC\ Load\ Rate) + (DC\ Loads, if\ any)$$

Because most loads are AC loads, the load rate is typically represented by the inverter's AC Power Output rating. Convert the inverter's maximum potential AC power draw to the maximum potential DC power draw from the battery bank by factoring in the inverter's efficiency rating.

$$Inverter\ DC\ Load\ Rate = (Inverter\ power\ rating\ kW\ AC) \div (Inverter\ efficiency)$$

Example: An inverter rated at 5 kW AC and 92% efficiency potentially draws 5.4 kW DC from the battery bank.

$$Inverter\ DC\ Load\ Rate = (5\ kW\ AC) \div (0.92) = \mathbf{5.4}\ kW\ DC$$

If the system includes DC Loads, no AC-to-DC conversion is necessary. Calculate the minimum quantity of PHI Batteries needed to ensure that the battery bank does not over-discharge by dividing the load rate by the MAX Continuous Discharge Rate per PHI Battery (found in Table 1.0 or on the relevant battery's specification sheet).

$$(Load\ Rate) \div (MAX\ Continuous\ Discharge\ Rate\ per\ Battery) = Minimum\ Battery\ quantity\ to\ prevent\ overdischarge$$

Example A: Three PHI 3.8 kWh-51.2V$_{nominal}$ batteries must be paired with an inverter rated at 5 kW AC and 92% efficiency to ensure the PHI Battery bank does not over-discharge to power the loads.

$$(5.4\ kW\ DC) \div (1.92\ kW\ DC) = 2.83 \rightarrow round\ to\ \mathbf{3}$$

Example B: Five PHI 3.8-25.6V$_{nominal}$ batteries must be paired with an inverter rated at 5 kW AC and 92% efficiency to ensure the PHI Battery bank does not over-discharge to power the loads.

$$(5.4\ kW\ DC) \div (1.15\ kW\ DC) = 4.72 \rightarrow round\ to\ \mathbf{5}$$

Note: Notice that the two different model batteries in the above example (51.2V$_{nominal}$ and 25.6V $_{nominal}$) have the same capacity rating (3.8 kWh) but different MAX Continuous Discharge ratings. In applications where greater instantaneous power is required of the battery, it is therefore more efficient to use the PHI 3.8 kWh-51.2V$_{nominal}$ battery with 1.92 kW of maximum continuous discharge versus the PHI 3.8 kWh-25.6V$_{nominal}$ battery with 1.15 kW of continuous discharge. The same advantages apply when examining the two different model batteries' surge capacity.

Example A and Example B, compared:

$$kW = \frac{Volts \times Amps}{1{,}000}$$

AC Load	DC Load (inv eff = 92%)	PHI 3.8 kWh-51.2V MAX Continuous Discharge		PHI 3.8 kWh-51.2V Surge Discharge		Battery QTY Needed to Meet Load Requirement (Continuous)	Battery QTY Needed to Meet Load Requirement (10 min. Surge)
5 kW AC	5.4 kW DC	37.5 ADC	1.92 kW DC	60 ADC	3.072 kW DC	2.8 → **3**	1.8 → **2**
		PHI 3.8 kWh-25.6V MAX Continuous Discharge		PHI 3.8 kWh-25.6V Surge Discharge		Battery QTY Needed to Meet Load Requirement (Continuous)	Battery QTY Needed to Meet Load Requirement (10 min. Surge)
5 kW AC	5.4 kW DC	45 ADC	1.152 kW DC	60 ADC	1.536 kW DC	4.7 → **5**	3.5 → **4**

Refer to the Battery Bank Sizing for Maximum Instantaneous Discharge (Load Rate) tables on the following page of this Integration Guide for a complete list of common OutBack inverters and the minimum quantity of PHI Batteries those inverters need to be paired with to ensure that the PHI Battery bank does not over-discharge. Over-discharging the PHI Batteries will destroy them and Void the Warranty.

In the case where the inverter's AC Power Output rating exceeds the connected loads' actual power draw (i.e. the inverter is rated at 5 kW but all loads amount to 3 kW of maximum instantaneous power draw), **SimpliPhi still expects that the proper additional precautions be made to ensure that the PHI Battery bank is not over-discharged**. This typically involves the installation of an additional overcurrent protection device between the PHI Battery bank and the inverter to ensure that the PHI Battery bank does not discharge beyond its maximum instantaneous power rating. Failure to do so will destroy the PHI batteries and Void the Warranty.

$$PHI\ Battery\ Bank\ MAX\ continuous\ discharge\ rate = (Battery\ quantity) \times (MAX\ Continuous\ Discharge\ Rate\ per\ Battery)$$

Example: Two PHI 3.8 kWh-51.2$V_{nominal}$ batteries must be installed with an additional 75 ADC-rated breaker between the battery bank and the inverter.

$$(PHI\ Battery\ Bank\ MAX\ continuous\ discharge\ rate) = 2 \times 37.5ADC = 75ADC$$

Minimum Battery Quantity per inverter *calculation results are listed below. When using more than one inverter in a system, PHI Battery bank sizing is more precise when the calculations described above are used instead of the following tables.*

48V Sizing for Maximum Instantaneous Discharge (Load Rate)

Only 51.2$V_{nominal}$ PHI Batteries can be paired with 48V-rated OutBack equipment.

48V Inverter Model	Inverter Power Rating (kW AC)	Inverter Efficiency	Load Rate (kW DC)	PHI 3.8-51.2V_{nom} MIN Battery Quantity	PHI 2.9-51.2V_{nom} MIN Battery Quantity
OutBack Radian 8048A	8	93%	8.6	5	6
OutBack Radian 4048A	4	93%	4.3	3	3
OutBack SkyBox	5	97%	5.2	3	4
OutBack VFXR 3648A	3.6	93%	3.9	3	3
OutBack FXR 3048A	3	93%	3.2	2	3

24V Sizing for Maximum Instantaneous Discharge (Load Rate)

Only 25.6$V_{nominal}$ PHI Batteries can be paired with 24V-rated OutBack equipment.

24V Inverter Model	Inverter Power Rating (kW AC)	Inverter Efficiency	Load Rate (kW DC)	PHI 3.8 - 25.6V_{nom} MIN Battery Quantity	PHI 2.9 - 25.6V_{nom} MIN Battery Quantity	PHI 1.4 - 25.6V_{nom} MIN Battery Quantity	PHI 730 - 25.6V_{nom} MIN Battery Quantity
OutBack VFXR 3524A	3.5	92%	3.8	4	4	6	11
OutBack FXR 2524A	2.5	92%	2.7	3	3	4	8

12V Sizing for Maximum Instantaneous Discharge (Load Rate)

Only 12.8$V_{nominal}$ PHI Batteries can be paired with 12V-rated OutBack equipment.

12V Inverter Model	Inverter Power Rating (kW AC)	Inverter Efficiency	Load Rate (kW DC)	PHI 1.4 - 12.8V_{nom} MIN Battery Quantity	PHI 730 -12.8V_{nom} MIN Battery Quantity
OutBack VFXR 2812A	2.8	90%	3.1	7	9
OutBack FXR 2012A	2	90%	2.2	5	7

3.2 – Sizing for Maximum Instantaneous Charge Rate (DC Coupled)

In a DC Coupled system, the solar PV array output can be curtailed using charge controllers. However, reducing the solar array's power output using charge controller programming implies that the PV array's output is also reduced for the entire remainder of the system, including the solar power available for powering loads and for exporting to the grid. Furthermore, greatly reducing the PV array's output via the charge controllers effectively wastes the solar PV array's power and puts strain on the charge controllers.

Calculate the minimum quantity of PHI Batteries needed to prevent over-charge from the solar PV array by considering both the solar array size and the charge controller's potential output. Whichever value is *less* should be used to size the PHI Battery Bank. If the solar array's maximum potential current output is less than the paired charge controller's Output Amps rating, then the solar array's maximum potential current output can be used to size the PHI Battery bank. If the charge controller's Amp rating is less than the solar array's maximum potential current output, then the charge controller's rating is used to size the PHI Battery bank.

Divide the system's potential charging current by the MAX Continuous Charge Rate per PHI Battery (found in Table 1.0 or on the relevant battery's specification sheet) to calculate the minimum quantity of PHI Batteries needed to ensure that the solar PV array does not over-charge the battery bank.

Example A: Three PHI 3.8 kWh-51.2$V_{nominal}$ batteries (used in a 48-Volt system) must be paired with a 4,500-Watt solar PV array wired to an 80 Amp-rated charge controller. In this case, the 80-Amp charge controller is used to determine the minimum PHI Battery quantity needed to prevent over-charging from the solar PV.

$$Watts = Amps \times Volts$$

$$4{,}500\ Watt\ Solar\ PV\ array = Amps \times 48\ Volts$$

$$\frac{4{,}500\ Watts}{48\ Volts} = \mathbf{93.75}\ Amps = MAX\ potential\ solar\ PV\ array\ output$$

$$80\ Amps < 93.75\ Amps \rightarrow \mathbf{80}\ Amps = MAX\ potential\ solar\ PV\ array\ output\ through\ the\ charge\ controller$$

$$(MAX\ potential\ charging\ current) \div (MAX\ Charge\ Rate\ per\ Battery)$$
$$= Minimum\ Battery\ quantity\ to\ prevent\ overcharge$$

$$(80A) \div (37.5A) = 2.13 \rightarrow round\ to\ \mathbf{3}$$

Example B: Two PHI 3.8 kWh-25.6V$_{nominal}$ batteries (used in a 24-Volt system) must be paired with a 2,000-Watt solar PV array wired to a 100 Amp-rated charge controller. In this case, the 2,000-Watt solar array is used to determine the minimum PHI Battery quantity needed to prevent over-charging from the solar PV.

$$Watts = Amps \times Volts$$

$$2{,}000\ Watt\ Solar\ PV\ array = Amps \times 24\ Volts$$

$$\frac{2{,}000\ Watts}{24\ Volts} = \mathbf{83.33}\ Amps = MAX\ potential\ solar\ PV\ array\ output$$

$$83.3\ Amps < 100\ Amps \rightarrow \mathbf{83.3}\ Amps = MAX\ potential\ solar\ PV\ array\ output\ through\ the\ charge\ controller$$

$$(MAX\ potential\ charging\ current) \div (MAX\ Charge\ Rate\ per\ Battery) = Minimum\ Battery\ quantity\ to\ prevent\ overcharge$$

$$(83.3A) \div (45A) = 1.85 \rightarrow round\ to\ \mathbf{2}$$

Refer to the Battery Bank Sizing for Maximum Instantaneous Charge Rate table below for a complete list of OutBack charge controllers and the minimum quantity of PHI Batteries those controllers need to be paired with to ensure that the PHI Battery bank does not over-charge (assuming that the charge controllers' full current output rating is utilized). Failing to do so will destroy the PHI batteries and Void the Warranty.

Sizing for Maximum Instantaneous Charge Rate

Assume the charge controller's current output is fully utilized.

		Minimum Battery Quantity							
Charge Controller Model	Max Output (ADC)	PHI 3.8 51.2V	PHI 2.9 51.2V	PHI 3.8 25.6V	PHI 2.9 25.6V	PHI 1.4 25.6V	PHI 730 25.6V	PHI 1.4 12.8V	PHI 730 12.8V
OutBack FM 100 / AFCI	100	3	4	3	3	4	8	3	4

3.3 – Sizing for Maximum Instantaneous Charge Rate (AC Coupled)

In an AC Coupled system, charge controllers do not regulate the PV solar array's output, and many battery-based inverters fail to effectively regulate the array's output for battery charging. Therefore, in an AC Coupled system, SimpliPhi assumes that all the connected PV array's potential power output will charge the system's batteries. Determine the minimum quantity of PHI Batteries needed to prevent over-charge from the solar PV array by dividing the solar array's power rating by the MAX Continuous Charge Rate per PHI Battery (found on the relevant battery's specification sheet).

Example: Four PHI 3.8 kWh-51.2V$_{nominal}$ batteries must be paired with 7.6 kW of AC Coupled solar PV to ensure the PHI Battery bank does not over-charge from the solar array.

$$(7.6\ kW) \div (1.92\ kW) = 3.96 \rightarrow round\ to\ 4$$

In addition to the Battery Bank Sizing requirements outlined above, also adhere to OutBack's AC Coupling Guidelines and system sizing considerations.

- AC Coupling with the Radian: http://www.outbackpower.com/downloads/documents/appnotes/ac_coupling_radian.pdf
- AC Coupling with the SkyBox: http://www.outbackpower.com/downloads/documents/appnotes/ac_coupling_skybox.pdf

CAUTION: Not all grid-tie inverters (including micro-inverters) successfully AC Couple with battery-based inverters. Some grid-tie inverter manufacturers require specific updates to their equipment (via their Support staff) when configuring an AC Coupled system. Make sure to contact the relevant grid-tie inverter manufacturer regarding the feasibility of AC Coupling *prior* to an AC Coupled installation using OutBack equipment and SimpliPhi batteries.

CAUTION: Radians operate in Grid Tied or Generator modes only when AC Coupled; they do not operate in Mini Grid or Grid Zero modes when AC Coupled. SkyBox AC Coupling allows for inverter operation in additional modes. For more information on this, refer to the above linked AC Coupling Application Notes or contact OutBack Power: Sales@OutBackPower.com.

Sizing for Maximum Instantaneous Charge Rate (AC Coupled)

Minimum Battery Quantity per inverter *calculation results are listed below. These calculations assume that the AC Coupled grid-tie inverter used in the system fulfills the maximum allowable rating according to OutBack's AC Coupling guidelines. When AC Coupling to a grid-tie inverter with a rating lower than described in the table below, or when using more than one inverter in a system, PHI Battery bank sizing is more precise when the calculation described in the example above is used instead of the following table.*

48V Inverter Model	Inverter Power Rating (kW AC)	MAX AC Coupled GTI Rating (kW AC)	PHI 3.8-51.2V_{nom} MIN Battery Quantity	PHI 2.9-51.2V_{nom} MIN Battery Quantity
OutBack Radian 8048A	8	7.6	4	5
OutBack Radian 4048A	4	3.8	2	3
OutBack SkyBox	5	5 (non-UL1741SA compliant) or up to 7.6 (UL1741SA compliant inverters only)	4	6

3.4 – Overall Battery System Sizing

Size the PHI battery bank so that the minimum number of batteries in the bank is the greater of the two figures obtained from the Discharge and Charge calculations. For example, a system that requires 5 PHI Batteries to ensure that the battery bank does not over-discharge and 3 PHI Batteries to ensure that the battery bank does not over-charge, should include a final minimum quantity of 5 batteries. Failure to do so will destroy the PHI batteries and will Void the Warranty.

Note that these sizing guidelines and program settings outlined in **Section 4.0 – Program Settings for PHI Batteries** assume that solar PV charging and charging via the inverter/charger **do *not* occur simultaneously**. If there is a possibility that these two charging sources might be active at the same time in your system, please consult OutBack Power (Support@OutBackPower.com).

Note also that the quantity of PHI Batteries calculated from this sizing guide is the *minimum* requirement to prevent over-discharge and over-charge from an instantaneous power perspective. The system may need more PHI Batteries in the battery bank in order to meet the system's energy requirement (the amount of power the batteries must supply to the loads *over time*).

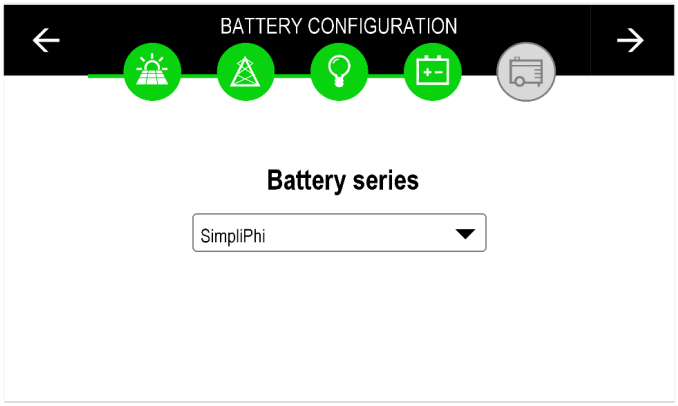
Refer to SimpliPhi's online Battery Bank Sizing Estimator tool for assistance with sizing the PHI Battery Bank according to connected loads and the desired number of days of autonomy: https://simpliphipower.com/support/battery-bank-sizing-estimator/.

CAUTION: Not all system discharge or charge characteristics can be mitigated via programming. Under-sizing a PHI Battery bank relative to the system's maximum discharge or charge rate will destroy the PHI Batteries and Void the Warranty.

4.0 – Program Settings for PHI Batteries

4.1 – SkyBox Settings

Unlike most other equipment, the OutBack SkyBox has PHI battery-related settings pre-programmed into versions 1.5.0 and later. Instead of programming custom settings into the equipment (as described in later sub-sections of this Section 4.0 – Program Settings for PHI Batteries), simply select "SimpliPhi" from the dropdown menu on the SkyBox's Battery Configuration screen in order to maintain the PHI Battery warranty:



Refer to this linked SkyBox: Commissioning with Energy Storage video for further instruction: https://www.youtube.com/watch?v=twmI7_og-Dw.

4.2 – Inverter Settings (Non-SkyBox)

In order to maintain the PHI Battery Warranty, it is critical to ensure that the appropriate settings are programmed in all system components. The settings outlined in the following section maintain a maximum 80% Depth of Discharge (DoD) for the PHI batteries, thereby optimizing the performance and life of the PHI batteries. Not all OutBack equipment includes all the below listed settings. Settings that are not explicitly listed below do not directly pertain to the PHI batteries. Refer to the relevant OutBack manual for more detailed information on any one of the listed settings.

OutBack equipment networked together via the HUB and with a MATE3s system controller can be programmed via the MATE3s (instead of directly in the inverter/charger and/or charge controller). Video instructions for

programming battery charging settings via the MATE3s are posted here: https://www.youtube.com/watch?v=RDsLpuSDG7o. (***Note:*** *This video shows inverter/charger programming; make sure to* also *program charge controller settings by selecting* ***Charge Controller*** *in the* ***Settings*** *menu.)*

The following Table outlines settings for the Radian and FXR/VFXR inverters, *not* the SkyBox.

Table 1.0 – Settings for PHI Batteries with OutBack Inverters Based on 80% DoD Levels

Inverter Settings > Battery Charging	51.2V_{nom} PHI Battery	25.6V_{nom} PHI Battery	12.8V_{nom} PHI Battery
Absorb Voltage	56V	28V	14V
Absorb Time	0.1 hours		
Float Voltage	N/A (*54V / 27V / 13.5V may be used as a placeholder value, but Float is disabled by setting Float Time to 0*)		
Re-Bulk Voltage	50.8V	25.4V	12.7V
Float Time	0 Hours		
Re-Float Voltage	N/A (*50V / 25V / 12.5V may be used as a placeholder value, but Float is disabled by setting Float Time to 0*)		
EQ Voltage	N/A (*54.4V / 27.2V / 13.6V may be used as a placeholder value, but EQ is disabled by setting EQ Time to 0*)		
EQ Time	0 Hours		
> Battery Protection			
Low Battery Cut-Out Voltage[1]	50V	25V	12.5V
Low Battery Cut-Out Delay	130 seconds		
Low Battery Cut-In Voltage	52V	26V	13V
High Battery Cut-Out Voltage	60V	30V	15V
High Battery Cut-Out Delay	1 second		
High Battery Cut-In Voltage	54V	27V	13.5V
> Mini Grid			
Mini Grid Connect to Grid	*Refer to Section 4.2.1*		
Mini Grid Delay			

> Grid Zero			
Grid Zero DOD Volts	*Refer to Section 4.2.2*		
Grid Zero DOD Amps			
Inverter Settings > AC Input			
AC Input Select Priority	*Program this setting according to the homeowner's system preference.*		
Charger Operating Mode	*Program this setting according to the homeowner's system preference.*		
Charger AC Limit	*Refer to Section 4.2.3*		
> Grid			
Grid Input Mode	*Program this setting according to the homeowner's system preference.*		
Grid-Tie	*Program this setting according to the system's setup.*		
Sell Voltage[2]	54V	26.4V	13.2V

Notes:

1. SimpliPhi recommends programming equpment as outlined in Table 1.0 above in order to maintain 80% DoD levels. Programming to 90% DoD (49.6V / 24.8V / 12.4V) and 100% DoD (48V / 24V / 12V) levels are permissable, but result in shorteneed cycle life (refer to the PHI Battery Warranty for more information).
2. Sell Voltage parameter appears in the OutBack Radian inverter only.

- Levels are typical @ 25°C and may need adjusting at temperature extremes.
- When performing rapid deep charge/discharge cycles the battery should be allowed to "rest" 15 minutes in between.

CAUTION: When PHI Battery quantities change the capacity and charge/discharge current settings must be reassessed. Failure to do so will Void the Warranty.

4.2.1 – Mini Grid Mode & Settings

According to the OutBack Radian Series Inverter/Charger Operator's Manual:

"In *Mini Grid* mode, the Radian inverter automatically rejects an AC source and runs solely from battery (and renewable) energy. The inverter only connects to the AC source (the utility grid) when the batteries run too low… The inverter will reconnect to the utility grid if the battery voltage decreases to the *Connect to Grid* set point after the *Delay* time period."

By programming *Mini Grid Connect to Grid* to 50.4V and *Mini Grid Delay* to 2 minutes, the Radian allows the batteries to discharge to about 80% DoD. A voltage of 50.4V is typically the recommend voltage setting for the *Connect to Grid* parameter.

In *Mini Grid* mode and while connected to the utility grid, "the inverter's charger can be set either On or Off. If the charger is turned on, the inverter will proceed through a full charging cycle. Upon reaching the end of the charging cycle, the inverter will disconnect from the grid."

4.2.2 – Grid Zero Mode & Settings

According to the OutBack Radian Series Inverter/Charger Operator's Manual:

"In *Grid Zero* mode, the Radian inverter remains grid-connected, but prioritizes the use of battery or renewable sources to run loads. It uses only renewable energy to recharge the batteries… Any time the

batteries exceed the *DoD Volts* setting by 0.8 Vdc or more, the Radian will send power from the batteries to the loads. As the battery voltage decreases to the *DoD Volts* setting, the inverter will reduce the rate of flow toward zero and loads will be powered by the grid. It will maintain the batteries at this setting until renewable sources recharge the batteries."

Remember, the programmed Re-Bulk Voltage in the inverter is ignored while in Grid Zero mode because the inverter's charger is off. In this mode, the batteries charge only from the renewable energy source via the connected charge controller(s).

"When *DoD Volts* is set low, this mode allows more renewable energy to be delivered from the batteries to the loads. However, it will also leave less battery reserve in the event of a grid failure."

By programming Grid Zero *DoD Volts* to 50V, the Radian inverter will begin curtailing the batteries' discharge at 50.8V. Setting Grid Zero *DoD Volts* to 50V is the lowest permitted value while still maintaining the PHI Batteries' ~80% maximum DoD.

"When *DoD Volts* is set high, the batteries will not be discharged as deeply and will retain more of a backup reserve. However, not as much renewable energy will be sent to the loads."

By programming Grid Zero *DoD Volts* to 51.6V, the Radian inverter will begin curtailing the batteries' discharge at 52.4V, nearly 100% Sate of Charge (SoC). It would not make sense to program Grid Zero *DoD Volts* to a value higher than 51.6V.

Refer to the Battery Voltage VS. SoC Table at the end of this document for further guidance.

According to the OutBack Radian Series Inverter/Charger Operator's Manual:

"To prolong cycle life and increase battery capacity, the rate of discharge can be limited using the *DoD Amps* setting. This item should be set lower than the current provided by the renewable source."

Refer to the Charger AC Limit Table for the maximum permissible Amps AC — charge or discharge — per battery.

4.2.3 – Radian Charger AC Limit Calculation

The OutBack Radian inverter/charger's Charger Limit setting is regulated on the AC input side of the charger (not the DC side of the charger). Convert the PHI Battery bank's maximum* continuous DC charging current to the charger's AC current limit by following these steps:

1. Convert the PHI Battery bank's maximum continuous DC charging current to DC watts.
2. Apply the charger efficiency.
3. Convert AC watts to AC current.

**When Grid charging specifically, it is permissible to charge the battery bank according to its maximum continuous DC charging current, but SimpliPhi recommends charging at less than the maximum current. In a Grid charging scenario, multiply the Charging Amps found according to this section by 40% or less.*

Example: Four PHI 3.8 kWh-51.2$V_{nominal}$ batteries (used in a 48-Volt system) are paired with an OutBack Radian GS8048A model inverter/charger.

1. Each PHI 3.8 kWh-51.2V battery has a maximum continuous DC charging current of 37.5 Amps DC, or 1,920 Watts DC at the battery's 51.2 nominal voltage. The four-battery bank has a combined maximum continuous DC charging current of 150 Amps DC, or 7,680 Watts DC.

$$Watts\ DC = Amps\ DC \times Volts\ DC$$

$$1{,}920\ Watts\ DC = 37.5\ Amps\ DC \times 51.2\ Volts\ DC$$

$$7{,}680\ Watts\ DC = 4 \times 37.5\ Amps\ DC \times 51.2\ Volts\ DC$$

2. Apply the charger efficiency. If the charger converts AC Input power to DC Charging power at an 85% efficiency rate, then over 9,000 Watts AC can be used as the charger's maximum AC Input.

$$\frac{7{,}680\ Watts\ DC}{0.85} = 9{,}035.3\ Watts\ AC$$

3. Convert AC watts to AC current, by dividing AC watts by the inverter's AC Voltage rating. The OutBack Radian has a 240VAC output rating, but some other OutBack inverters are rated at 120VAC.

$$\frac{9{,}035.3\ Watts\ AC}{240\ Volts\ AC} = \mathbf{37.6\ Amps\ AC}$$

The OutBack Radian GS8048A has a maximum AC Input Charge Current of 30 Aac, lower than the calculated 37.6 Aac maximum for the four-battery bank. Therefore, the Radian's inverter/charger can operate at its full 30 Aac-rated charger output without over-charging the PHI battery bank.

Typically, a properly sized PHI Battery bank will have a maximum charging current greater than the paired inverter/charger's maximum potential charging output. If a PHI Battery bank is under-sized relative to its paired inverter, in addition to programming a lower inverter/charger charge limit, other additional precautions must also be taken to protect the battery from over-discharge (refer to Section 3.1 – Sizing for Maximum Instantaneous Discharge (Load Rate)).

PHI Batteries' Maximum Charge Rates Table

Refer to either the "Amps AC at 240VAC" or the "Amps AC at 120VAC" column depending on the AC Output rating of the inverter in use. Values are per battery; calculate the Charger AC Limit by multiplying the per-battery value by the number of batteries. If necessary, round figures down to the closest whole number.

Table 2.0 – PHI Batteries' Maximum Charge Rates

PHI Battery Model	MAX Continuous Charge Rate per Battery (ADC)	MAX Continuous Charge Rate per Battery (Watts DC)	Watts AC (assume 85% Charger Efficiency)	Amps AC Charge Limit per Battery at 240VAC	Amps AC Charge Limit per Battery at 120VAC
PHI 3.8-51.2V$_{nom}$	37.5	1,920	2,259	9.4	18.8
PHI 3.5-51.2V$_{nom}$	34	1,741	2,048	8.5	17.1
PHI 3.4-51.2V$_{nom}$	33	1,690	1,988	8.3	16.6
PHI 3.8-25.6V$_{nom}$	45	1,152	1,355	5.6	11.3
PHI 3.5-25.6V$_{nom}$	45	1,152	1,355	5.6	11.3
PHI 3.4-25.6V$_{nom}$	45	1,152	1,355	5.6	11.3
PHI 2.9-51.2V$_{nom}$	28.5	1,459	1,717	7.2	14.3
PHI 2.7-51.2V$_{nom}$	26	1,331	1,566	6.5	13.1
PHI 2.6-51.2V$_{nom}$	25	1,280	1,506	6.3	12.5
PHI 2.9-25.6V$_{nom}$	45	1,152	1,355	5.6	11.3

PHI 2.7-25.6V$_{nom}$	45	1,152	1,355	5.6	11.3
PHI 2.6-25.6V$_{nom}$	45	1,152	1,355	5.6	11.3
PHI 1.4-25.6V$_{nom}$	28.5	730	858	3.6	7.2
PHI 1.3-25.6V$_{nom}$	26	666	783	3.3	6.5
PHI 1.4-12.8V$_{nom}$	45	576	678	2.8	5.6
PHI 1.3-12.8V$_{nom}$	40	512	602	2.5	5.0
PHI 730-25.6V$_{nom}$	14	358	422	1.8	3.5
PHI 675-25.6V$_{nom}$	13	333	392	1.6	3.3
PHI 730-12.8V$_{nom}$	28.5	365	429	1.8	3.6
PHI 675-12.8V$_{nom}$	26	333	392	1.6	3.3

4.3 – FM100 / AFCI Charge Controller Wiring & Settings

The FM100 and FM100 AFCI charge controller's Aux terminals 7 and 8 must be utilized for the Battery Sense to function. Refer to page 21 of the FM100 charge controller manual for additional information regarding the device's Battery Sense terminals and Battery Sense function:
http://www.outbackpower.com/downloads/documents/charge_controllers/flexmax_100/flexmax100_manual.pdf

A twisted-pair cable can be wired from Aux terminal 7 (negative) and 8 (positive) to any of the (respective) negative and positive battery terminals in the PHI Battery bank. If the system includes more than one charge controller, daisy chain the wiring from Aux terminals 7 and 8 in the multiple charge controllers.

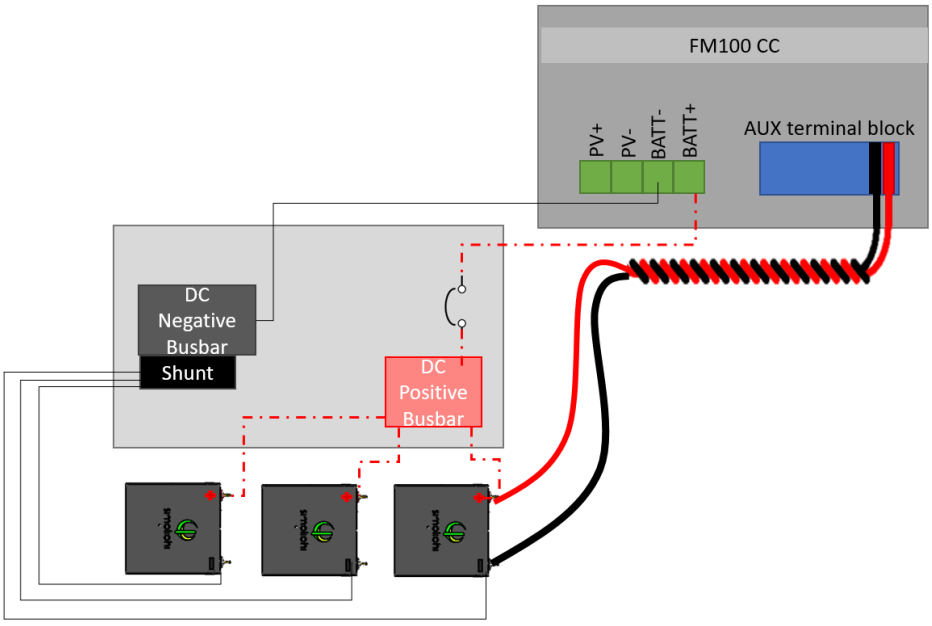


Table 3.0 – Settings for SimpliPhi PHI Battery w/ OutBack Charge Controller

Charger	51.2V_{nom} PHI Battery	25.6V_{nom} PHI Battery	12.8V_{nom} PHI Battery
Absorb Voltage[1]	56.4V	28.2V	14.1V
Absorb Time	0.1 hour		
Float Voltage	54V	27V	13.5V
ReBulk Voltage	51.2V	25.6V	12.8V
DC Current Limit	PHI battery banks sized according to **Section 3.2 – Sizing for Maximum Instantaneous Charge Rate (DC Coupled)** do not require any limitation of the charge controller's DC Current output.		
Absorb End Amps[2]	2% of the PHI Battery bank's capacity		
	OR disabled (End Amps = 0) if the system includes a FNDC		
MPPT	*Refer to page 44 of the FM100 Manual*		
Battery Equalize			
Equalization Voltage	*Although Equalize is Disabled, the below values may be used as placeholders.*		
	56.4V	28.2V	14.1V
Equalization Time	*Although Equalize is Disabled, 0-1 Hours may be used as a placeholder value.*		
Automatic Battery Equalization	0 Days (disables Equalization)		
Grid-Tie Mode			
Enable Grid-Tie Mode	N (No) when the system does not export energy onto the grid, and/or when the entire system is not composed of all OutBack devices networked to each other via the HUB.		
	Y (Yes) when the system exports energy onto the grid and the entire system is composed of OutBack devices (including a grid-interactive OutBack inverter) networked to each other via the HUB.		

Notes:
1. Setting the charge controller's Absorb Voltage higher than inverter's Absorb Voltage prioritizes charge controller charging over inverter charging. If the system does not utilize an inverter/charger for battery charging from an AC power source, the Absorb Voltage in the charge controller may be programmed to the same Absorb Voltages listed in Section 4.2 – Inverter Settings.
2. Refer to **Section 1.3.1 – Absorb End Amps**.

- Levels are typical @ 25°C and may need adjusting at temperature extremes.
- When performing rapid deep charge/discharge cycles the battery should be allowed to "rest" 15 minutes in between.

1.3.1 – Absorb End Amps

Ideally, the end of the PHI battery bank's Absorb charging phase is indicated by a low current (2% of the battery bank's Amp-hour rating) rather than by its length of time in the Absorb stage. In scenarios where the OutBack system contains a **single** charge controller and no FLEX net DC (FNDC) device, this low-current trigger can be programmed using the Absorb End Amps setting in the charge controller. In scenarios where a FNDC is included in the OutBack system (there is more than one FM100 or for any other reason), this low-current trigger is instead programmed via the FNDC's Return Amps setting and

Absorb End Amps is disabled in the charge controller (set to 0). Note that in any OutBack system that includes a FNDC, the OutBack equipment will defer to the Return Amps setting in the FNDC rather than the Absorb End Amps setting in the FM100.

In either situation, the low-current trigger setting is calculated by multiplying the nominal per-battery Amp-hour value times the number of batteries in the PHI Battery bank, times 0.02:

$$Absorb\ End\ Amps = (Ah\ per\ PHI\ battery) \times (Quantity\ of\ PHI\ batteries) \times (0.02)$$

The table below includes the per-battery Amp-hour (Ah) value for a wide variety of PHI Battery models, including legacy batteries.

Table 4.0 – PHI Batteries' Capacity Ratings

PHI Battery Model	Capacity Rating per Battery (Ah)	2% of Capacity Rating per Battery
PHI 3.8-51.2V_{nom}	75*	1.5
PHI 3.5-51.2V_{nom}	69*	1.38
PHI 3.4-51.2V_{nom}	67*	1.34
PHI 3.8-25.6V_{nom}	151	3.02
PHI 3.5-25.6V_{nom}	138	2.76
PHI 3.4-25.6V_{nom}	134	2.68
PHI 2.9-51.2V_{nom}	57*	1.14
PHI 2.7-51.2V_{nom}	52*	1.04
PHI 2.6-51.2V_{nom}	51.2	1.024
PHI 2.9-25.6V_{nom}	115	2.3
PHI 2.7-25.6V_{nom}	105	2.1
PHI 2.6-25.6V_{nom}	102.4	2.048
PHI 1.4-25.6V_{nom}	57	1.14
PHI 1.3-25.6V_{nom}	52	1.04
PHI 1.4-12.8V_{nom}	115	2.3
PHI 1.3-12.8V_{nom}	105	2.1
PHI 730-25.6V_{nom}	28.5	0.57
PHI 675-25.6V_{nom}	26	0.52
PHI 730-12.8V_{nom}	57	1.14
PHI 675-12.8V_{nom}	52	1.04

Note: Battery Ah capacities less than 100Ah are not programmable in the FLEXnet DC.

CAUTION: When PHI Battery quantities change the capacity and charge/discharge current settings must be reassessed. Failure to do so will Void the Warranty.

4.4 – FLEXnet DC Settings

While the FLEXnet DC (FNDC) provides data logging of shunt information, it does not provide reliable State of Charge (SoC) measurements of the PHI Batteries when successive partial charging takes place at variable charge and discharge rates over many cycles. For this reason, using an FNDC in conjunction with PHI Batteries can frequently be misleading. SimpliPhi certainly recommends against using the FNDC with PHI Battery banks rated at an Amp-hour (Ah) value less than 100Ah (the lowest programmable value in the FNDC).

Table 5.0 – Settings for SimpliPhi PHI Battery w/ OutBack FLEXnet DC

FLEXnet DC Settings	51.2V_{nom} PHI Battery	25.6V_{nom} PHI Battery	12.8V_{nom} PHI Battery
Battery Ah[1]	*Refer to Table 4.0 – Capacity Ratings per Battery (Ah)*		
Charged Voltage (V)	54V	27V	13.5V
	0.4/0.2/0.1 volts lower than the lowest charger's Absorb voltage setting		
Charged Time	1 minute		
Charged Return Amps[2]	2% of the PHI Battery bank's capacity (*Refer to Table 4.0*)		
Battery Charge Factor	98%		
Relay Invert Logic	No		
AUX Relay Set Points	All Relay Set Points remain as the **Default** settings because the PHI Battery does not require that the relay be utilized.		

Notes:

1. Per PHI Battery – These settings are calculated by multiplying the per-battery Ah value times the # of batteries. Refer to Table 4.0 – Capacity Ratings per Battery (Ah). Note that **100Ah is the minimum** programmable value.
2. This setting is calculated by either (A) multiplying the per-battery Amp-hour (Ah) value times the # of batteries, then multiplying by 0.02, or (B) multiplying the per-battery 2%-capacity value times the # of batteries. Refer to Table 4.0 – 2% of Capacity Rating per Battery for all PHI Battery models' per-battery 2%-capacity value.
   To avoid conflict between the Return Amps parameter programmed in the FNDC and the Absorb End Amps parameter in any connected OutBack charge controller, disable the charge controller's Absorb End Amps parameter by setting it to **0** when a FNDC is included in the OutBack system.

- Levels are typical @ 25°C and may need adjusting at temperature extremes.
- When performing rapid deep charge/discharge cycles the battery should be allowed to "rest" 15 minutes in between.

CAUTION: When PHI Battery quantities change the capacity and charge/discharge current settings must be reassessed. Failure to do so will Void the Warranty.

Instead of using the FNDC for SoC readings, the PHI Batteries' most accurate SoC gauge is according to voltage:

Table 6.0 – Battery Voltage VS. State of Charge (SOC) at C/2 Discharge Rate

SOC	51.2V_{nom} PHI Battery	25.6V_{nom} PHI Battery	12.8V_{nom} PHI Battery
100%	> 52.5 VDC	> 26.25 VDC	> 13.13 VDC
95%	51.7 VDC	25.9 VDC	12.93
90%	51.65 VDC	25.8 VDC	12.91
75%	51.4 VDC	25.7 VDC	12.85
50%	51.0 VDC	25.5 VDC	12.75
20%	50.2 VDC	25.1 VDC	12.55
10%	49.5 VDC	24.8 VDC	12.38
0%	48.0 VDC	24.0 VDC	12.0

4.5 – MATE3s Settings

4.5.1 – FNDC Advanced Control

The MATE3s System Display and Controller allows for the monitoring and programming of all connected OutBack equipment.

Table 7.0 – Settings for SimpliPhi PHI Battery w/ OutBack FLEXnet DC Advanced Control

FNDC Advanced Control	
FNDC Advanced Control	Low SoC Warning = 20%
FNDC Advanced Control	Critical SoC Warning = 10%

4.5.2 – Advanced Generator Start

Advanced Generator Start (AGS) capabilities are built into OutBack equipment. Refer to OutBack's GS Load Center Manual for generator wiring instructions, and program the AGS via the MATE3s. According to OutBack, "AGS Mode utilizes the auxiliary (AUX) output on the inverter or charge controller and is compatible with any **two-wire start** generator." Verify generator compatibility directly with OutBack Power: Support@OutBackPower.com. Refer to page 117 in the MATE3s manual for the AGS Functional Test.

In the MATE3s's **Main Menu** (accessed by pressing the **TOP** key on the MATE3s), select **Settings**, then **MATE3s**, then **Advanced Generator Start**.

Table 8.0 – Settings for SimpliPhi PHI Battery w/ OutBack MATE3s AGS

AGS Setup			
AGS Enabled	Y to enable the AGS mode		
Port	Identifies the HUB port (1-10) for the device that is going to control the gen		
Fault Time	The amount of time the generator is given to connect before an AGS Fault message appears and a fault is logged in the system		
Control (Radian inverters only)	Selects which terminals will be used for AGS: AUX Output or AUX Relay		
Warm Up Time	Individual to the specific generator		
Coll Down Time	Individual to the specific generator		
DC Generator	Y if a DC Generator is used		
AGS Voltage Start	51.2V_{nom} PHI Battery	25.6V_{nom} PHI Battery	12.8V_{nom} PHI Battery
24 Hour Start	Disable N		
2 Hour Start	Disable N		
2 Minute Start	Enable Y, minimum values below (correlate with 80% DoD)		
	50.4V	25.2V	12.6V
AGS Load Start			
Enabled	Enable Y when necessary (refer to application described below)		
Start (kW)[1]	1.9 kW per PHI 3.8-51.2V_{nom} model battery		
	1.1 kW per PHI 3.8-25.6V_{nom} battery		
	1.5 kW per PHI 2.9-51.2V_{nom} model battery		
	1.1 kW per PHI 2.9-25.6V_{nom} model battery		
	0.7 kW per PHI 1.4-25.6V_{nom} model battery		
	0.5 kW per PHI 1.4-12.8V_{nom} model battery		
	0.3 kW per PHI 730-25.6V_{nom} model battery		
	0.3 kW per PHI 730-12.8V_{nom} model battery		
Start Delay	Varies depending on the characteristics of the loads. ~0-1 minutes can be used.		
Stop (kW)	Varies depending on the characteristics of the loads. The Start kW minus 100 Watts can be used but may need adjustment.		
Stop Delay	Varies depending on the characteristics of the loads. ~0-1 minutes can be used.		

Notes:

1. Per PHI Battery – These settings are calculated by multiplying the per-battery kW value times the # of batteries. Refer to Table 2.0 – MAX Continuous Charge Rate per Battery (Watts DC) and convert Watts to kiloWatts for legacy battery specifications.

- Levels are typical @ 25°C and may need adjusting at temperature extremes.
- When performing rapid deep charge/discharge cycles the battery should be allowed to "rest" 15 minutes in between.

According to OutBack, the AGS's *2 Minute Voltage Start* is "considered an emergency start set point and … will start the generator regardless of *Quiet Time* settings." Programming this parameter according to the settings listed in Table 8.0 above ensures that the battery does not discharge below ~80% Depth of Discharge. Triggering the generator to turn on from the *AGS Voltage Start* setting not only results in the loads being powered from the generator instead of the PHI battery bank, but also initiates a full battery charge cycle via the inverter/charger.

According to OutBack, AGS "*Load Start* will start a generator whenever the total system AC load wattage exceeds the *Start* set point for the programmed amount of time (*Delay*). The generator will then be stopped when the AC load has dropped below a Stop set point for a programmed amount of tie (*Delay*)." This setting is especially useful when a PHI Battery bank is slightly under-sized relative to the inverter's Load Rate (refer to Section 3.1 – Sizing for Maximum Instantaneous Discharge). If the PHI Battery bank is sized such that the its maximum continuous discharge rate meets or exceeds the inverter's Load Rate, it is unnecessary to utilize this setting.

When the generator is running because of Load Start, the inverter system will charge the batteries. However, it is not programmed to perform a complete charge cycle. If the generator stops upon reaching its *Stop* criteria/set point, the charge might not be completed.

AGS Voltage Start and AGS Load Start settings can be used in parallel. Whichever condition is met first starts the generator.

Because PHI Battery SoC readings in the OutBack equipment are unreliable in partial charging applications, SimpliPhi recommends *against* using the AGS SoC Start parameter and favors the AGS Voltage Start and/or AGS Load Start parameters instead.