

# How To AC Couple Grid Tied Inverters with OutBack Frequency Shifting Inverters

This application note will explain how to AC couple a Grid Tied Inverter (GTI) to an OutBack inverter. When there is a grid outage, this method employs a frequency shifting technique to prevent the GTI from overcharging the battery bank during times when the GTI is putting out more power than can be consumed by the loads. The excess power from the GTI can harm the battery bank in the form of an unregulated charge exceeding safe charging limits of the batteries. When safe charging limits are exceeded, the OutBack inverter will shift the frequency upwards from 60 Hz to as much as 64.5 Hz to make the GTI incrementally reduce its output (Freq/Watt compliant inverters) or disconnect itself from the AC coupled circuit (any IEEE 1547-compliant inverter).

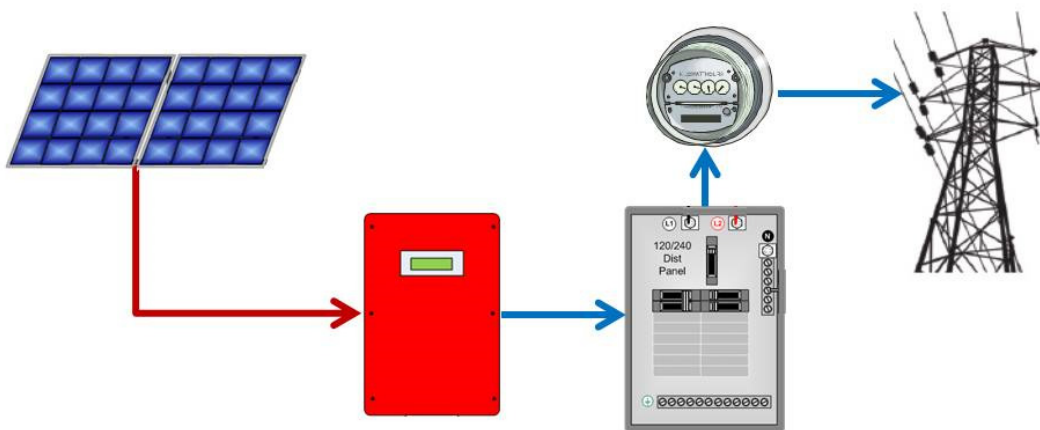
## Introduction

The frequency shifting technique to safeguard overcharging of the battery bank not only curtails the GTI when the active battery charging set point is exceeded, but also when the AC Charger limit is surpassed. Additionally, the step rate of the frequency shift is user adjustable from 0.02 to 5.00 seconds to allow better optimization of system performance. While overall AC coupling performance is highly dependent on the ratio of GTI current to load current, OutBack’s implementation of voltage and current regulation with adjustable slew rate will result in the highest performing AC coupled system, especially in the case of an Freq/Watt compliant GTI that responds to closed loop control.

OutBack’s Frequency Shift AC Coupling is only employed in the Radian GS(A) class inverter at this time. It requires a firmware upgrade on both the Radian inverter and MATE3s system display and controller. The firmware is only available by download on the OutBack Power website. See the release notes for the latest update on regulatory compliance and other product information affected by this update.

## Theory of Operation – Live Grid

Figure 1 shows the current path for a normal Grid Tied Inverter from the PV solar panels through the inverter, to the main service panel and on out to the grid. In a normal GTI application, power produced from the PV array is consumed by loads connected to the main service panel with excess power going out to the grid. However, with grid loss the GTI has no way to synchronize itself to the grid – a requirement for operation – so it shuts down and is unable to use any potential energy from the PV array.

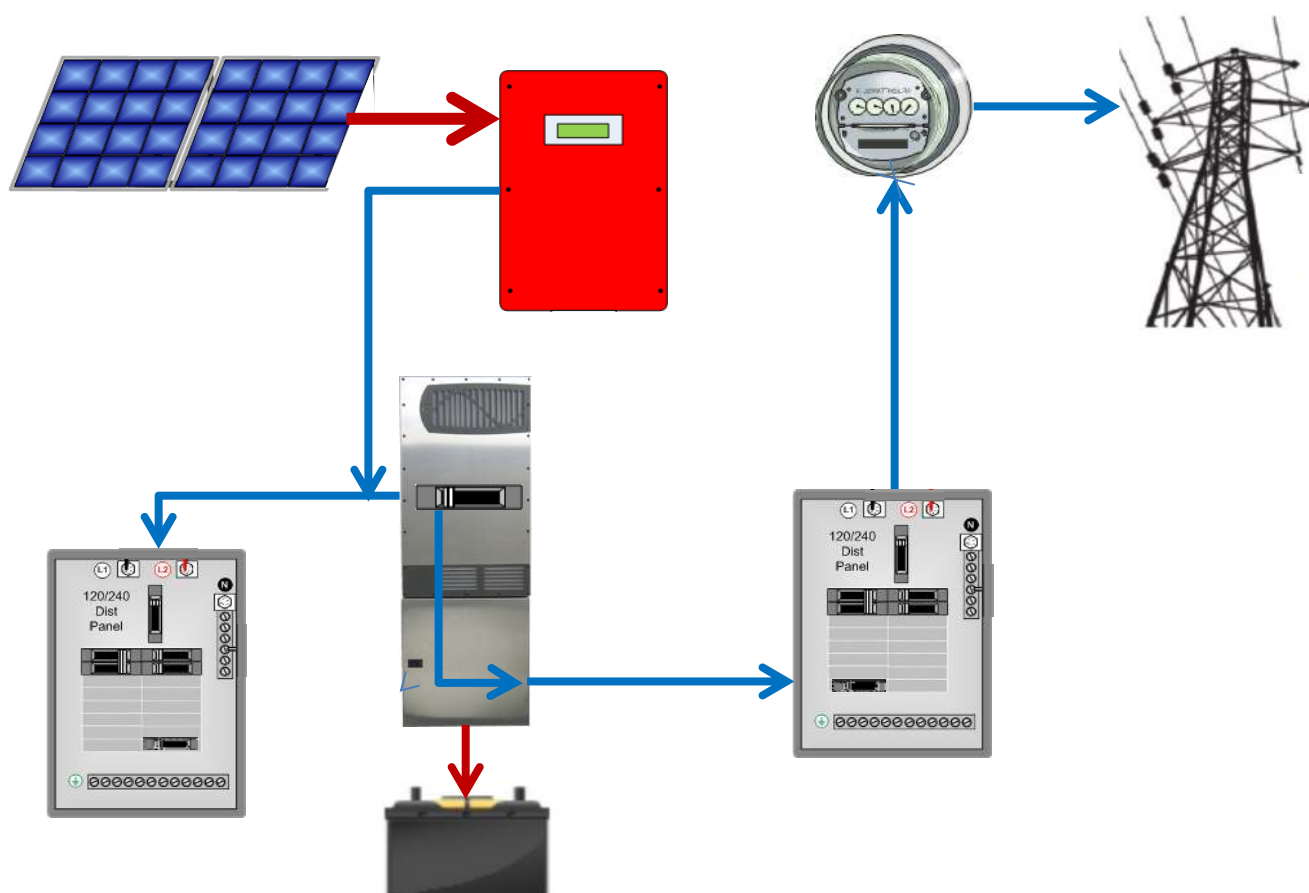


**Figure 1 Normal GTI Power Flow**

## Application Note

By connecting (coupling) the output of the GTI to the output of a storage based inverter (SBI), the SBI can act like a grid source that the GTI can synchronize to and process power from the PV array to a backup load panel. The backup load panel is required so loads can be powered from either or both inverters without backfeeding the main service panel during a grid outage (see next section on Grid Outage operation). Figure 2 shows the new current paths from the PV array which now includes the backup load panel, the battery bank, as well as main service panel loads before continuing on out to the power grid if any excess PV power has been produced.

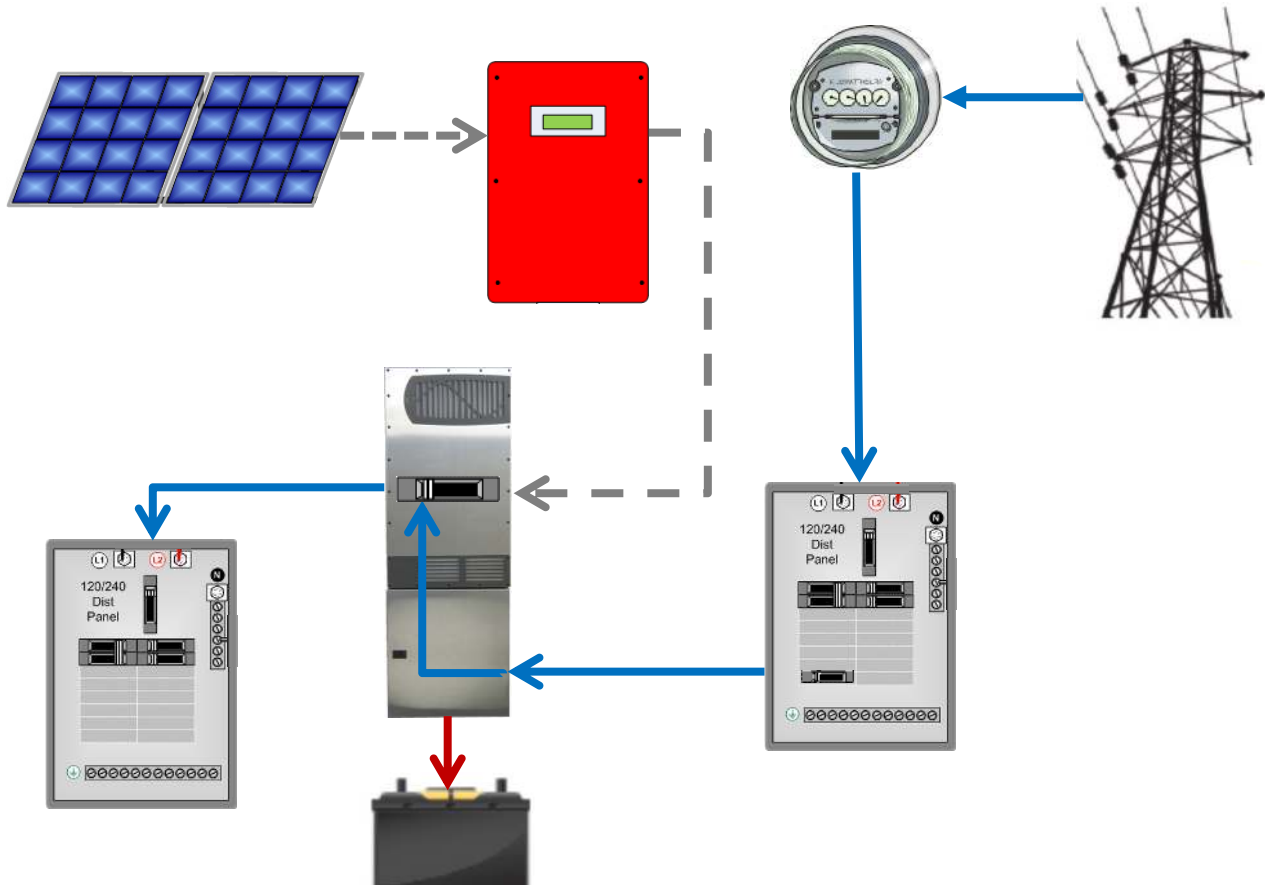
The SBI, in this case the OutBack Radian inverter, will only allow current to pass to the main service panel and out to the grid in its **Grid Tied** input mode. No other Radian input modes will be allowed to synchronize and connect to the grid when the **AC Coupling** function has been selected in the MATE3s system display and controller.



**Figure 2 GTI Power Flow with Active PV**

## Application Note

In addition to exporting GTI current out to the main service panel, a separate parallel current path to charge the battery bank from solar can exist if either the **Refloat** or **Rebulk** charging targets are reached. However, with a live grid and no PV available, the backup load panel and battery charging (if needed) will be powered from the grid as shown in Figure 3.



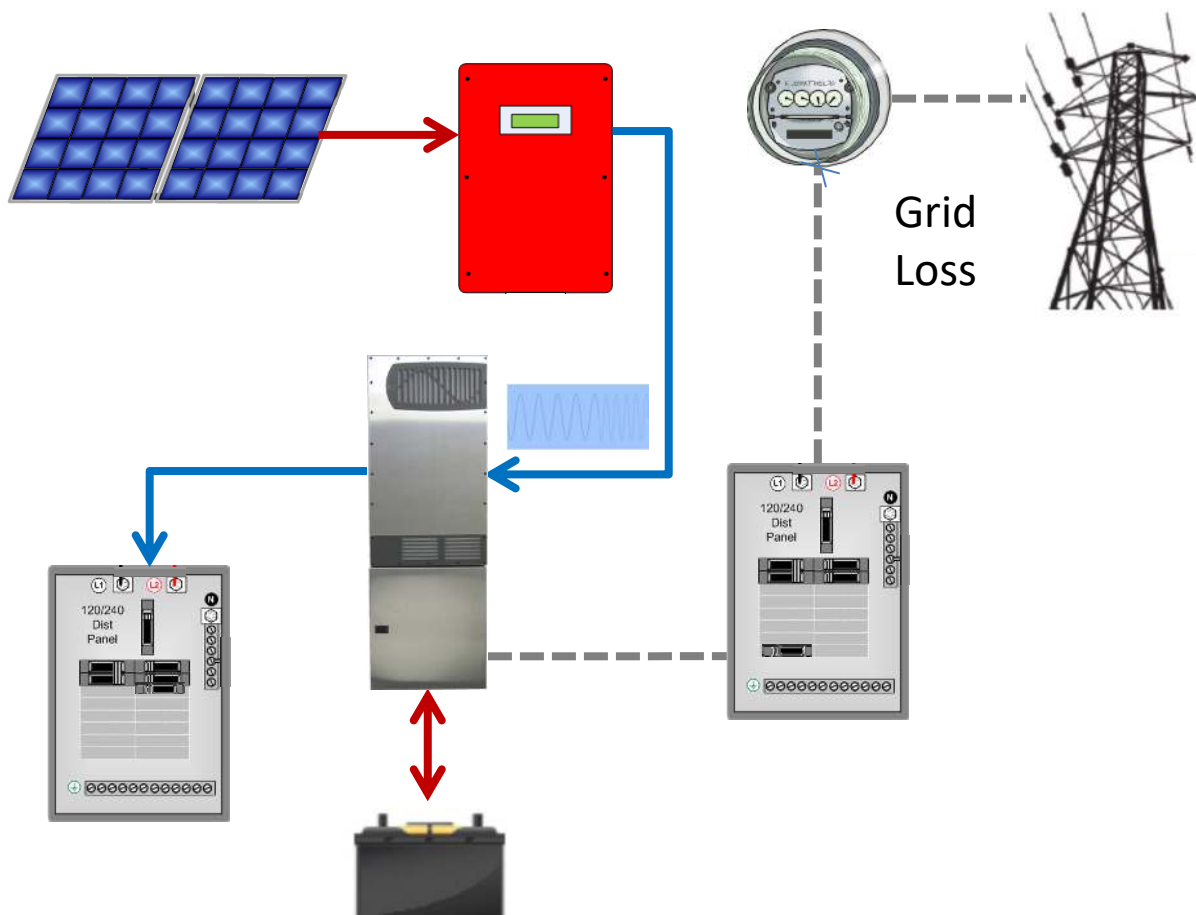
**Figure 3 GTI Power Flow without PV**

## Application Note

### Theory of Operation – With Grid Outage

During a grid outage when the sun is shining, the Radian inverter becomes an AC source to which the GTI can synchronize. This allows the PV power to flow to the backup panel's connected loads, as well as charge the batteries if the GTI is generating more power than can be absorbed by the loads.

Figure 4 shows all possible current flows, the paths of which can change depending on several different factors. If the PV generation can satisfy the backup panel and battery charging loads, then PV power flows in those two directions. If the backup panel load demand exceeds the GTI power generation, then the Radian inverter will stop charging the battery (if Absorb or Float charging is active) and invert DC power from the battery bank and contribute current to the backed up loads in parallel with the GTI.



**Figure 4 AC Coupled current flows with sufficient load demand and frequency shift curtailment**

If the batteries become fully charged and the load demand falls below the GTI power production, then the excess power from that production will flow back through the Radian inverter in an unregulated charge back onto the batteries. When the battery bank voltage raises more than 0.4V volts above the active charging voltage target then the Radian inverter begins to shift its output frequency above 60 Hz until the battery voltage starts to level or drop off, but not above 64.5 Hz. The inverter's frequency shift to a higher frequency will also be enabled if the AC charge current coming back onto the battery bank exceeds the **AC Charge Current** limit setting.

## Application Note

**Example:** There is a grid outage and the Radian becomes the new AC source for the GTI which then delivers 3400 watts to the load. The load then drops to 1,000 watts, meaning the other 2400 watts (10 Aac at 240V) will come back through the Radian inverter to the battery bank. If the 10 Aac GTI charging current is less than the AC Charging limit, then it will continue delivering charge current to the battery bank. If greater than the AC Charging limit, the Radian output frequency will start to rise until the GTI reduces its output if Freq/Watt compliant, or just go offline if non-Freq/Watt compliant. If the Radian backfeed current to the battery bank stays below the AC Charger limit, but the battery voltage eventually rises above the active voltage target (Absorb, Float or SellRE), then frequency shift will also be enabled.

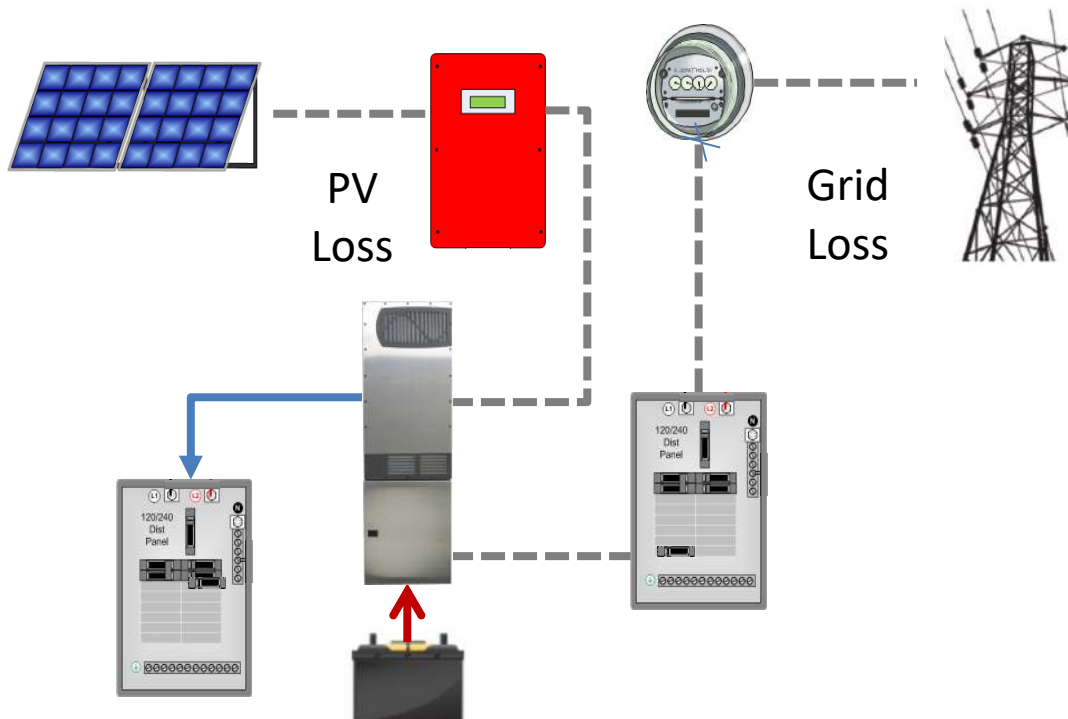
There is a significant installed base of non-Freq/Watt legacy GTIs that will just simply go off line and wait to reconnect for the time specified by the local jurisdiction (usually 5 minutes in N. America). Newer Freq/Watt compliant inverters may actually “feather” back their output to allow some degree of charging regulation to the battery bank. Depending on the difference between load demand current and GTI output current, this feathering back of the GTI output may or may not be enough to prevent the frequency shift from reaching its 64.5 Hz maximum and shut down the Freq/Watt compliant GTI as well.



### IMPORTANT:

The GTI connect time must be greater than or equal to the Radian connect time. If the GTI connect time is shorter, the battery bank is full and grid power comes back, then the Radian will try to feather back the GTI charging current with a frequency shift that will never allow the Radian to reconnect to the grid. The cycle will keep repeating until the GTI is no longer receiving power from the PV array.

Should the GTI go offline, then the Radian inverter is powering the loads as in the backup mode of operation. See Figure 5. After the reconnect time period, the GTI will try to reconnect to the Radian inverter's output voltage where the cycle would repeat again until the load or battery charging demand increases, or PV production goes down, or some combination thereof.



**Figure 5 Off-grid current flow due to PV loss or GTI power overcharging battery bank**

## Application Note

Once PV production is gone for the day, then the Radian inverter will power the loads in the backup mode until sun returns the next day, or the battery bank reaches low battery cutout (LBCO). If the battery bank reaches LBCO, then the Radian inverter can no longer power the backed up loads or be a voltage source for the GTI to start again and recharge the batteries.

To recover the batteries, either an AC generator, or a DC charging source must be connected to the battery bank in order for the system to recover, and begin AC coupling PV power through the GTI again. Use caution when connecting an AC generator; there is risk that the GTI may backfeed the AC generator and cause catastrophic failure. To avoid damaging the generator and/or voiding the GTI warranty, two possible generator solutions are discussed after the **Solution** section below.

## Solution

The Radian inverter is limited to a maximum of 25 Aac GTI load current at 240 Vac which means a 6kVA GTI is the maximum that can be connected. However, the Radian Frequency Shift solution does support stacking up to three Radian inverters in parallel.

Programming the Radian is a fairly simple task. The **Absorb**, **Float** and **SellRE**, and **AC Charger Input** settings that are used by the AC Coupling function, are programmed as explained in the Radian Operator's Manual and battery charging applications notes. The new AC Coupling function is located in the MATE3s **Inverter** menu, but is only accessible after entering the Installer password. Programming steps are described below.

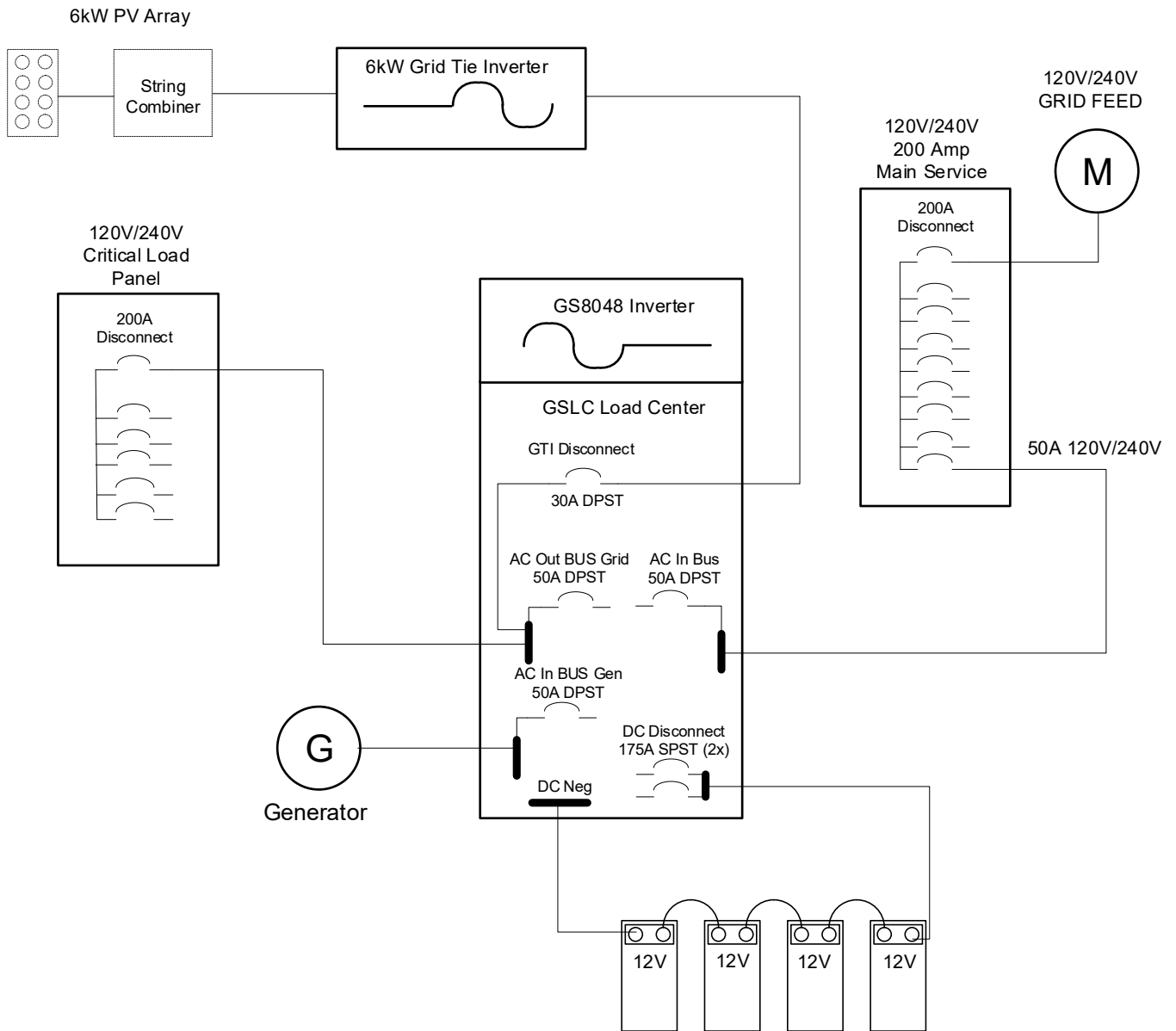


### IMPORTANT:

- ❖ Radian AC Coupling firmware version 1.6.70 must be downloaded from the OutBack website and installed.
- ❖ A MATE3s system display with firmware version 1.4.1 or newer is required for AC Coupling operation.
- ❖ Previous OutBack system display products (MATE, MATE3) cannot be used for this operation.

Setting up the AC Coupling function with the OutBack Radian inverter requires a connection between the Radian and the GTI. While the connection could be made in the Backup Load Panel, it is best to use the Radian GSLC load center so that a disconnect can be installed and easily accessed if the GTI needs to be quickly disconnected or an overload condition should arise. OutBack Power has a 30 Aac panel mount circuit breaker compatible with the GSLC that can be used as a disconnect. This connection is show below in Figure 6. Alternatively, if an over current protection device (OCPD) already exists in the output circuit of the GTI, then the GTI connection could be made directly from the GTI OCPD to the Radian AC output bus bar.

# Application Note



**Figure 6 Single line diagram of GTI inverter connection to Radian inverter**

## Application Note

### Procedure

#### Programming the MATE3s and Radian Inverter

1. Download the MATE3s and Radian AC Coupling firmware from the OutBack Power website.
2. Copy the firmware files to the SD card and install from the MATE3s **Main Menu**.
3. Enter the Installer password.
4. Select **Settings** from the MATE3s **Main Menu**.
5. Select **Inverter** menu and scroll down to the **AC Coupling** settings.
6. Change **AC Coupling** from **N** to **Y**, and change the **Freq Shift Response Time** (0.02 to 5.0 seconds) if desired. This setting adds/subtracts delay in the frequency steps between 60.0 and 64.5 Hz.
7. Press the **UP** key to move back to the **Inverter** menu and program the Absorb and Float charger settings according to the battery manufacturer's specifications.
8. Move to the **Grid Tied** settings in the **Inverter** menu if the **SellIRE** setting is to be changed from its default setting of 52.0 volts. **NOTE:** the **SellIRE** setting does not affect the exporting of GTI current back to the main service panel. The GTI current moves from the AC output to the AC input through a relay so the **SellIRE** setting has no affect. However, the **SellIRE** setting becomes the active voltage target during frequency shift operation when the Absorb and Float timers have been zeroed. A higher setting from 52.0 to equal the **Float** setting may allow the GTI to operate over a wider battery voltage range when the Backup Load panel is lightly loaded. If using lead-acid batteries, most can operate safely at Float voltages for extended periods.

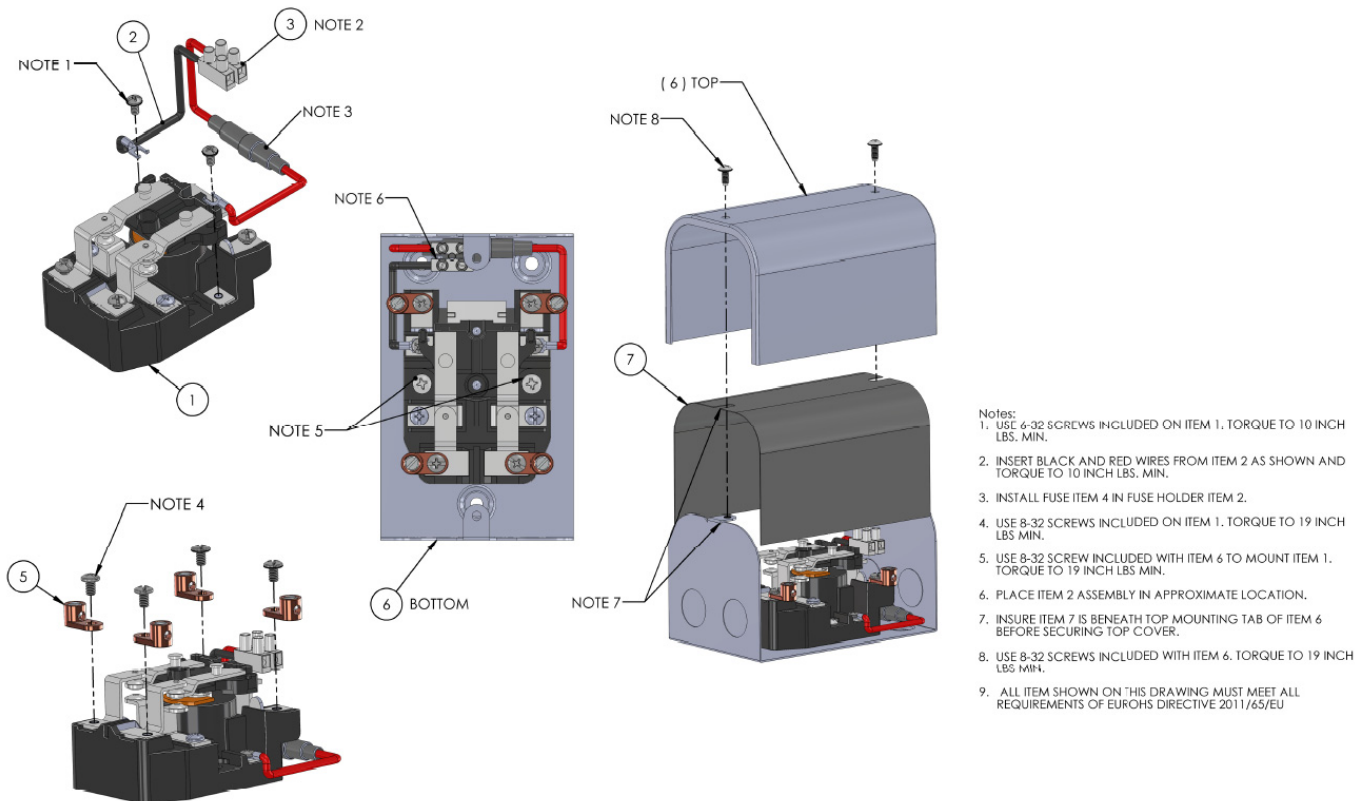


## Application Note

### Precautions Using a Generator When AC Coupling

Most residential generators, and even some commercial grade generators, are not designed to synchronize with another AC source. They may experience catastrophic failure if the other AC source is a “stiffer” source and can overpower the weaker AC coupled generator.

To prevent the backfeed from the GTI into the generator, a safety relay can be utilized that disconnects the GTI inputs from the Radian AC output bus bars when the generator is started, either using the MATE3s AGS generator start function, or some other method.



**Figure 7 GS-AC-GEN-KIT, Generator Protection Relay from OutBack**

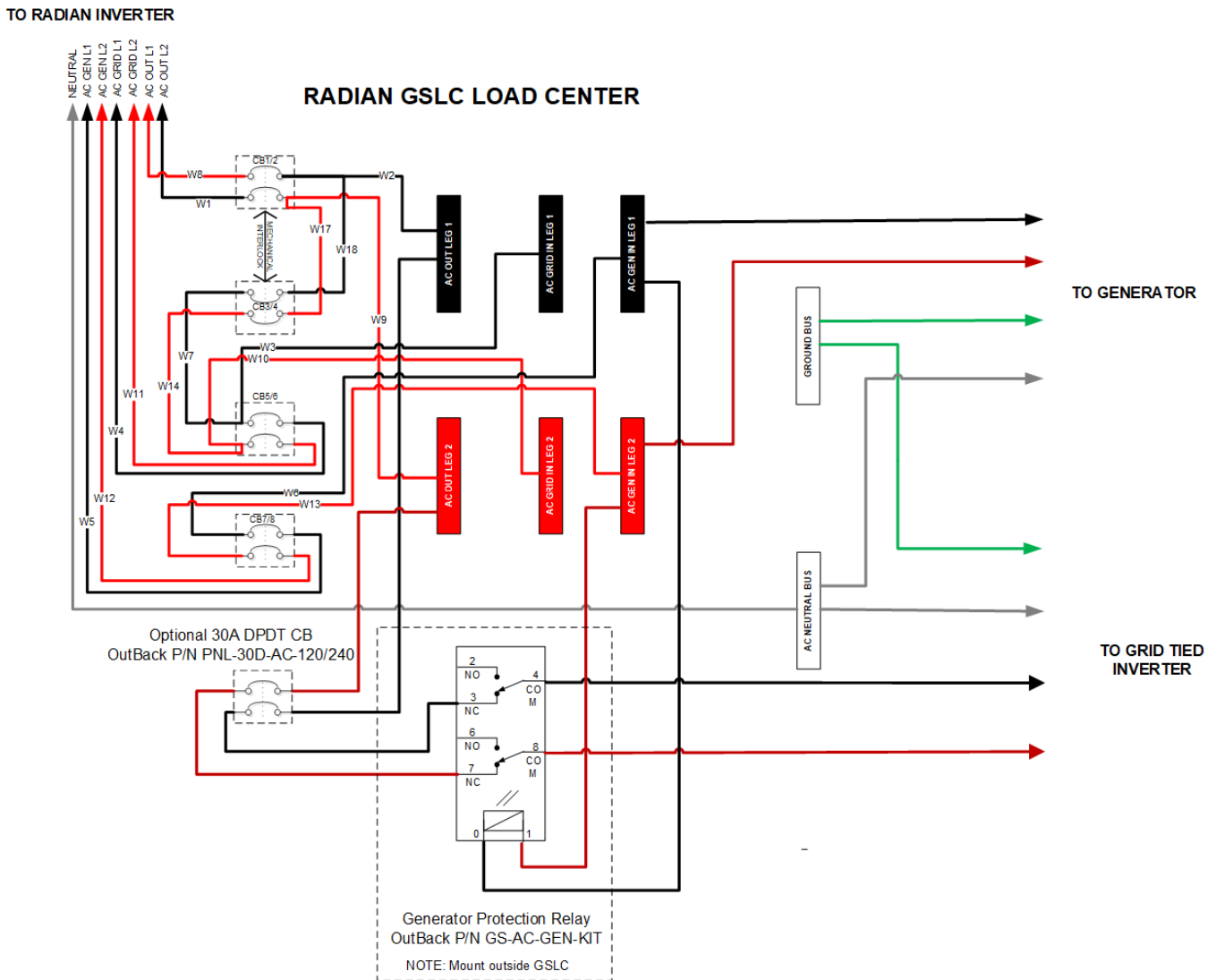
Figure 8 on the next page shows the normal operation with the Radian inverter connected to the GTI through the 2PDT relay. Should the generator ever start — automatically or manually — the live AC voltage at the GSLC load center Gen AC Inputs will activate the 2PDT relay coils and force the normally closed (NC) contacts to the normally open (NO) position which opens the GTI connection so there is no danger of backfeeding the generator from the GTI.

While the suggested 2PDT relay in this example has been tested by OutBack Power, it has not been listed with the Radian GSLC load center. The local authority having jurisdiction may require an approval stamp from a licensed engineer before approving the installation. If this approval cannot be obtained, then a second solution is shown in Figure 9 and described on page 11.

# Application Note

For the automatic method using the lockout relay, the generator L1 and L2 phases can be connected to the **GEN IN** bus bars, with the generator ground and neutral connected to their respective bus bars. The L1 and L2 connections from the AC Gen In bus bars are then connected to the relay coil terminals. The GTI L1 and L2 connections can be made to the 2PDT to the common relay contacts (pins 4 & 5) as shown in Figure 8 and then the NC contacts (pins 3 & 7) are connected to the AC Output bus bars.

To automate the generator start using the OutBack MATE3s system display and controller, see **Advanced Generator Start (AGS)** programming instructions in the MATE3s literature for specific steps for setup. It is recommended to use the Voltage Start function with the appropriate low battery settings. SOC start is normally disabled as the SOC accuracy can be off significantly when the batteries are not being fully charged on a regular basis. Voltage Start should be more than adequate to keep the batteries from getting discharged too deeply. Also, the **Generator** input mode should be selected for the **Gen AC Input Mode and Limits** in the **Inverter** settings menu.



**Figure 8 Generator Protection Relay and GTI Disconnect**

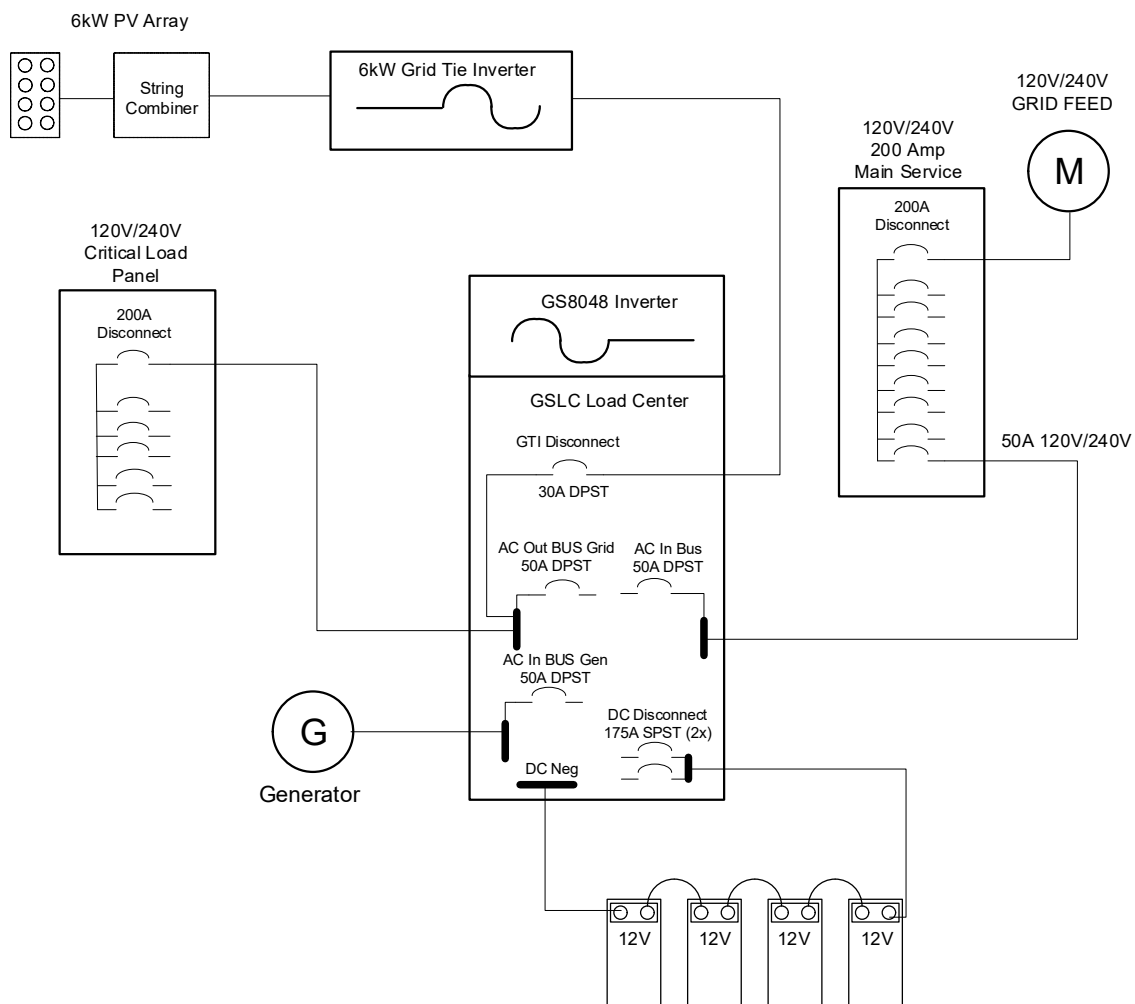
# Application Note

If the automated method of disabling the GTI during generator operation cannot be approved by the local authorities having jurisdiction, then there is a manual method where the generator is connected to the **GEN IN AC** input terminals in the GSLC load center. The **Generator** input mode should be selected for the **Gen AC Input Mode and Limits** under the **Inverter** settings.

Figure 8 shows a single line diagram with the generator connected. The manual operation whereby the GTI is disconnected with the 30A CB/Disconnect BEFORE manually starting the generator will ensure that the generator does not get back-fed by the GTI when it is producing power from the PV array.

	<p><b>CAUTION: Equipment Damage</b></p> <p>The GTI disconnect must always be open when manually operating the generator or the generator could experience catastrophic failure if power is back-fed from the GTI.</p>
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Where the previously discussed automated solution using the 2PDT GTI disconnect relay is not allowed, this could provide a way to charge the battery bank and power loads when the GTI is not able to sustain the load and battery charging demands. Please note the **CAUTION** above.



**Figure 9 Single line diagram of manual generator start and GTI disconnect method**

## Application Note

### 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.

### Contact Information

Address: Corporate Headquarters  
17825 – 59th Avenue N.E.  
Suite B  
Arlington, WA 98223 USA

Email: [Support@outbackpower.com](mailto:Support@outbackpower.com)

Website: <http://www.outbackpower.com>

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