

## How To Set Up SimpliPhi™ Batteries Using OutBack Chargers

### Introduction

The main focus of this application note will be on setting up OutBack charging sources for best operational performance for the SimpliPhi™ model 3.8 lithium ferro phosphate (LFP) batteries. Basic specifications are listed in Table 1 with program settings in Table 2.

Table 1 SimpliPhi Model 3.8 Specifications

PHI 3.8	24V	48V
Nominal DC Voltages	25.6	51.2
Amp Hours	151	75
Rated kWh Capacity @ C/2	3.8 kWh@100% DOD, 3.04 kWh@80% DOD	
Max Discharge Rate (10 minutes)	60 Adc	
Max Continuous Discharge Rate	45 Adc	37.5 Adc
Max Continuous Charge Rate	45 Adc	37.5 Adc
DC Voltage Range	20 to 28	48 to 56
Depth of Discharge	Up to 100%	
Operating Efficiency	98%	
Operating Temp	-20° to 60°C	
Charging Temp	0° to 49°C	
Self-Discharge Rate	<1% loss per month	
Cycle Life	10,000+ (@ 80% DOD)	
Memory Effect	None	
Warranty Period	10 Years or 10,000 cycles (@80% DOD)	
Dimensions	13.5 x 14 x 8 inches / 0.88 cu. ft.	
Weight	78.24 lbs (35.5 kg)	

Table 2 Program Settings for SimpliPhi Model 3.8 kWh 24V/48V

INVERTER	80% DoD, 10k cycles	90% DoD, 5k cycles	100% DoD, 3.5k
Absorb Voltage and Time	27.2 / 54.4, 1 hour	27.2 / 54.4, 1 hour	28 / 56, 1 hour
Float Voltage and Time	27 / 54 (default), Time = 0 = Disable		
Re-Float Voltage	25 / 50 (Disabled, leave at default)		
Re-Bulk Voltage	25.4 / 50.8		
AC Input Mode	Grid Tied/Support (GS8048A / GS7048E defaults, adjust as needed)		
SellRE (Offset) Voltage	27 / 54		
AC Charger Limit in AC Amps	24V = 5A @ 240V (5.2 @ 230V), or 10A @ 120V 48V = 8A @ 240V (8 @ 230), or 17A @ 120V		
Low Battery Cut-Out Voltage	25.2 / 50.4, 130 sec delay	24.8 / 49.6, 1 sec delay	24 / 48, 1 sec delay
Low Battery Cut-In Voltage	26 / 52		
<b>CHARGE CONTROLLER</b>			
Absorb Voltage and Time	27.4 / 54.8, 1 hour	28.2 / 56.4, 1 hour	
Float Voltage	27.2 / 54.4 (Default)		
Rebulk Voltage	25.4 / 50.8		
DC Current Limit	45 / 37 Use full 80A for multiple batteries (see Tips and Precautions)		
Absorb End Amps	0		
<b>FLEXnet DC (FN-DC)</b>			
FN-DC Battery Ah	140 / 100 (see Tips and Precautions)		
FN-DC Charge Voltage	27 / 54 Time = 1 min	27.8 / 55.6 Time = 1	
FN-DC Charged Return Amps	8A / 4A (multiply this value times the number of batteries)		
FN-DC Battery Charge Factor	98% 98%		
FN-DC Relay Invert Logic	No		
FN-DC Relay Voltage	Default		
FN-DC Relay SOC High/Low	Default		
FN-DC Relay Delay	Default		
<b>MATE3 AND MATE3s</b>			
FLEXnet DC Advanced Control	Low SOC Warning = 20%		
FLEXnet DC Advanced Control	Critical SOC Warning = 10%		

## OutBack Inverter and Charge Controller Setup Procedure

The SimpliPhi batteries have a very fast current drop-off when the Absorb voltage target is met. This can be problematic, as when the SimpliPhi batteries are full, the current drops to nearly zero. This is unlike a lead acid battery where the end amps are typically 2-3% of the battery Ah rating and never drop to zero. Under these lightly loaded conditions, the OutBack charging devices cannot regulate as well, causing voltage fluctuations that may rise above the limit of the SimpliPhi input overvoltage protection circuit and shutdown the battery. If the charge voltage creeps up to the SimpliPhi input protection voltage (~60-62 volts), then the Charge Termination Control function can be implemented to end the charge cycle, and prevent the open circuit charging voltages to wander above the SimpliPhi input protection voltage. The settings used by Charge Termination Control are listed under the FN-DC setup on page 5.

The following steps are performed in the Main Menu of the MATE3 or MATE3s system display. Bring up the Enter Password screen using the LOCK navigation key. Enter the password 141 for the Main Menu.

### 1. Enter the inverter settings for the charger.

- a. From the Main Menu, select the Settings menu.
- b. From the Settings menu, select the Inverter menu.
- c. From the Inverter menu, select the Battery Charging screen. Enter the Absorb charging settings listed in Table 2. Set the Float charging time to zero to disable it (as the SimpliPhi battery only requires a single charging source voltage).
- d. Press the UP navigation key and select the AC Input and Current Limit screen. Enter the charger settings listed in Table 2.  
**NOTE:** the values listed are for maximum charge current.
- e. Press the UP navigation key and select the Low Battery screen. Enter the Low Battery Cut Out and Cut In voltages listed in Table 2.

### 2. Enter the inverter settings for operating modes.

- a. From the Main Menu, select the Settings menu.
- b. From the Settings menu, select the Inverter menu.
- c. From the Inverter menu, select the AC Input Mode and Limits screen for the appropriate input. Set Input Mode for desired operating mode.
  - o Grid Connected Offset (AC "blending") modes: Grid Tied, Grid Zero, Support or Mini Grid
  - o Off-Grid modes: Backup or Generator

**NOTE:** More information on input modes can be found in the Radian or FXR *Operator Manuals* and the application notes on Offset and AC Input Modes, located at [www.outbackpower.com](http://www.outbackpower.com).

### 3. Enter the charge controller charger settings.

- a. From the Main Menu, select the Settings menu.
- b. From the Settings menu, select the Charge Controller menu.
- c. From the Charge Controller menu, select the Charger screen. Enter the Absorb and Float settings listed in Table 2.

**NOTE:** The table shows settings for Model 3.8. For other models, set the Absorb and Float voltages 0.4 Vdc higher than the inverter settings (0.2 Vdc for 24V systems) to give priority charging to the charge controller.

### 4. Enter the charge controller current limits.

- a. Each charge controller has its own current limit from the maximum setting down to five amps. Typically the charge controller is left to the maximum setting so all available RE is accessible at all times. If for some reason the maximum current from the charge controller output needs to be limited, it can be changed from the default maximum setting on the system display using the following steps.
  - i. From the Main Menu, select the Settings menu.
  - ii. From the Settings menu, select the Charge Controller menu.
  - iii. From the Charge Controller menu, select the Charger screen. Scroll to Current Limit and enter the setting Leave Absorb End Amps at 0.

The output power of a given charge controller is the product of the maximum output current, 100 amps in this case, and the battery voltage. Some charge controller designs employ higher PV inputs without increasing the output current, which is ineffective. While a higher input voltage results in fewer, longer input strings, the controller will only convert that added energy if the output current is increased to match.

For example, the OutBack FLEXmax 80 was designed with an ideal input power to output power ratio. This 80-amp charge controller will always have a maximum string configuration of three PV modules in series due to the 150 V<sub>OC</sub> input limit, and possibly only two if high power modules are used in a cold environment. It set a benchmark at its introduction to the market for many charge controllers developed since.

## OutBack FLEXnet DC Setup Procedure

The FLEXnet DC Battery Monitor (FN-DC) provides three main functions: 1) data logging of shunt information (including daily kWh), 2) charge termination control, and 3) state of charge (SoC). Charge termination control will terminate charging from all OutBack chargers (including inverters and charge controllers) when the FN-DC Battery Setup settings of Charged Voltage and Time, plus the Charged Return Amps are all met. Meeting these charge parameters is an indication that the battery is full and charging should stop. This can save wear and tear on the batteries if multiple absorption cycles are initiated with minimal battery discharge. In this case, the charge parameters will probably be met more quickly than the Absorb time and can terminate the cycle so the batteries do not become overcharged. Meeting the charge parameters will also set the SoC to 100%.

The Charged Voltage setting is typically 0.2 Vdc lower than the lowest charger's Absorb voltage setting. This ensures the parameter is met in case there is a discrepancy between the voltmeters of the charging device and the FN-DC. The time setting is typically about 1-3 minutes depending on the battery. Return Amps is typically 2-3% of the battery amp-hours, but use the settings in Table 2 with the SimpliPhi batteries. The charging current drops off more dramatically when the charging voltage is met.

The FN-DC battery function that measures amps in and out of the battery can only determine SoC after measuring against other factors. These include the Battery Ah and the Charge Factor (BCF) settings. This allows the FN-DC to determine when the battery bank is full. For example, if the batteries are 90% efficient then it would take 100 Ah plus another 10% (10 Ah) to fully recharge a 200 Ah battery bank that had been discharged 50%. In this case, the FN-DC would measure 100 Adc on the discharge, then 110 Adc on the recharge before indicating the batteries are at the point of 100% SoC.

However, a single SimpliPhi 3.8 battery only has 75 Ah, and the lowest FN-DC setting is 100 Ah. Therefore a single battery with the FN-DC will cause SoC reading errors. Since two batteries or more will be required in most applications, it is not recommended to use single batteries with OutBack inverter systems. In addition to the single battery SoC reading error, a single battery presents a risk for overcharging. There is also a risk of inadequate power for backed up loads.

More information on the FN-DC can be found in the product literature on the OutBack website under Products/SystemsManagement/FLEXnet DC, as well as an FN-DC application note under Home/Resources/Documents/Product Application Notes.

### 1. **Enter the FN-DC Battery Setup settings in the system display.**

- a. Bring up the Enter Password screen using the LOCK navigation key. Enter the password 141 for the Main Menu. Press the Settings selection from the Main Menu.
- b. From the Settings menu, select the Battery Monitor menu.
- c. From the Battery Monitor menu, select Battery Setup.
- d. On the Battery Setup screen, enter the TOTAL battery bank amp-hours in Battery Ah.
- e. Set Charged Voltage to 0.2 Vdc lower than the lowest Absorb volts setting in Table 2.
- f. Set Charged Return Amps to the value in Table 2.
- g. Set Time to 1 minute.

### 2. **Enter the Charge Factor as the battery efficiency. This number is 98% for the SimpliPhi batteries.**

**NOTE:** Charge Termination Control is enabled by default in the FLEXnet DC Advanced Control menu. There is no need to change the setting unless for some reason this function needs to be disabled.

If the Grid Tied function is being used to sell back to the grid, it is possible the battery bank may never see an absorption cycle completed. This is because the inverter's Sell RE set point is never exceeded when the charge controller is on during the day. For applications utilizing offset and the Sell RE set point, there is a function under the FLEXnet DC Advanced Control settings called Enable Auto Grid-Tie Control. Changing from the default of N(o) to Y(es) will disable the Grid Tied mode at midnight and not re-enable it until the batteries have been allowed to go through an absorption cycle if necessary.

## OutBack MATE3 and MATE3s Setup Procedure

The MATE3 and MATE3s system displays monitor the FN-DC for low battery bank SoC and will report a Low SOC Warning when the setting is reached. The same is true for the Critical SOC Warning when its setting is reached. The default settings of 50% and 60% respectively, are more for lead-acid batteries which are rarely discharged more than 50%. As the SimpliPhi batteries are typically discharged 80% to 100%, these default settings will cause the warning lights and events to activate prematurely. Follow the steps below to reduce the number of warnings and events for the times that the bank is discharged more than 50%.

### 1. Enter the SoC warning settings in the system display.

- a. Bring up the Enter Password screen using the LOCK navigation key. Enter the password 141 for the Main Menu. Press the Settings selection from the Main Menu.
- b. From the Settings menu, select the MATE3 (or MATE3s) menu.
- c. From the MATE3 menu, select the FLEXnet DC Advanced Control screen. For the Low SOC Warning, enter 20% (lowest setting). For the Critical SOC Warning, enter 10% (lowest setting).

Table 3 - SoC voltages

SOC	24V	48V
100%	> 26.25 VDC	> 52.5 VDC
95%	25.9 VDC	51.7 VDC
90%	25.8 VDC	51.65 VDC
75%	25.7 VDC	51.4 VDC
50%	25.5 VDC	51.0 VDC
20%	25.1 VDC	50.2 VDC
10%	24.8 VDC	49.5 VDC
0%	24.0 VDC	48.0 VDC

The SoC voltages from SimpliPhi listed in Table 3 can also be a useful alternative to the FN-DC SoC % readings.

## Tips and Precautions

If the SimpliPhi batteries are discharged at a fast enough rate, then it is possible to completely discharge the battery before the low battery cut-out (LBCO) is able to stop the inverter from powering loads. If the inverter does not stop drawing power from the battery before LBCO is activated, and the battery is fully discharged, then the whole inverter system can shut down.

Inverters with UL1741SA firmware versions 001.001.006 or higher (that also incorporate enhanced grid protection settings) have an extended LBCO range to 54 Vdc. This is unlike older inverter firmware revisions that have a maximum LBCO setting of 48Vdc. In many cases, the 48 Vdc setting will not be high enough in a fast discharge application.

In the discharge curve in Figure 1, the drop-off below 49 Vdc is very fast. Setting the LBCO voltage and delay to the values in Table 2 should prevent the battery from becoming fully discharged with UL1741SA inverters with firmware versions 001.001.006 or higher.

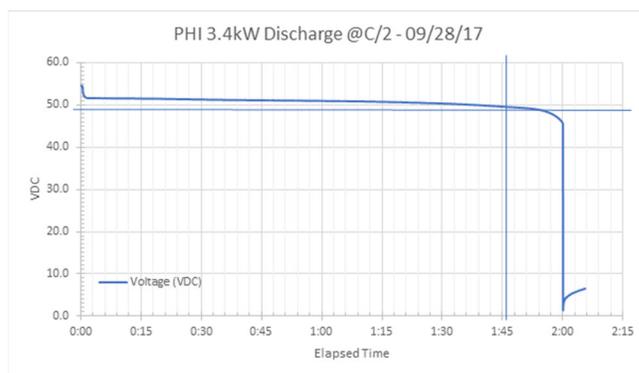


Figure 1 - SimpliPhi battery discharge curve

For the pre-SA firmware inverters, even an increased LBCO setting to 49-50 Vdc may still not prevent a dead battery condition as there is a delay of approximately five minutes before the LBCO function actually disconnects from the battery input terminals.

For fast discharge applications that do not have the extended LBCO range, or where even the extended LBCO range is not enough, there is another solution. The FLEXnet DC relay can be used to detect the voltage drop-off with little or no delay. The relay contacts can then be connected to the INVERTER ON/OFF terminals to turn the inverter off and prevent the batteries from being completely discharged. See connections in Figure 2. The settings that have worked under test conditions in the OutBack test lab are listed in Table 2. These can be tailored for the best results in a given application.



Figure 2 - how to prevent dead battery condition

## Guidelines for Sizing the Inverter and Charging Sources

SimpliPhi states in their warranty that a C/2 charge/discharge rate should not be exceeded, with a recommendation that the battery bank be greater than twice the kW load. This is illustrated in the examples below. The calculations assume the following.

- Battery rated power =  $Bat_{kWh}$
- Inverter power full load =  $Inv_{kW}$
- Maximum battery charge current =  $IBat_{ChrgMax}$
- PV charge controller maximum =  $IPV_{ChrgMax}$
- Recommended minimum number of batteries to optimize solar harvesting =  $B\#$
- Discharge equation:  $B\#Inv \geq Inv_{kW} / Bat_{kWh}$
- Charge equation:  $B\#PV \geq IPV_{ChrgMax} / IBat_{ChrgMax}$

## Higher Voltage and Current - Flexible String Sizing

To optimize the battery bank and protect against over-discharge (voiding the battery warranty) the battery bank should be sized at least twice the kW rating of the inverter.

Example:

- If Inverter is rated at 8kW
- And Battery is rated at 3.8kWh
- Then C/2 load is 1.9kW
- And  $B\#Inv \geq 8kW \div 1.9kW = 4.21$ , rounded up to 5

So a properly sized battery bank would have a minimum of 5 batteries. This ensures no greater than C/2 battery load.

## PV / Charge Controller Battery Bank Sizing

To optimize solar harvesting a properly sized battery bank should be able to accept the maximum PV charge current.

Refer to the PHI battery max continuous charge current specification which may differ from C/2 depending on model. Then divide the max charge controller output by the maximum battery charge current to determine the minimum number of batteries required to optimize PV.

Example ( $B\#PV \geq IPV_{ChrgMax} / IBat_{ChrgMax}$ ):

If Maximum battery charge current = 37.5A

And PV Charge controller max = 80A

Then  $B\#PV \geq 80A/37.5A = 2.13$ , rounded up to 3

A properly sized system would have a minimum of 3 batteries. This maximizes the use of available PV while ensuring the batteries are never stressed by overcharging.

Conversion for up to five SimpliPhi 24V and 48V batteries are listed in the tables below, courtesy of SimpliPhi Power.

Table 4

Conversion from DC to AC limit for 1 to 5 PHI 3.8 kWh 24V batteries (45Adc limit per battery)

A	B	C	D	E	F
# of Parallel Batteries	DC Current Limit	ADC x VDC (24)	WDC ÷ Charger Efficiency (85% = .85)	Column D ÷ Inverter Voltage (120 or 240 VAC, dep. on inverter; <u>240</u> VAC used below)	Round down (only whole #s can be used as input)
1	45A	1,080 WDC	1,270.59 WAC	5.29 AAC	5 AAC
2	90A	2,160 WDC	2,541.18 WAC	10.59 AAC	10 AAC
3	135A	3,240 WDC	3,811.76 WAC	15.88 AAC	15 AAC
4	180A	4,320 WDC	5,082.35 WAC	21.18 AAC	21 AAC
5	225A	5,400 WDC	6,352.94 WAC	26.47 AAC	26 AAC

Table 5

Conversion from DC to AC limit for 1 to 5 PHI 3.8 kWh 48V batteries (34 Adc limit per battery)

A	B	C	D	E	F
# of Parallel Batteries	DC Current Limit	ADC x VDC (48)	WDC ÷ Charger Efficiency (85% = .85)	Column D ÷ Inverter Voltage (120 or 240 VAC, dep. on inverter; <u>240</u> VAC used below)	Round down (only whole #s can be used as input)
1	37.5A	1,800 WDC	2,118 WAC	8.82 AAC	8 AAC
2	75A	3,600 WDC	4,235 WAC	17.65 AAC	17 AAC
3	112.5A	5,400 WDC	6,353 WAC	26.47 AAC	26 AAC
4	150A	7,200 WDC	8,471 WAC	35.29 AAC	35 AAC
5	187.5A	9,000 WDC	10,588 WAC	44.12 AAC	44 AAC

**CAUTION:** The OutBack Remote Temperature Sensor (RTS) should never be used with SimpliPhi LFP Batteries. Temperature compensation will exceed the battery charging parameters.

**CAUTION:** The SimpliPhi model 3.8, 24V and 48V batteries **\*must not\*** be connected in series under any circumstance or the BMS may be damaged. SimpliPhi has a different BMS for series connected batteries.

## About OutBack Power

OutBack Power is a leader in advanced energy conversion technology. OutBack products include true sine wave inverter/chargers, maximum power point tracking charge controllers, and system communication components, as well as circuit breakers, batteries, accessories, and assembled systems.

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