Application Note

How To AC Couple Grid Dependent Inverters with the OutBack Radian Inverter

This application note explains how to AC couple a Grid Dependent Inverter (GDI) to an OutBack Radian inverter. When a grid outage occurs, this method uses a frequency-shifting technique to prevent the GDI from overcharging the battery bank (during times when it delivers more power than can be consumed by the loads). The excess GDI power 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 GDI incrementally reduce its output (Freq/Watt compliant inverters) or disconnect itself from the AC coupled circuit (any IEEE 1547-compliant inverter).

NOTE: This application note does NOT apply to the OutBack SkyBox product. Please read the *AC Coupling with SkyBox* application note for background information and setup.

Introduction

The frequency shifting technique to safeguard overcharging of the battery bank not only curtails the GDI when the active battery charging set point is exceeded, but also when the AC Charger limit is surpassed. While overall AC coupling performance is highly dependent on the ratio of GDI 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 GDI 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 to the Radian Inverter/Charger and a MATE3s System Display and Controller. The firmware is only available by download on the OutBack Power website www.outbackpower.com. 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 GDI from the PV panels through the inverter, to the main service panel and on out to the grid. In a normal GDI 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 GDI has no way to synchronize itself to the grid – a requirement for operation – so it shuts down and is unable to use any energy from the array.

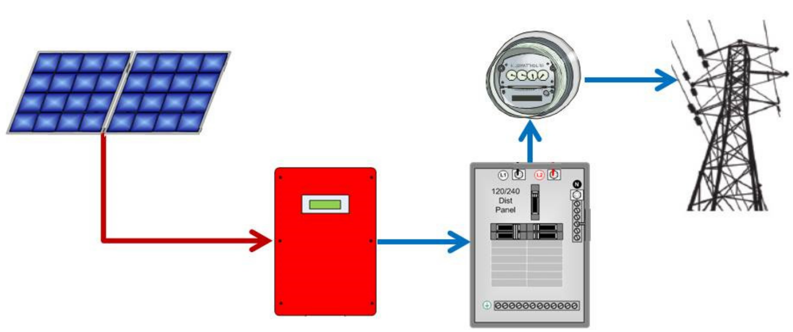

Figure 1 – Normal GDI Power Flow

By connecting (coupling) the output of the GDI to the output of a storage based inverter (SBI), the SBI can act like a grid source that the GDI 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 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 Radian inverter, will only allow current to pass to the main service panel and out to the grid in its ***Grid Tied*** input mode. ***Generator*** mode is the only other Radian input mode allowed to synchronize and connect to the grid when the AC Coupling function has been selected in the MATE3s system display. It is recommended that ***Generator*** mode is only used when a generator is deployed and connected to the **GEN AC** input of the Radian. The generator protection relay available from OutBack Power should also be used if the generator is not rated for AC coupling applications. Most residential class generators require this relay.

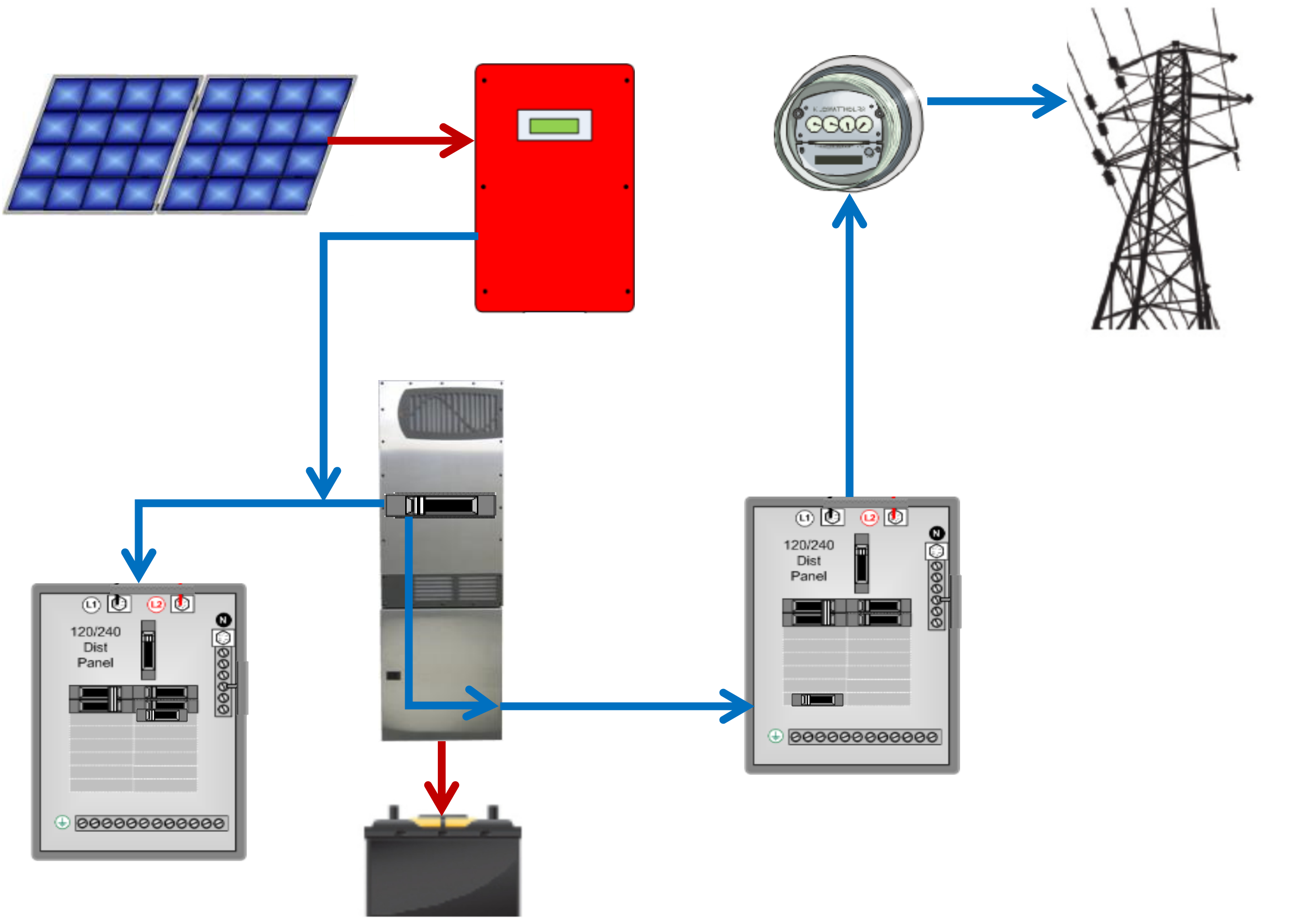

Figure 2 – GDI Power Flow with Active PV

In addition to exporting GDI current out to the main service panel, a separate parallel current path to charge the battery bank from PV power can exist if either the ***Refloat*** or ***Rebulk*** charging voltages 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.

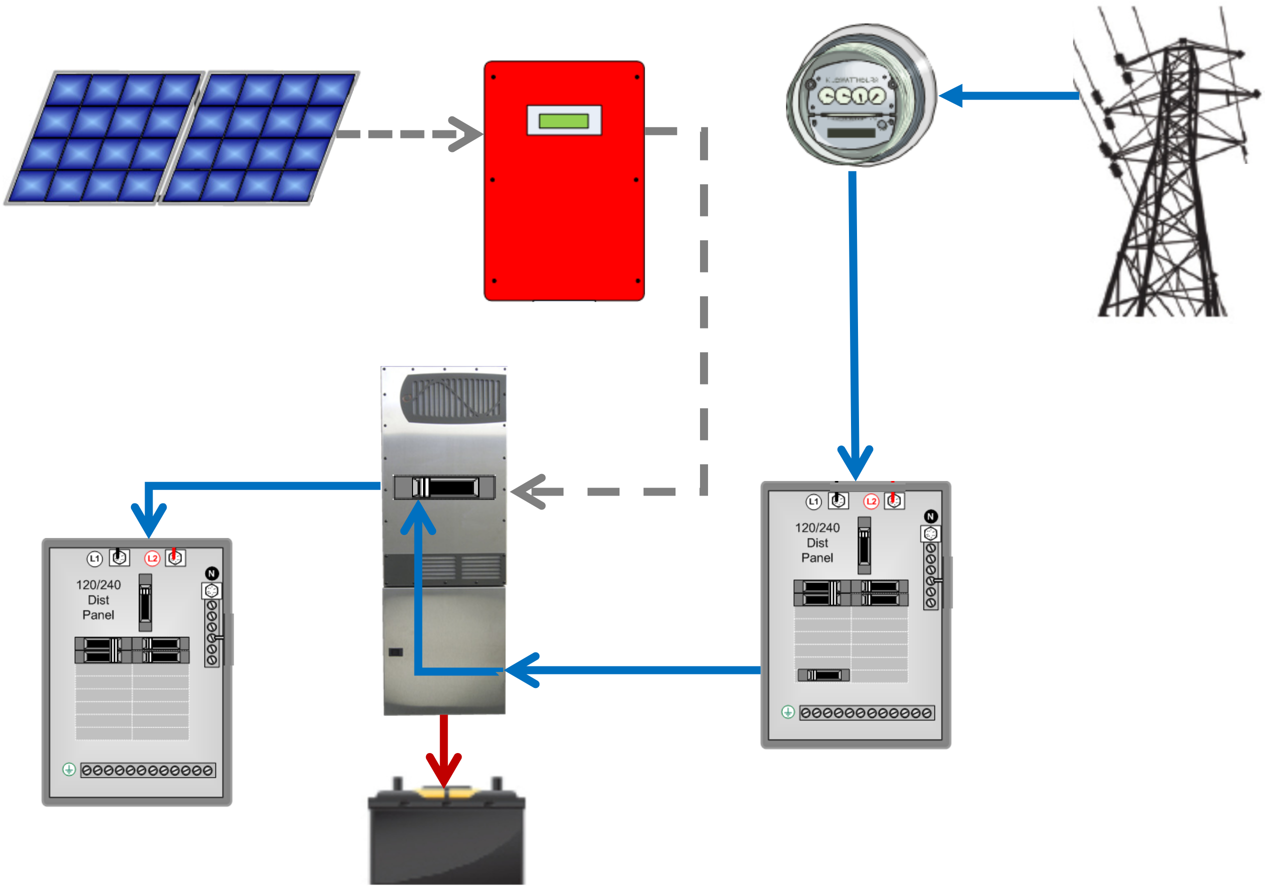

Figure 3 – GDI Power Flow without PV

Theory of Operation – With Grid Outage

During a grid outage when the sun is shining, the SBI in this case the Radian inverter becomes an AC source to which the GDI can synchronize. This allows the PV power to flow to the backup panel's connected loads, as well as charge the batteries if the GDI 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 GDI 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 GDI.

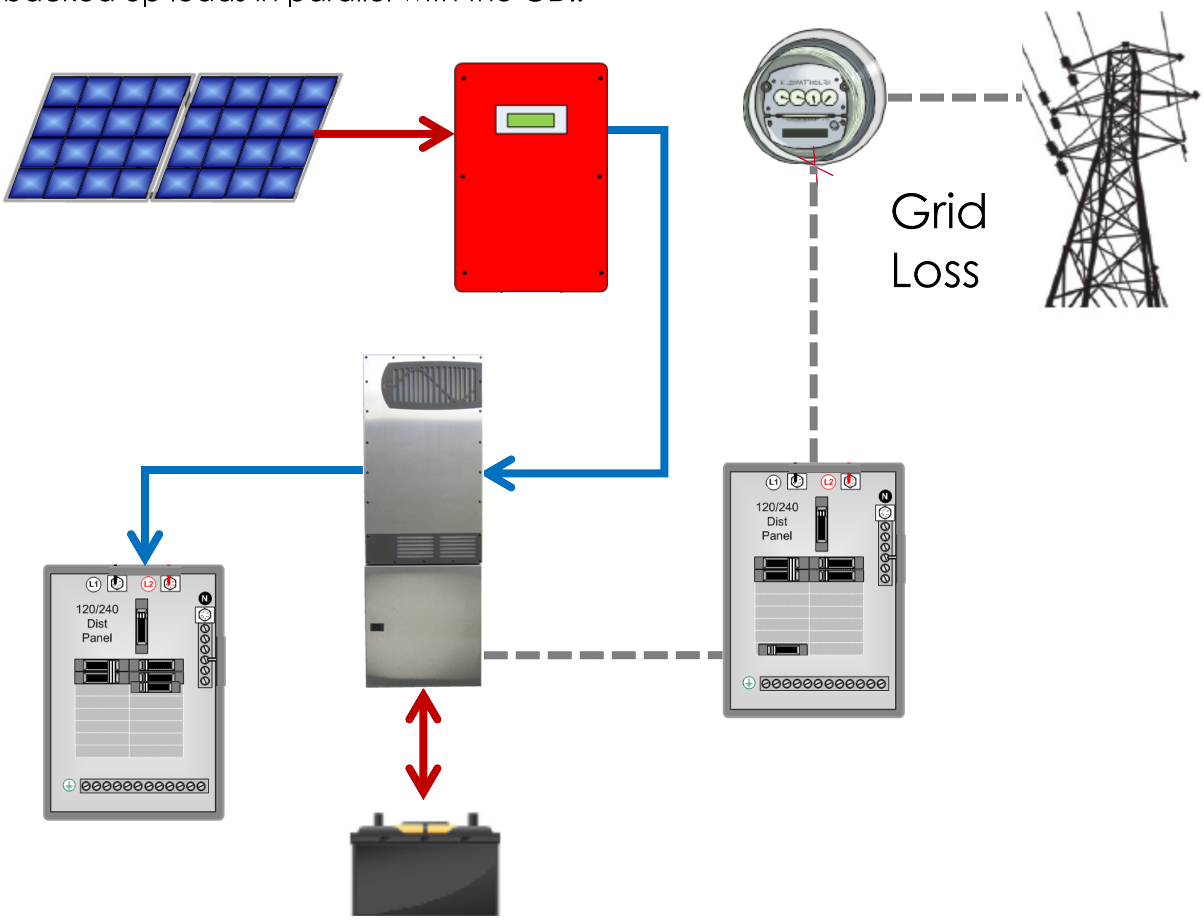

Figure 4 – AC Coupled current flows with sufficient load demand and frequency shift curtailment

If the batteries become fully charged and the load demand falls below the GDI power production, then the excess power from that production will flow back through the Radian inverter in an unregulated charge back to the batteries. When the battery 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 regulation will also be enabled if the AC charge current coming back onto the battery bank exceeds the ***AC Charge Current*** limit setting.

> **EXAMPLE**: There is a grid outage and the Radian becomes the new AC source for the GDI 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 GDI 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 GDI 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 charge 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 GDIs that will just simply go off line and wait to reconnect for the time specified by the local jurisdiction (usually 5 minutes in North 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 GDI output current, this feathering back of the GDI 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 GDI as well.

IMPORTANT

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

Should the GDI 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 GDI 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.

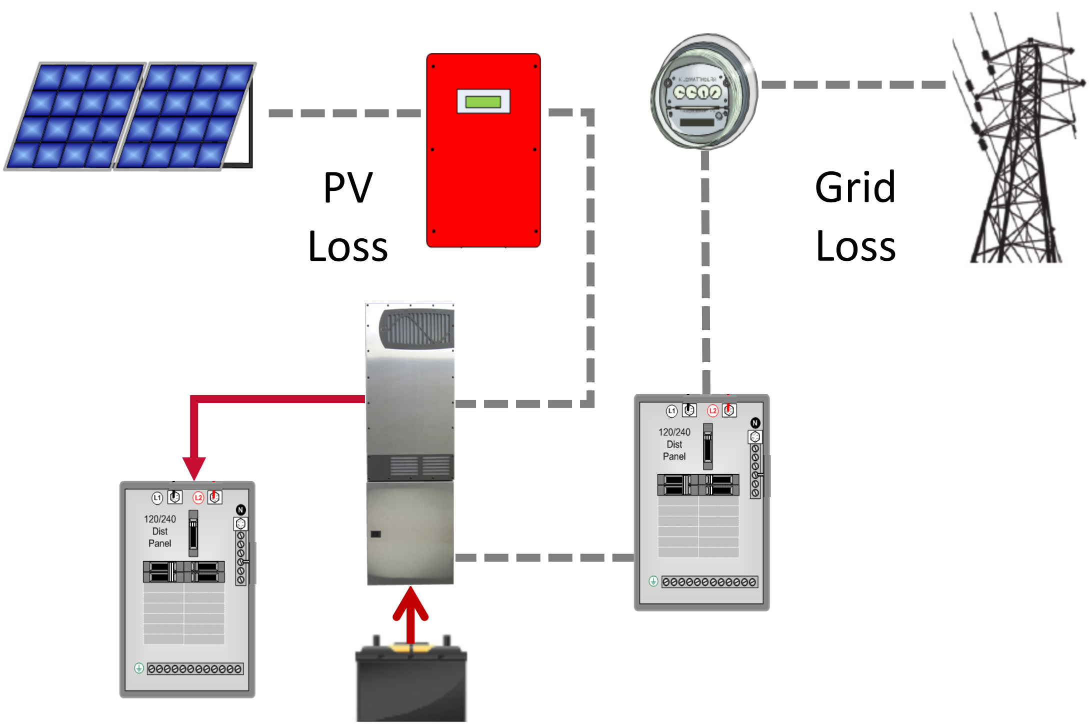

Figure 5 – Off-grid current flow due to PV loss or GDI power overcharging battery bank

Once PV production is gone for the day, 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 GDI 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 GDI again. Use caution when connecting an AC generator; there is risk that the GDI may backfeed the AC generator and cause catastrophic failure. To avoid damaging the generator and/or voiding the GDI warranty, a recommended generator solution is discussed after the **Solution** section below.

Solution

The Radian with frequency shift AC coupling has a maximum limit of 7.6 kVA for the GDI. Note that this is an increase over the 6 kVA limit of OutBack's earlier AC coupling solution that used a blackout relay that had a slower response to battery overvoltages and no protection for over current charging. Additionally, the Radian Frequency Shift solution now supports 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 under **Procedure** on the next page.

IMPORTANT:

- ❖ Radian AC Coupling firmware version 001.006.070 must be downloaded from the OutBack website and installed.
- ❖ A MATE3s system display with firmware version 001.004.001 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 GDI. While the connection could be made in the backup load panel, it is best to use the Radian load center (GSLC), so that a disconnect can be installed and easily accessed if the GDI 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 overcurrent protection device (OCPD) already exists in the output circuit of the GDI, then the GDI connection could be made directly from the GDI OCPD to the Radian AC output bus bar.

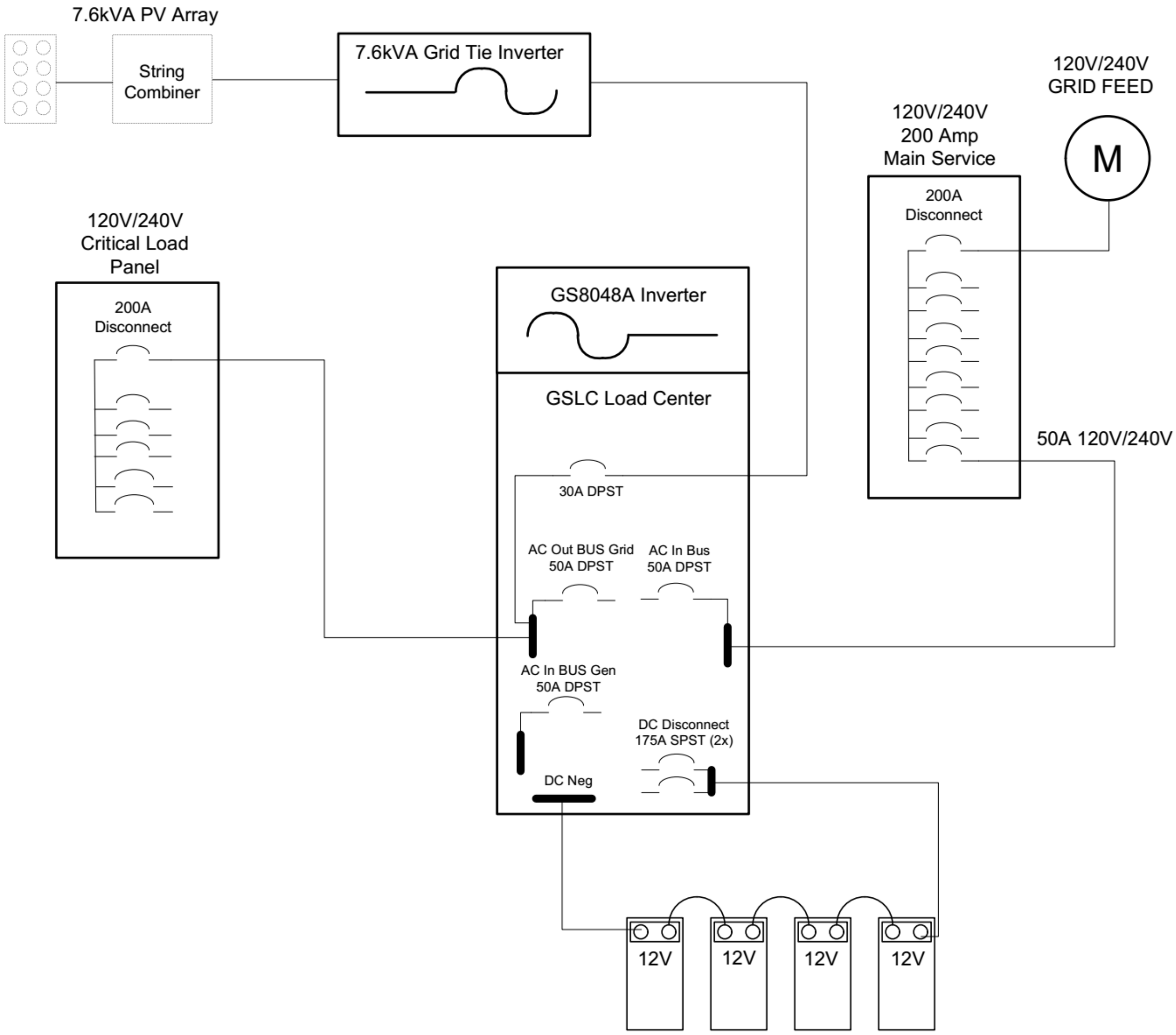

Figure 6 – Single line diagram of GDI inverter connection to Radian inverter

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 ***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.

   CAUTION: Settings >1-2 seconds may cause elevated battery charging voltages. Verify all setting changes from default of 0.02 seconds with low loads to ensure highest recommended charging voltages are not being exceeded.

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 ***SellRE*** setting is to be changed from its default setting of 52.0 volts.

   NOTE: The ***SellRE*** setting does not affect the exporting of GDI current back to the main service panel. The GDI current moves from the AC output to the AC input through a relay so the ***SellRE*** setting has no affect. However, the ***SellRE*** 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 GDI 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.

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 GDI into the generator, a safety relay must be utilized that disconnects the GDI 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.

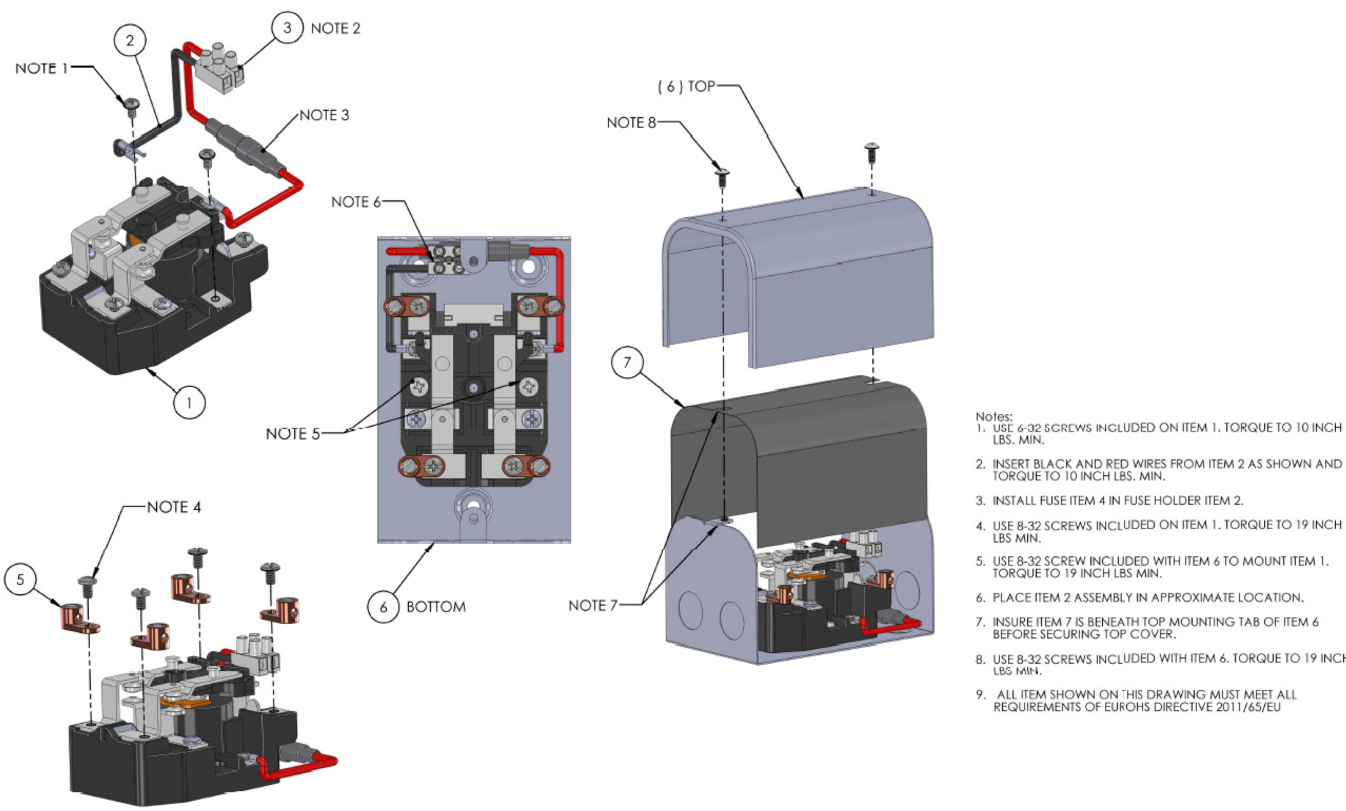

Figure 7 – GS-AC-GEN-KIT, Generator Protection Relay from OutBack

Figure 8 shows the normal operation with the Radian inverter connected to the GDI through the 2PDT relay. Should the generator ever start — automatically or manually — the live AC voltage at the GSLC **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 GDI connection so there is no danger of backfeeding the generator from the GDI.

While the suggested 2PDT relay in this example has been tested by OutBack Power, it has not been listed with the GSLC. The local authority having jurisdiction may require an approval stamp from a licensed engineer before approving the installation.

When 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 **AC GEN IN** L1 and L2 bus bar connections are connected to the relay coil terminals. The GDI L1 and L2 connections can then b-e made to the 2PDT common relay contacts (pins 4 & 5) as shown in Figure 8. The NC contacts (pins 3 & 7) are then 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 discharging too deeply. Also, from the ***Gen AC Input Mode and Limits*** in the ***Inverter*** settings menu, the ***Generator*** input mode should be selected.

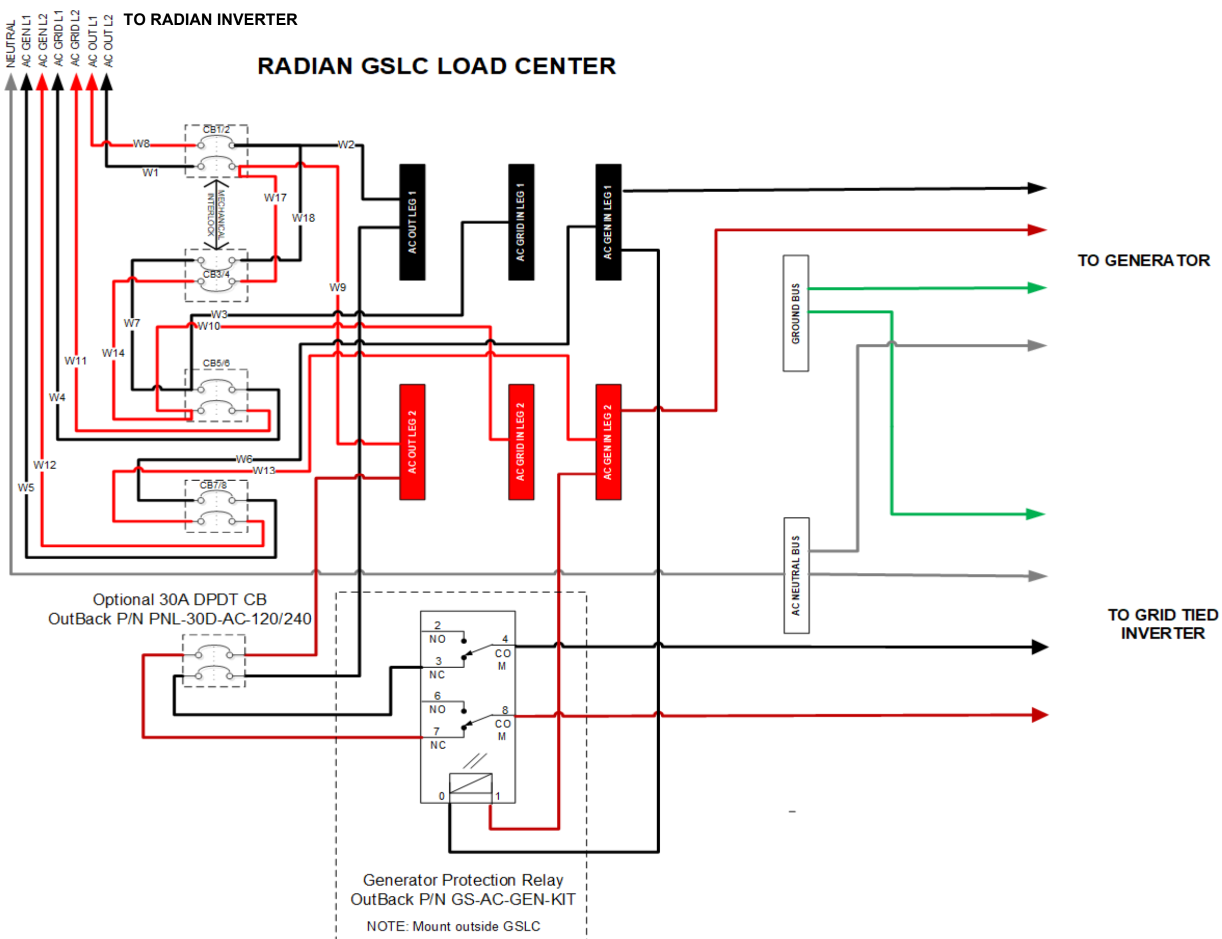

Figure 8 – Generator Protection Relay and GDI Disconnect

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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Other

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