Application Note

# Discussion: New operating modes for the Radian Family Inverter/Chargers GridZero AC Input Mode & Advanced Battery Charge Profile Option

## Models: GS8048A, GS4048A, GS7048E, GS3548E

**Overview:** as part of OutBack Power's on-going commitment to both off-grid and "next grid" technologies and performance, the acclaimed Radian series of Grid/Hybrid inverter/chargers is being upgraded with two new operating mode innovations: GridZero and Advanced Battery Charge.

1. GridZero is designed to optimize the use of renewably generated energy, battery storage and utility power to eliminate solar variability on the grid and power the majority of loads on the premises throughout the course of a 24 hour period, while using utility power at key moments to allow the system the ability to operate loads that would otherwise overload or overwhelm the system. Two different regional examples are discussed in this application note.

2. Advance Battery Charge is a profile option to support leading-edge battery technologies such as Lithium-Ion and others, and offers enhanced diagnostics for improved performance.

## GridZero

**GridZero benefits:** As part of the advance programming in the Grid/Hybrid performance of the Radian inverter line, GridZero is the newest of the seven AC Input Mode selections available on the Radian inverter/charger. GridZero helps a PV/solar or other renewable system owner maximize the portion of their energy consumption met by the renewable source, while minimizing the portion purchased from the utility by fully utilizing energy storage. Specifically, this mode:

1. Puts battery and renewable energy to the most effective use while minimizing dependence on the grid, and without requiring a sell-back of power to the utility grid to achieve good system economics. GridZero mode allows a PV system to maximize the contribution of renewable energy to the home's energy consumption, while eliminating the effect of solar variability to the utility grid.
2. Allows a smaller inverter and battery system to perform like a much larger one, by seamlessly blending in utility power to support surges or load spikes, lowering the cost-of-entry to grid-interactive solar.
3. The inverter/charger remains connected and synchronized to the utility grid in case the grid is needed. If large loads require the use of grid power, no destabilizing transfer is required—the process is seamless.
4. Simple programming with only two setpoint adjustments needed to determine the rate, priority and amount of energy to use

**How it operates:** In GridZero mode, the Radian inverter powers the home's loads primarily from battery (and renewable) energy while remaining connected to an AC source. Using the DC sources, the inverter attempts to decrease the use of the AC source to zero. The inverter only draws on the AC source when loads to the battery exceed the preselected values (see figure 1).

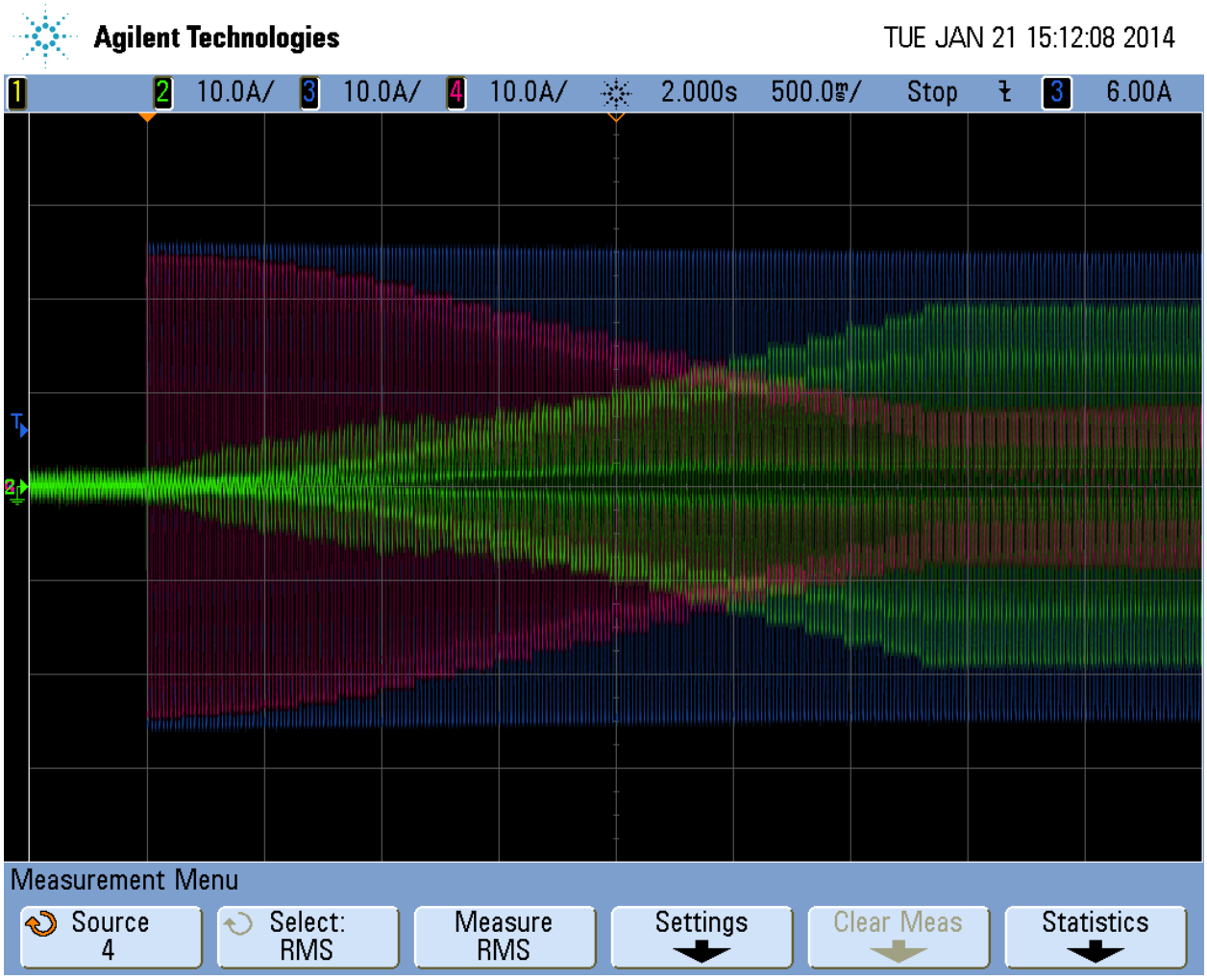


Figure 1

When the GridZero mode is selected, the renewable source and the battery bank are prioritized first to power any loads on the system. This is in contrast to the other Radian AC input modes such as Grid-tie, Backup or UPS, where utility power is typically prioritized first and battery power second.

When the loads on the system exceed the desired DoD Amps, the utility grid is used to meet the portion of the load that exceeds that setpoint. This allows a relatively small battery and inverter to serve load spikes or surges that would otherwise overwhelm or overload the system, by seamlessly blending utility power in parallel with battery power for the duration of the surge (see figure 2).

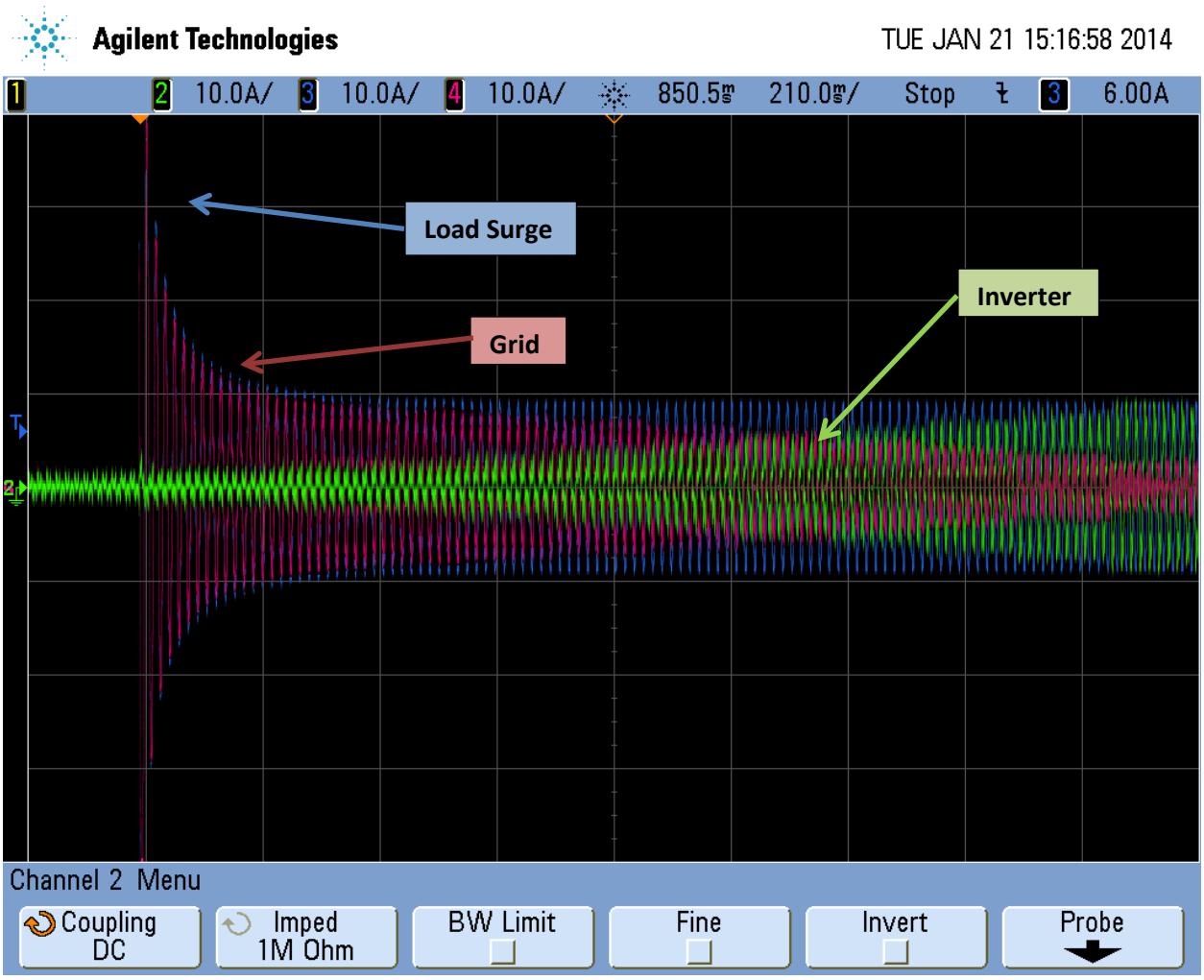


Figure 2

The mode also allows the battery to serve loads in the home throughout the evening and night by discharging to those loads, thereby reducing or eliminating the need to purchase utility power. The renewable source recharges the battery the following day. If the battery has been discharged to the DoD Volts indicating that the battery is depleted, the utility grid can be used to meet all loads until the renewable resource can fully recharge the battery.

During a typical 24-hour period, the PV generation will happen at the top of the day, and typical home usage will happen at the beginning and the end of the work day. In Grid Zero mode, the batteries are charged during the day and discharged at a user settable rate each night. Any load demand above the user setting will be provided by the grid.

| Mode operation | AC Input Mode example | | | | | | |
|---|---|---|---|---|---|---|---|
| | GridZero Mode | Grid-Tie Mode | Mini-Grid Mode | Support Mode | Generator Mode | Back Up | UPS |
| Supporting the AC Output | Yes | Yes | No | Yes | No | Yes | Yes |
| Selling to the AC Input | No | Yes | No | No | No | No | No |
| Transfer to Inverter based on battery VDC | Yes | No | Yes | No | No | No | No |
| Priority to Battery/DC Sources | Yes | No | Yes | No | No | No | No |
| Charge from Low Quality AC Input Waveform | No | No | No | No | Yes | No | No |

In order to comply, operationally the inverter/charger must meet these criteria:

1. Be grid connected but not sell power back to the grid.
2. Power the majority of the loads from the battery, with loads above a certain threshold supported by the utility grid.
3. Be capable of cycling the battery to power the loads.
4. Use PV-generated electricity to recharge the battery, and prevent charging the battery with grid power.
5. Assign system priority to PV/solar (see red area in the figure _ below).

**Examples of GridZero applications**

**Example #1:** European example: In many European countries, the past rapid adoption of PV was driven by high Feed-in Tariff (FiT) programs that incentivize solar by paying a premium for renewably generated energy. With FiT rates now well below the retail cost of electricity in most regions, these markets have changed to an increasing focus on "Self Consumption" programs which attempt to increase the consumption of self-generated renewable energy while reducing the portion of energy required by the home that is purchased from the utility at high rates. In addition, in some countries or regions there is a barrier to exporting excess renewable energy to the grid. A battery-based PV system can be a key element to meeting this requirement; however, the size of investment for a full system has slowed adoption of additional renewable energy systems. The GridZero mode provides a lower cost of entry into a residential renewable system because designers and installers can specify a smaller inverter/charger and battery while delivering large-system performance and advantages.

**Example #2:** North American example 1: In Hawaii, residents are investing their own money to save on long-term electricity costs and for the benefit of the environment. The result is a surplus of solar energy beyond what they can use in their homes. In the past, this extra energy would be exported back into the power grid to reduce the local utility's consumption of oil used in the generation of electricity and the resulting greenhouse gases that contribute to global warming. However, many of Hawaii's electrical utilities have cited an abundance of solar-generated electricity, which if sold back to the grid, could actually destabilize it and threaten system reliability. Therefore, utilities have begun to limit the availability of homes and businesses to interconnect and export, as well as requiring additional studies on whether grid upgrades are necessary and, if they are, are asking residents adding solar to pay for them. In this business environment, the uncertainty facing contractors and residents to connect most small rooftop systems to the utility grid is considerable, and implementing systems using

conventional grid-tie technology is becoming economically unfeasible. (1) GridZero provides a tool to let homeowners fully utilize the benefits of solar while remaining connected to the grid, at the same time eliminating any potentially destabilizing solar variability from the grid.

**Example #3:** California has established a statewide goal of reducing or eliminating greenhouse gas emissions, and they are achieving this by increasing the portion of consumed energy generated by renewables, while implementing zero-emissions load balancing to manage variability on the grid. In ***Grid Zero*** mode, the Radian inverter powers the home from battery while remaining connected to the grid. Using energy stored in the battery, the inverter attempts to decrease the use of the AC source to zero. The inverter only draws on the utility grid when no other energy is available. The PV recharges the battery whenever the sun shines. With Grid Zero never selling to the Grid, this mode answers utility concerns about both renewable energy generation and grid stability.

In all scenarios, since GridZero does not put PV power back onto the grid but stores it for future use and prioritizes self-consumption, it resolves the utility's concern about excessive production on high-penetration circuits while allowing the utility to maintain the customer relationship. The consumers can reap the benefits of self-consumption of PV energy while only using the grid to support surges, spikes, or their own demand during times of high usage.

**Accessing GridZero mode in a Radian system using a MATE3**

GridZero must be enabled using the MATE3 system display, and two parameters are adjusted by the installer or system operator to dictate how the Radian inverter/charger selects the priority of energy to use (see figure 3 below). The two parameters, which are adjustable in GridZero operation, are:

- DoD Volts or battery depth of discharge DC voltage limit
  - 48Vdc default, 0.4 increments – range is 44-64VDC
- DoD Amps, or load AC discharge rate limit.
  - 5aac – 1amp increments – range is 1- 30

In the MATE3 system display, the selectable options are ***DoD Volts*** and ***DoD Amps***. Any time the batteries exceed the ***DoD Volts*** setting, 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. It will maintain the batteries at this setting.

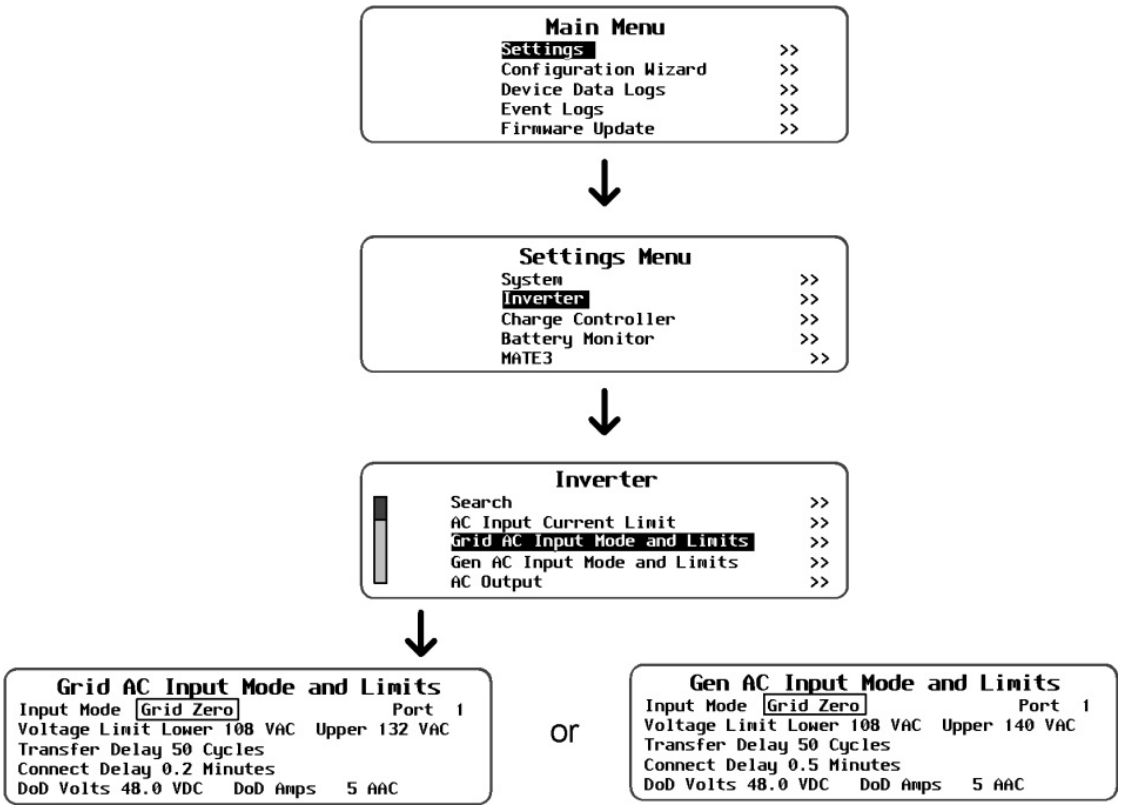


Figure 3 – GridZero Mode MATE3 System Set-up

The Radian inverter can manage large quantities of power. To prevent damage to the batteries from rapid discharge, the rate of discharge can be limited using the ***DoD Amps*** setting. This item should be set lower than the amperage provided by the renewable source.

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 of a reserve in the event of a grid failure. 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

The batteries should not be completely discharged, and must maintain some capacity to support the loads in case of grid failure. The exact voltage and percentage will vary with battery type and size. The renewable energy source must exceed the size of the loads. The renewable source will charge the batteries after this mode discharges them.

The inverter's battery charger does not function in ***GridZero*** mode.

Considerations:

- If the renewable energy source is not greater than the size of the inverter loads, this mode cannot be used correctly. The renewable source must be capable of charging the batteries as well as running the loads. This occurs when renewable energy production exceeds the ***DoD Amps*** setting.
- The inverter's battery charger cannot be used in this mode. However, the charger menu settings and timer operations are not changed when this mode is selected.

- The battery will discharge whenever possible in the attempt to "zero" grid usage. If the ***DoD Amps*** setting is limited or loads are not present, the batteries will be unable to accept much renewable recharging the next time it is available. The renewable energy will be wasted, leaving the system dependent on the utility grid more than necessary.

## Advanced Battery Charge

**Advanced Battery Charge:** with energy storage and battery back-up functionality at the center of every OutBack system, it is vital that next-grid designs are able to leverage both existing and newer storage technologies in order to be truly future-ready. OutBack Power's experience in emerging battery technologies for selected industrial partners and applications is the foundation for a broader implementation in next-generation residential and commercial systems using lithium-ion, aqueous-ion, flow and other storage chemistries. Industry sources project that as application volumes increase, lithium-ion batteries will experience the most dramatic cost declines and represent a significant portion of the emerging energy storage market. IHS Inc. states that the global PV/solar energy storage market will reach nearly $30 billion in the next three years with about two-thirds of that grid-connected, and costs to decline by 40% or more over that same time period, making widespread new technology implementation an inevitability.[5] The new Radians are ready for the energy storage future, with new voltage and time limits expanded.

- Extended charge stage operational ranges of 44 - 64VDC
- The ability to extend any charge stage to operate continuously
- The ability to disable any charge profile completely

Lithium-ion, sodium-sulfur, and similar advanced battery technologies may require charger settings that are very different from the typical defaults required by traditional lead acid batteries or a three-stage cycle in general. The advanced battery charge capability of the Radian system allows the installer to coordinate the specific charging profiles required by each given battery technology. All charger settings are adjustable throughout the full range, and charging stages and timers can be either eliminated or extended indefinitely (see figure 4). For example: typical Li-ion chargers are voltage-limiting devices, with the battery being similar to lead acid system but with a higher voltage per cell, tighter voltage tolerance and the absence of float charge at full charge. The Radian Advanced Battery Charging is a voltage limited current source.

See the battery manufacturer settings for the recommended settings for your application.

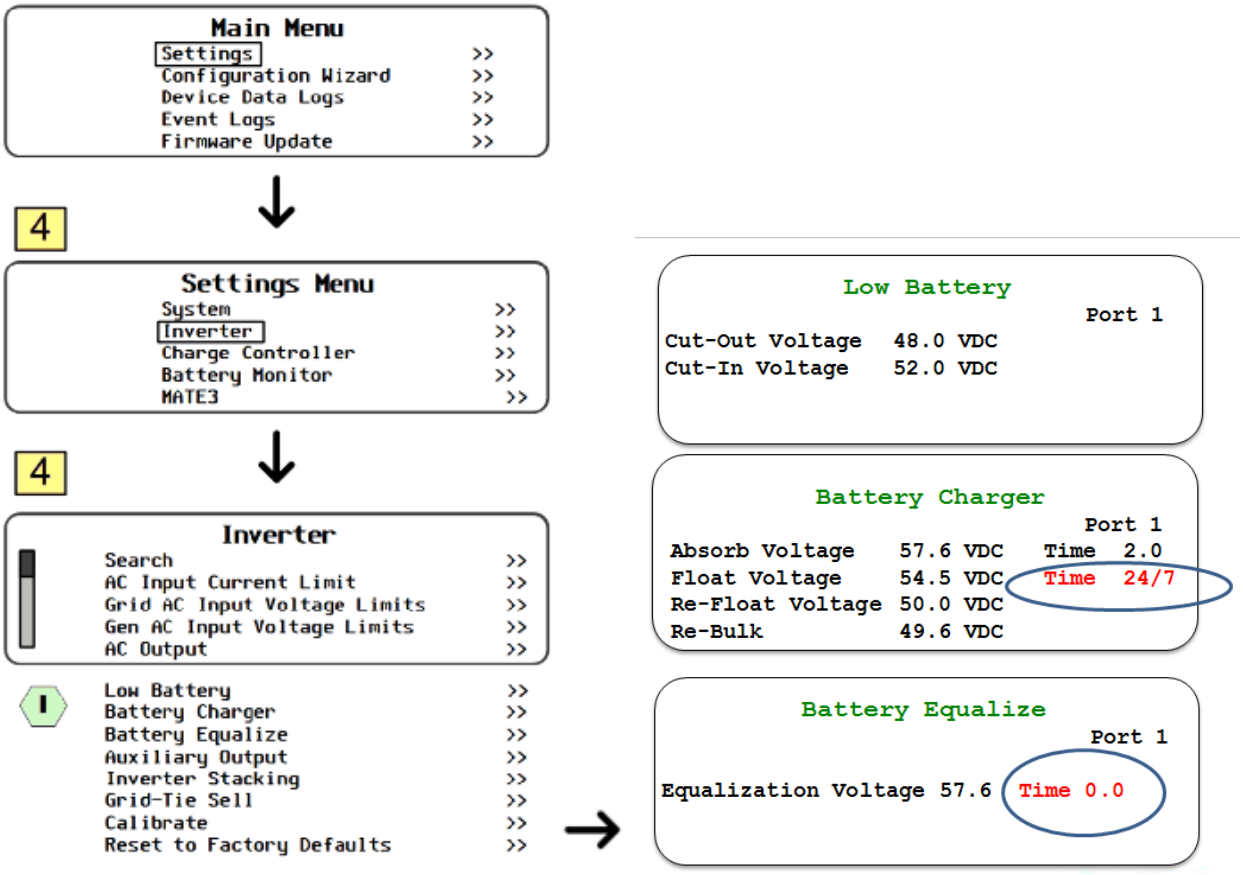


Figure 4 – Advanced Battery Charging (ABC) MATE3 System Set-up

Summary of OutBack Radian inverter/charger operating modes

| AC Input Mode | Description | Use scenario |
|---|---|---|
| **Mini Grid** | Where renewable and battery sources are the primary source of electricity, this mode enables the system to operate off-grid the majority of the time and switch-over to grid-connected when conditions warrant it. | Ideal for sites where sufficient renewable energy enables mostly off-grid operation. |
| **Grid tied** | Uses power from both renewable sources and the utility grid for running loads and charging batteries; any excess energy can be sold back to the grid. | Systems in regions with FiT (feed-in-tarrif), net-metering, or other incentive programs. The larger the renewable energy system, the greater the benefit. |

| | | |
|---|---|---|
| **GridZero** | Draws on grid electricity only when needed to supplement renewable and stored energy sources, such as when load requirements exceed the capacity of those sources. Enables a smaller renewable system to perform like a larger one by blending-in utility power only when needed, reducing grid-dependency. | Ideal for use in areas where policies, incentives and regulations are subject to change and utility sell-back options may be becoming more limited. |
| **Support** | Augments a limited AC source, such as a generator or weak grid, by adding battery power when needed to prevent load demand from overloading the available energy supply. | Ideal for sites with small generators or inadequate grid power. |
| **Backup** | Where the main application is providing power in the event of grid failure. OutBack inverter technology protects and manages expensive battery banks with features such as monitoring and adjustable battery temperature compensation. | Ideal for systems in applications where computers and other sensitive loads or site-specific equipment are present. |
| **UPS** | An immediate back-up mode when staying powered is essential and ultra-fast response time in switching to battery back-up is critical. | Ideal for commercial applications where uninterrupted power is mission-critical. |
| **Generator** | Allows a wider use of less-than-optimum AC sources, such as a noisy utility grid or generator, and reduces intermittency or shut-down under that condition. Ensures stable, dependable operation regardless of local power quality. | Ideal for using a generator even when that generator is undersized or has power-quality issues. |

Figure 5 - Radian Series Inverter/Charger Operating Modes

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(1) Sources: http://truth-out.org/buzzflash/commentary/item/18389-booming-solar-energy-halted-by-hawaii-utility-because-it-produces-too-much-power

(2) http://www.scientificamerican.com/article.cfm?id=a-solar-boom-so-successfull-its-been-halted&page=2

(3) http://www.pv-magazine.com/news/details/beitrag/californian-utilities-hit-out-against-battery-stored-solar-power_100012982/#axzz2oigmF9NP

(4) http://www.renewableenergyworld.com/rea/news/article/2013/08/solar-battery-backup-under-attack-in-california

(5) The Potential for Energy Storage in the PV Industry, June 17, 2013, IHS Inc./IMS Research. Report in conjunction with InterSolar Europe

(6) http://batteryuniversity.com/learn/article/charging_lithium_ion_batteries