OutBack Battery Setup Using OutBack Chargers

This application note will provide some background information on OutBack lead-acid batteries as well as OutBack charging sources and their optimal setup for the most common applications. There are three different types of OutBack lead-acid batteries: Absorbed glass mat (AGM), tubular gel (OPzV) and flooded lead-acid (FLA). These not only have variations in chemical makeup, but their charging parameters, maintenance and application tradeoffs can also be significantly different. The directions below should be followed carefully with regards to installation, charger programming and maintenance to ensure the best possible battery life and safe operation.

Introduction

The main focus of this application note will be on setting up OutBack charging sources for best operational performance for both float and cycling applications. However, it's helpful to understand basic battery characteristics and other factors that can affect these applications before diving into the details.

First, some terminology and quick facts about lead-acid batteries.

Days (hours) of Autonomy: number of days (hours) the batteries will run loads without recharging.

Cycle: a single discharge and recharge of the battery

SoC: state of charge expressed in percent available total capacity.

DoD: depth of discharge expressed in percent of total capacity removed.

Ambient Battery Temperature: low temperatures reduce capacity, high temperatures reduce cycle life.

DoD vs. Cycles: Deeper discharges per cycle reduces battery life. For example, the RE battery discharged to 20% DoD = 3300 cycles, and discharged to 80% DoD = 675 cycles.

Charge/Discharge Rate: the faster the rate of charge or discharge, the less battery capacity.

One common factor in poor battery performance is improper battery sizing for a given system configuration and load use profile. System sizing is a fairly extensive topic of its own and will not be discussed here in its entirety, but some basic cautions should be understood. A battery bank that is undersized relative to a large photovoltaic (PV) array runs the risk of being overcharged by that PV array via the charge controller unless limits are put onto the array's output. However, limiting the array's output can curtail some of the PV power at the array as potential energy that never gets converted. Similar overcharging risks are possible with the inverter's charger as well if not properly constrained, but without the consequence of curtailing potential renewable energy (RE). Oversizing the battery bank relative to the PV array could run the risk of undercharging the batteries, or over-relying on the inverter's charger from an AC source using expensive grid or generator power. Undersizing the battery bank relative to load demand could mean a lack of adequate backup power during a grid power outage. These system behaviors should be carefully considered and factored into an overall system sizing calculation before purchasing and setting up the system battery bank.

When evaluating the battery tradeoffs for your application, consider how often the batteries will be discharged and how much capacity of the battery will be used for a given discharge cycle. For example, a solar generation application for "selling" back to the grid or self-consumption, plus backup power, will not need a cycling battery. Also, fewer batteries will be needed since the batteries can be discharged deeper. A "float" battery will usually have a lower price, lower self-discharge and up to fifty percent more years of life, making the float battery a better choice than a battery designed for high cycle applications.

A common battery cycling application is for off-grid applications where the batteries are often discharged and recharged daily. However, other cycling applications are arising where stored energy is used to reduce or eliminate utility surcharges for high peak demands and time-of-use charges. By going off-grid or self-consuming during these times, expensive surcharges can be avoided. If the batteries are sized for these ancillary services as well as backup power for grid loss, then savings from using stored energy to avoid utility surcharges will provide a faster return on investment of a PV generation system, and will provide the security of backup power for grid loss events.

Historically, many off-grid systems were designed for two days of autonomy with depth of discharge limited to 50%. This might still make sense depending on site location and lifestyle of the occupants, but for every day of autonomy that is added to the first day, the battery bank will increase in size by the same amount for each day added. Since batteries are often the most expensive component in the PV system, it might be more economical to enlarge the PV than doubling the size of the battery bank for a second day of autonomy, or tripling the size for a third day.

For a grid connected system, one day of autonomy that matches the sun cycle will be most efficient and cost effective. When sizing the battery bank, be sure to add together the hours per day of ancillary services to the 24-hour energy demand of the backup loads. The PV array should also be sized to power loads *and* charge the batteries at the same time.

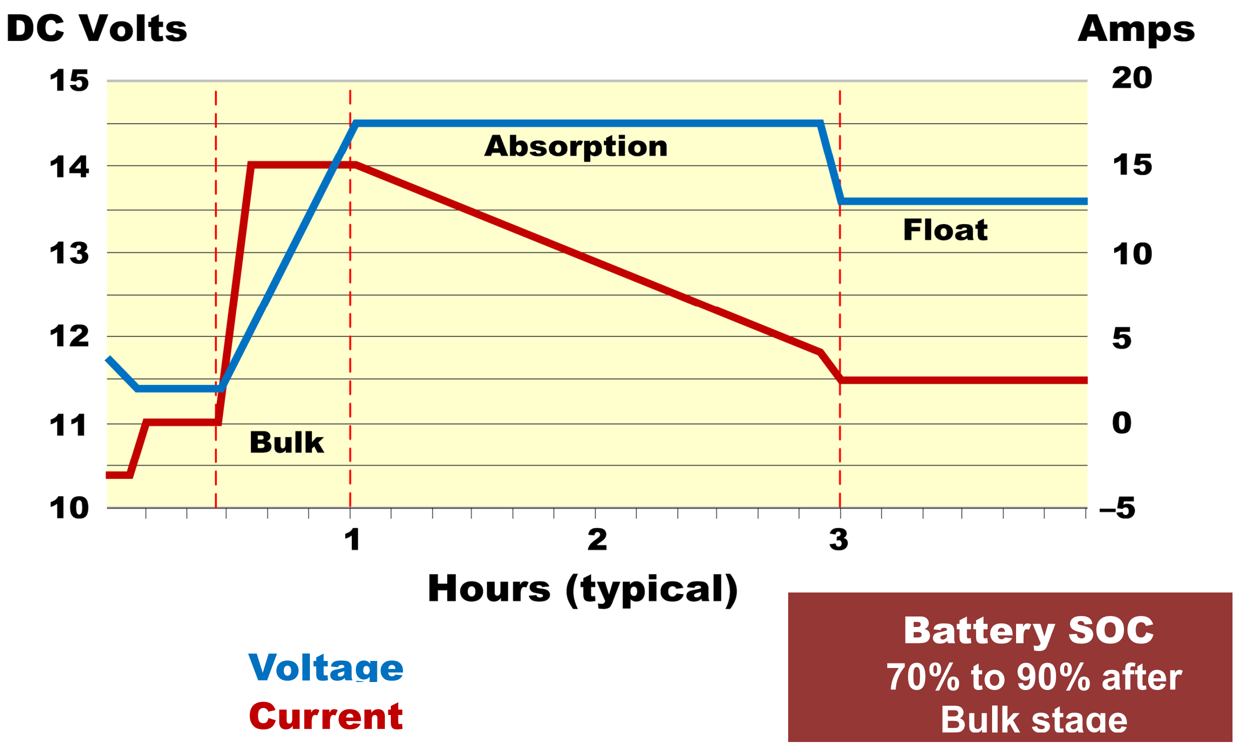
In addition to float and cycling characteristics, tradeoffs like operating temperature and flooded versus sealed batteries will affect price and performance as well, and are summarized below in Table 1.

Table 1 - Comparison of OutBack Batteries

Spec	FLA	RE	NC	PLR	PLC	OPzV
Volts	2 Vdc & 6 Vdc	2 Vdc	12 Vdc	12 Vdc	12 Vdc	2 Vdc
Ah @ C100	290 to 1400	800 to 2700	200	200	200	450 to 3000
Round Trip Efficiency	85%	90%	95%	97%	95%	80%
Operating Temp C	-4°C to 49°C	-20°C to 50°C	-20°C to 60°C	-40°C to 45°C	-40°C to 65°C	-20°C to 45°C
Cycles @ 50% DoD	2800	1800	2600	1500	3000	3000
Cycles @ 80% DoD	1600	600	750	800	800	1950
Chemistry	Flooded	AGM	AGM	AGM	AGM	GEL
Float Life Years	3	10	10	15	15	20 (@20°C)
Float Applications	Poor	Good	Good	Better	Better	Best
Cycling Applications	Best	Good	Better	Good	Best	Best
Shelf Life	2 mo.	6 mo.	6 mo.	24 mo.	24 mo.	6 mo.
Price Scale (1-5)	$	$$$$	$$$	$$$	$$$$	$$$$$

It's important to note that battery capacity, cycle life, and float life are all influenced by ambient temperature, charge/discharge rates, and depth of discharge associated with each cycle and cycling frequency. Since each site will operate under a unique set of circumstances, there is a high degree of variability on what kind of battery performance will be seen over the life of the battery bank for any given site location and usage case.

Also, note that Shelf Life decreases significantly as storage temperature rises. See battery manuals for specific details on each battery type.



Solution

Figure 1 above shows the three charging stages of a lead-acid battery. The first bulk stage is referred to as constant current since the battery cannot support a higher voltage until energy in the form of electrical current restores the battery's energy capacity. The Bulk stage may start when AC power is lost on the inverter AC input, or when the ***Re-Bulk*** voltage setting is reached. It ends when the charging voltage rises to the Absorb voltage which is the point where current starts to drop off from the maximum bulking current. The battery is about 90% SOC at the beginning of the Absorb stage for an AGM battery, but could be as little as 70 percent SOC for a flooded lead-acid (FLA) battery. The Absorb stage ends when the Absorb timer zeroes out, or if Charge Termination Control is enabled, the Absorb stage is terminated when the OutBack Power FLEXnet DC charge parameters are met (return amps, charge volts and time).

The battery is full or 100 percent SOC at the end of the Absorb stage as indicated by the current reaching a "floor" current known as return amps (a.k.a. end amps). The return amps current is typically around 2-3 percent of the Ah rating of the battery. Once the battery has received an Absorb charge (some battery manufacturers use the term Bulk in place of Absorb) the battery is left in an open-circuit state while the inverter passes through AC power to the loads. When the battery is not charging, then it will be in a state of self-discharge, even without a connected electrical load. Once the battery is discharged to a pre-determined state (what OutBack refers to as the ***Re-Float*** voltage) then the inverter charger is activated with a charging voltage a few volts lower than the ***Absorb*** voltage setting. At the end of a pre-determined Float time, the Float charge is discontinued until the battery once again self-discharges to the ***Re-Float*** voltage and the Float charge stage is repeated.

The OutBack charge controller functions similar to the inverter charger in that it has a Bulk/Absorb cycle as well as a Float stage. The charge controller enters a Bulk stage each morning when the solar energy hits the PV array strong enough to "wake" the charge controller. The Bulk/Absorb cycle ends when the ***Absorb*** voltage is met and the Absorb timer zeroes out. Unlike the inverter charger, the charge controller does not go "silent" after the Absorb stage, but drops the output to the Float voltage level. It's presumed if there is PV power available, then it should be utilized for battery charging, load consumption, selling excess power to the grid, or any combination thereof. There is no charge controller ***Re-Float*** setting since it will always be converting and regulating PV power as long as solar energy is present, unless the batteries are full and there is no AC load demand, in which case it would go silent.

For a renewable energy system using both inverters and charge controllers, it is usually preferred to have the charge controller with priority for charging to save costs over charging from the grid or a generator. This can be accomplished by setting the charge controller battery charging slightly higher than the inverter charger settings. The steps for accomplishing this and other charging optimizations are listed below.

OutBack Inverter and Charge Controller Charging Setup Procedure

1. Enter the inverter charger settings using the MATE3
    a. Press the LOCK key and enter the **141** password.
    b. Press the ***Settings*** selection from the ***Main Menu***
    c. Scroll to and select ***Inverter***
    d. Scroll to and select ***Battery Charger*** and enter the ***Absorb*** and ***Float*** charging settings listed in Table 1 for the appropriate RE, GH or NC battery type.
2. Enter the Charge Controller charger settings using the MATE3
    a. Press the LOCK key and enter the **141** password.
    b. Press the ***Settings*** selection from the ***Main Menu***
    c. Scroll to and select ***Charge Controller***
    d. Scroll to and select ***Charger*** and enter the ***Absorb*** and ***Float*** charging settings listed in Table 1 for the appropriate RE, NC, GH, OPzV or FLA battery type. Set the ***Absorb*** and ***Float*** voltages 0.4 higher (0.2 for 24 Vdc systems) than the inverter settings to give priority charging to the charge controller.

Table 2 - OutBack Inverter and Charge Controller Settings

Battery Type	***Absorb Volts***	***Absorb Time***	***Float Volts***	***Float Time***	***Re-Bulk Volt***	***Re-Float Volt***
PLC 12V	14.1 (56.4) [1]	2 Hours [2]	13.5 (54.4) [1]	= ***Abs Time***	12/24/48 [3]	12.5/25/50 [3]
RE 2V	2.32 (55.6) [1]	2 Hours [2]	2.25 (54) [1]	= ***Abs Time***	12/24/48 [3]	12.5/25/50 [3]
PLR 12V	14.7 (58.8) [1]	2 Hours [2]	13.8 (55.2) [1]	= ***Abs Time***	12/24/48 [3]	12.5/25/50 [3]
NC 12V	14.4 (57.6) [1]	2 Hours [2]	13.6 (54.4) [1]	= ***Abs Time***	12/24/48 [3]	12.5/25/50 [3]
OPzV 2V	2.45 [4] (58.8)	2 Hours [5]	2.35 [4] (56.4)	= ***Abs Time***	12/24/48 [3]	12.5/25/50 [3]
FLA 6V / 2V	7.26 / 2.42 (58)	2 hours [2]	6.75 / 2.25 (54)	= ***Abs Time***	12/24/48 [3]	12.5/25/50 [3]
Batteries Supported But No Longer Available						
RE 12V	14.4 (57.6) [1]	2 Hours [2]	13.6 (54.4) [1]	= ***Abs Time***	12/24/48 [3]	12.5/25/50 [3]
GH 12V	14.4 (57.6) [1]	2 Hours [2]	13.6 (54.4) [1]	= ***Abs Time***	12/24/48 [3]	12.5/25/50 [3]

[1] If using both inverter and charger controller, set the charge controller 0.4 volts higher (0.2 for 24 Vdc systems) to give the charge controller charging priority.
[2] Will always be 2 hours if charge rate is 10 percent of battery bank amp-hours. For higher or lower charge rates, use the formula AR ÷ ½ of charge amps = Absorb time, where AR = amp-hours remaining after Absorb voltage is first reached (100% - RT Efficiency x Battery Bank Ah).
[3] Default values for 12/24/48 volt systems. May need to be adjusted for site application.
[4] For operating temperature of 15 to 35°C. See owner's manual for other temperature ranges.
[5] Two hours maximum per day

3. Inverter Settings for Inverter Operating Modes
    i. Press the LOCK key and enter the **141** password.
    ii. Press the ***Settings*** selection from the ***Main Menu***
    iii. Scroll to and select Inverter
    iv. Scroll to and select ***Grid AC Input Mode and Limit***
    v. Set the ***Input Mode*** for desired Offset Mode
        1. Grid Connected Offset (AC "blending") modes: ***Grid Tied***, ***Grid Zero***, ***Support*** or ***Mini Grid***
        2. Off-Grid modes: ***Backup*** or ***Generator***

        NOTE: more info on AC input modes can be found in the Radian and FXR Operator Manuals and the Offset and AC Input Modes application notes on www.outbackpower.com

4. ***AC Input Charger Limit***: An ideal charging current is around 10-13 percent of the Ah rating of the battery bank, but in some cases this may take longer than desired so a charging current up to the maximum allowed may be used instead. The OutBack inverter charger current limit setting is made from the AC input side of the charger, not the DC side of the charger, so the AC charging current must be calculated then entered as the charger limit setting.
    a. First, a conversion of DC charge current to DC watts is made (AC and DC watts are the same), then charger efficiency applied, then conversion of AC watts to AC current. Using a DC charge current of 40 amps as an example, multiply 40A x 48 Vdc = 1920 Wdc ÷ 0.85 efficiency = 2258 Wac ÷ 240 Vac (120 Vac for 120V inverter) = 9.4 Aac. Only whole numbers can be entered so round up or down.
    b. Enter the inverter charger settings using the MATE3
        i. Press the LOCK key and enter the **141** password.
        ii. Press the ***Settings*** selection from the ***Main Menu***
        iii. Scroll to and select Inverter
        iv. Scroll to and select ***AC Input and Current Limit***
        v. Scroll to ***Charger AC Limit*** and enter the setting

5. 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 MATE3 using the following steps.
        i. Press the LOCK key and enter the **141** password.
        ii. Press the ***Settings*** selection from the ***Main Menu***
        iii. Scroll to and select ***Charge Controller***
        iv. Scroll to and select ***Charger***
        v. Scroll to ***Current Limit*** and enter the setting, ***Leave Absorb End Amps***, at 0
    b. Global Charge Control (GCC) is a MATE3 function that limits the total charge controller current to prevent overcharging of the batteries. For example, if the max charging current for a battery bank is 100A, then max current setting for GCC is also set to 100A. If the inverter is contributing 50A, then the GCC function in the MATE3 will then limit the total charge controller output to 50A so the total net current to the batteries will be 100A.

        It's important to note that GCC does not regulate or affect inverter charging at all, it just factors the inverter current into the equation for total net current to the battery bank.

        Also important: The GCC uses the charge controller's Grid Tied function to implement the global current control. Therefore, GCC can only be used for Off-Grid applications. Use the following steps to program the MATE3 for Global Charge Control.

i. Press the LOCK key and enter the **141** password.
ii. Press the ***Settings*** selection from the ***Main Menu***
iii. Scroll to and select ***MATE3***
iv. Scroll to and select ***Global Charger Output Control***
v. Change the ***Enable*** setting to ***Y***(es), and enter the desired maximum charge amps.

OutBack FLEXnet DC Setup Procedure

1. The FLEXnet DC (FN-DC) Battery Setup. The FN-DC provides three main functions; data logging of shunt information including daily kWh, Charge Termination Control and State of Charge (SoC). Charge Termination Control will terminate charging from all OutBack chargers when the Battery Setup settings of ***Charged Voltage*** and ***Time*** plus the ***Charged Return Amps*** that was discussed earlier, are all met. Meeting the Charge Parameters is an indication the battery is full and charging should stop. This can save wear and tear on the batteries if for some reason multiple Absorb cycles are initiated with minimal discharge of the batteries. In this case, the Charge Parameters will most likely be met quicker than the ***Absorb*** time and can terminate the Absorb stage so the batteries don't get overcharged. Meeting Charge Parameters will also set SoC to 100 percent. The ***Charged Voltage*** setting is typically 0.2V lower than the lowest charger Absorb voltage setting to ensure the parameter is met in case there is a discrepancy between the charging device voltmeter and the FN-DC voltmeter. The time setting is typically about 3-10 minutes depending on the battery. ***Return Amps*** is typically 2-3 percent of the battery bank amp-hours, but should be set closer to 3 percent to ensure the charge parameters are met.

   An FN-DC battery function that measures amps in and out of the battery to determine SoC uses the battery bank amp-hours setting and the ***Battery Charge Factor*** (BCF) to determine when the battery bank is full. For example, if the batteries are 90 percent efficient then it would take 100 amps plus another ten percent (10 amps) to fully recharge a 200 Ah battery bank that had been discharged 50 percent. So in this case, the FN-DC would measure 100A on the discharge then 110A on the recharge before indicating the batteries are 100 percent SoC. More information can be found in the FN-DC manual on the OutBack website, as well as an FN-DC application note in the *App Notes* section of the website.

2. The steps for entering FN-DC Battery Setup settings in the MATE3 are show below.
   a. Press the LOCK key and enter the **141** password.
   b. Press the ***Settings*** selection from the ***Main Menu***
   c. Scroll to and select ***Battery Monitor***, then select ***Battery Setup***
   d. Enter the TOTAL battery bank amp-hours in the ***Battery Ah*** field.
   e. Enter the ***Charged Voltage*** 0.2 Vdc lower than the lowest ***Absorb*** volts setting.
   f. Enter the time to about 3-10 minutes.

3. Enter the ***Charge Factor*** as the battery efficiency. This will be 90% for all OutBack AGM batteries except for the NC batteries which should be entered as 95%.

   NOTE: ***Charge Termination Control*** is enabled by default under the MATE3 FN-DC Advanced Control settings. There is no need to change the setting unless there is a need for it to be disabled.

4. If the Grid Tied function is being used to sell back to the grid, it's possible the battery bank may never see an Absorb stage completed due to the ***Sell RE*** setpoint never being exceeded when the charge controller is on during the day. So for applications utilizing offset and the Sell RE setpoint, there is a function under the MATE3 ***FN-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 Absorb stage if necessary.

Battery Commissioning

1. Always measure and record each cell or battery voltage in each string of the battery bank, or take specific gravity readings for FLA batteries. One or more batteries that are significantly lower than the others could indicate a defect battery. See the appropriate battery manual for acceptable levels.
2. The voltages measured in step 1 above will determine whether to apply a normal bulk charge to commission the battery bank, or whether a freshening or equalization charge should be applied to the battery bank for its initial charge. Consult the appropriate battery manual for specific initial charging instructions based on the battery voltages, or specific gravity measurements for FLA batteries.
3. After the initial charge cycle has been completed, it is suggested to load the battery bank with all the site loads turned on. Then monitor for voltage drops across the batteries, as well as even battery voltages and string currents during discharge. If there are bad cabling or bus bar connections, they will show as excessive voltage drops across connecting cables and bus bars. If one of the new batteries is defective, then it will show as a significantly lower voltage than others in the string, and a warranty claim should be filed as soon as possible.

Tips and Precautions

- **How To Avoid Problems With SoC Readings**
  Sequential partial charge cycles can lead to erroneous SoC readings since the amps out/amps in counter along with the battery charge factor is only applied when 100 percent SoC is reached. The best way to see if the SoC reading is off is to compare the battery bank voltage with the 100 percent SoC reading being displayed. A healthy 48-volt battery bank will read over 51 Vdc at rest (open circuit) when new and fully charged. If the battery bank is over 51 Vdc and the SoC reading is less than 100% (99% is acceptable as it doesn't actually go to 100% until the batteries start to discharge), then cycle the FN-DC power by unplugging the FN-DC cable from the OutBack HUB, wait 20-30 seconds then plug it back in again. If the battery bank is less than 51 Vdc, then charge the battery to greater than 51 Vdc (at rest and not rapidly discharging from the charge voltage) before cycling the power. This will reset the SoC reading to 100 percent.

  Both the amps out/amps in counter and the Charge Parameters Met function will reset the SoC reading to 100 percent. The ***Days Since Charge Parameters Met*** reading can be viewed to check how long it has been since Charge Parameters have been met. This reading can be found under the <**Battery Monitor**> soft key menu on the MATE3. Press the soft key under the battery icon on the MATE3 home display (2nd key from left under the display). Then press the <**Next**> soft key and ***Days Since Parameters Met*** is displayed at the bottom of the screen.

- **AC Coupling Applications**
  Many AC Coupling applications are Float applications where a battery based inverter has been added to an existing grid-tied inverter (GTI) to provide backup power during a power outage. The PLR batteries are best for this Float application, but some site owners employ AC coupling on a daily basis in either an off-grid application or some kind of ancillary utility service like peak shaving or going off-grid during high time of use charges. For these cycling applications, the PLC, RE, NC or OPzV batteries would be best. However, be aware that any battery in an AC coupling application will be receiving an unregulated charge when AC coupled and not grid connected, which is very hard on the batteries and will shorten the battery life.

- **Temperature Corrected Charging**
  Like many chemical reactions, temperature is also factor in lead-acid battery charging. At temperatures below 25C, the charging voltage is increased to overcome a less active chemical reaction at the lower temperatures. At temperatures above 25C, the voltage is reduced to prevent overcharging and permanent damage to the battery. OutBack supplies a remote temperature sensor (RTS) with all inverters and charge controllers. The lack of an RTS installed in an OutBack system may void the battery warranty, especially when battery charging is done above 25C. Only one RTS per system is required, but the deployment of the RTS can vary depending on the both device type and combination of device. It is highly recommended to read and understand the RTS application note in the *App Notes* section of the OutBack website.

About OutBack Power Technologies

OutBack Power Technologies 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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