HV Solar Inverter System GUI Overview

January 2012

The HV Solar Inverter System GUI provides a simple interface to evaluate some of the functionalities of the HV Solar Inverter System from Texas Instruments. The HV Solar Inverter System includes two EVMs from TI: (1) HV Solar MPPT DC-DC, (2) HV Solar DC-AC Inverter. The GUI is located at:

```
..\controlSUITE\development_kits\HV_SOLAR_DCAC\~GUI\~Source\
```

The GUI features:

- Allows user to start/stop the Inverter System.
- Monitor some of the system parameters. These parameters are boost stage DC bus voltage, panel voltage, panel current, panel power, isolated DC bus voltage, inverter stage output voltage, output current, frequency and output power.
- Allows user to monitor the operating mode or status of the Inverter and DC-DC stages.
- Ability to restart Inverter system once the fault condition has been cleared.
- Configure Inverter output for two utility settings, (1)120V/60Hz, (2)220V/50Hz
- Enable/Disable grid tie function for the DC-AC Inverter

Getting Started

Setting up the Hardware

Caution

There are high voltages present on the HV Solar Inverter System (DC-AC Inverter EVM and DC-DC EVM). It should only be handled by experienced power supply professionals in a lab environment. The system has been tested to work only with a solar panel emulator such as, Agilent Technologies E4360A SAS Mainframe with two Solar Array Simulator DC Modules (E4362A, 0~130V, 0~5A). This system has not been tested to work with an actual solar PV panel.

Prior to applying the panel emulator output to this system, a voltmeter should be connected across the DC-DC EVM output to monitor the DC-DC bus voltage. Then the panel emulator should be turned on to output only 100V~150V. This will allow the bias supplies on both the EVMs to turn on. Once the bias supplies start drawing power from the DC bus, the panel emulator voltage should then be slowly increased to its maximum open circuit voltage (200V ~ 300V) while monitoring the DC-DC output. This DC-DC output voltage should not exceed more than 410V when the Inverter and its output load is connected. This way any overvoltage condition at the DC-DC output (during start-up) can be avoided.

This overvoltage condition tends to happen when the DC-AC Inverter EVM output remains under open circuit (no load connected) until the minimum DC-DC bus voltage is established and, then, a start command is issued from the GUI. The DC-AC output open circuit condition is caused by its output relays remaining in off condition prior to the start command issued from the GUI.

Also, there is no output over-current protection implemented on the DC-DC board and so the user should take appropriate measures for preventing any output short circuit condition across DC-DC EVM output.

For jumper and switch configuration needed to power on C2000 HV Solar Inverter System please refer to the individual EVM's quick start guides. Before applying any power, make sure these jumpers and switches are installed properly.

Set up the Solar Inverter System

Connect the two EVMs as per the diagrams in Figure 1 and Figure 2.

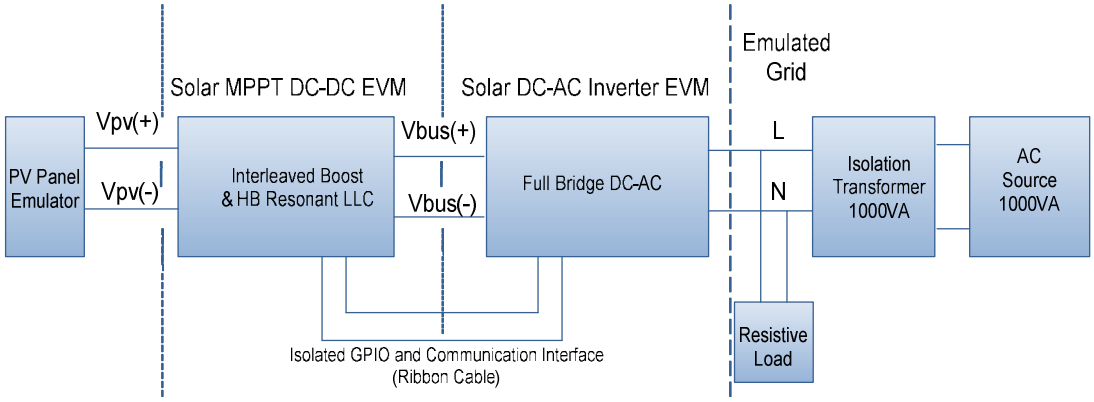


Figure 1 Block Diagram of Solar Inverter System Setup

For the safety, we strongly suggest using an isolation transformer between the external AC source and the inverter output. For noise immunity, small common mode filter inductors also need to be connected at the interface between the two boards. These are shown in Figure 2.

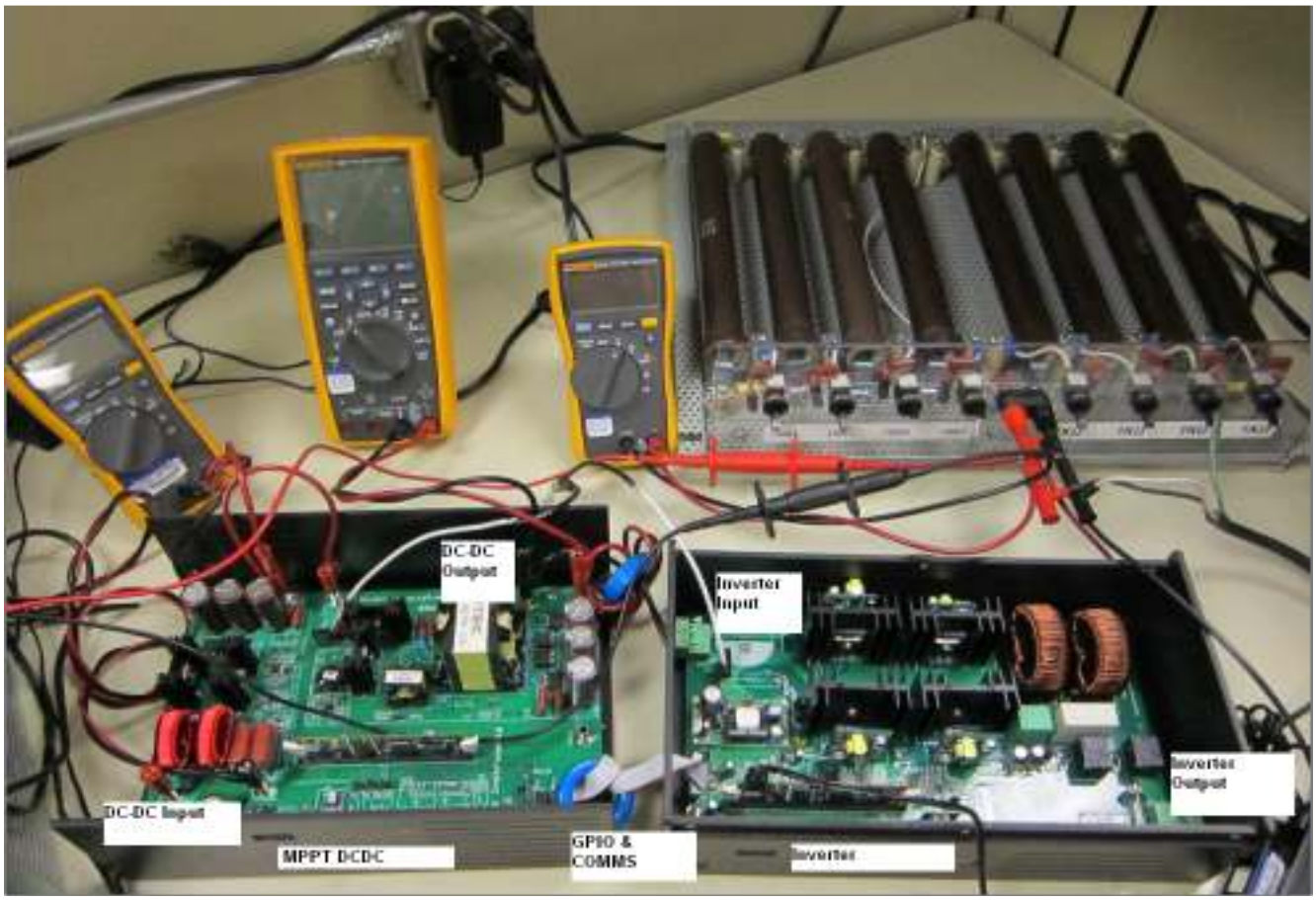


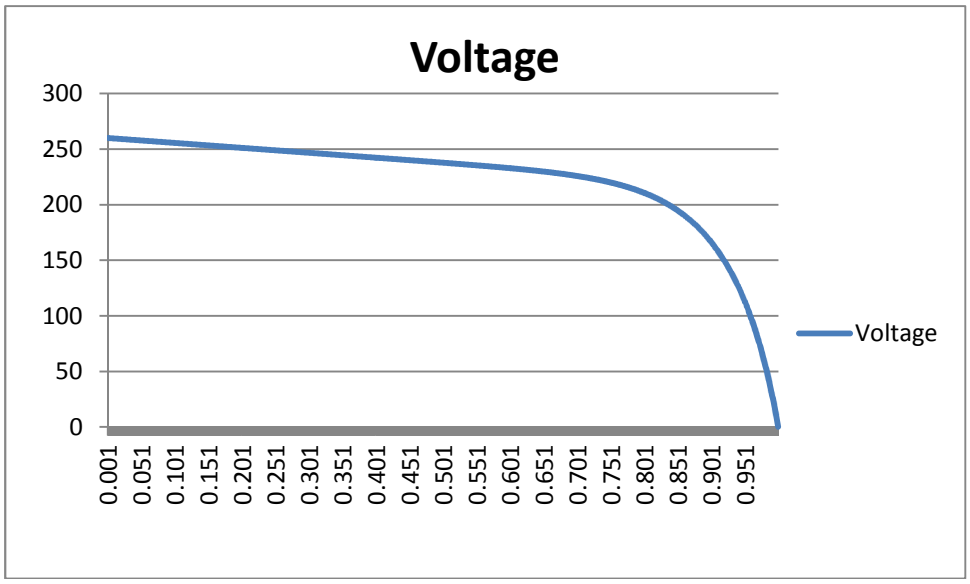
Figure 2 Solar Inverter System Test Setup

Set up the DC-DC EVM and the PV Panel Emulator

Use an external +12Vdc supply at JP1 to power up, for now, all the control circuits on the DC-DC EVM. By default, Piccolo controller is enabled to boot from FLASH and run the HV Solar DC-DC code. Turn on the switch SW1 (in PCB section or macro labeled as M3) by placing it towards the electrolytic caps (C5, C6 and C7 located in M3). This will apply the external +12Vdc supply to the DC-DC EVM. Check the led LD3 on the control card. If the LED flashes, then continue to do the next steps. Otherwise, check the auxiliary power, the control card jumper configuration for boot from flash, or reload the program.

Use a solar panel emulator (200V to 300V, 500W max) to provide input power to the EVM. Agilent Technologies SAS Mainframe E4360A, with two Solar Array Simulator DC Modules (E4362A, 0~130V, 0~5A), could be used for this purpose. Configure the panel emulator to emulate the following solar panel characteristics, connect it to the EVM input but **do not turn on panel power at this time.**

Example Panel Emulator Parameters 1		
Voc	Open circuit panel voltage	**260V**
Vmpp	Panel voltage for max power point tracking (MPPT)	**220V**
Impp	Panel current for max power point tracking (MPPT)	**0.75A**
Isc	Short circuit panel current	**1A**



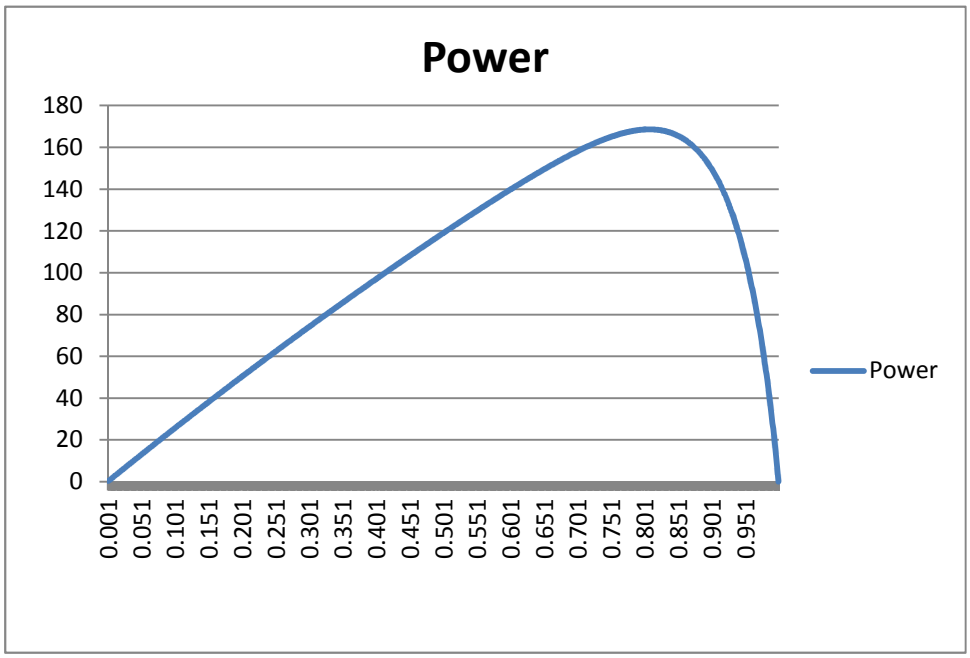


Figure 3 Example Panel Emulator Characteristics

Set up the DC-AC Inverter EVM and the Load

The DC-AC Inverter can be controlled either by a Piccolo (CC2803x) control card or a Concerto (CCF28M35xx) control card. For jumper and switch configuration related to each of these control cards please refer to the DC-AC Inverter EVM quick start guide. Select the desired control card and connect it to the 100pin header U2 on the Inverter EVM.

Now connect USB connector to the control card on the DC-AC Inverter EVM. Use the ribbon cable to connect the 10-pin header CN5 on the Inverter EVM to the other 10-pin header H2 on the DC-DC EVM. **Ensure that the ribbon cable is installed properly so that all 10 pins on both headers are connected one to one** (pin 1 on CN5 connects to pin 1 of H2 and so on). Use an external +15Vdc supply at J1 to power up, for now, all the control circuits on the DC-AC Inverter EVM. By default, the controller (Piccolo or Concerto) is enabled to boot from FLASH and run the HV Solar DC-AC Inverter code. Turn on the switch S1 by placing it away from J1 and towards the 10-pin header CN5. This will apply the external +15Vdc supply to the DC-AC Inverter EVM. Check the led LD2 on the control card. If the LED is flashes in every 1 second then continue to do the next steps. Otherwise, check the auxiliary power, the control card jumper configuration for boot from flash, or reload the program. Also, at this point the led LD2 on the DC-DC EVM should start flashing indicating the communication between the two EVMs. If this does not happen then check the ribbon cable connection between the two EVMs.

Connect an appropriate resistive load to the DC-AC Inverter EVM output connector CON2 (LINE.L & LINE.N terminals). As in the example above, if the panel emulator is configured to supply 165W of power at MPPT point, then select a load resistor value of 100 ohm. This will make the EVM output voltage to rise to about 120Vrms when delivering 165W of output power. The resistor power rating should be at least 200W. Connect the DC-DC output terminals Vo-R and GND-S to the DC-AC input connector (CON1) terminals +BUS and GND respectively.

As shown in Figure 1, connect the external AC source and the isolation transformer across this resistive load of 100 ohm. Set the AC source to output 120V, 60Hz but **do not turn on AC source power at this time.**

Running the Application using the GUI

By default the hardware is configured to boot from a pre-Flashed code. The GUI only works with the FLASH configuration in the corresponding CCS project.

1) Browse to `..\controlSUITE\development_kits\HV_SOLAR_DCAC\~GUI` and double-click on SOLAR-GUI.exe. The following figure shows a screen shot for the GUI.

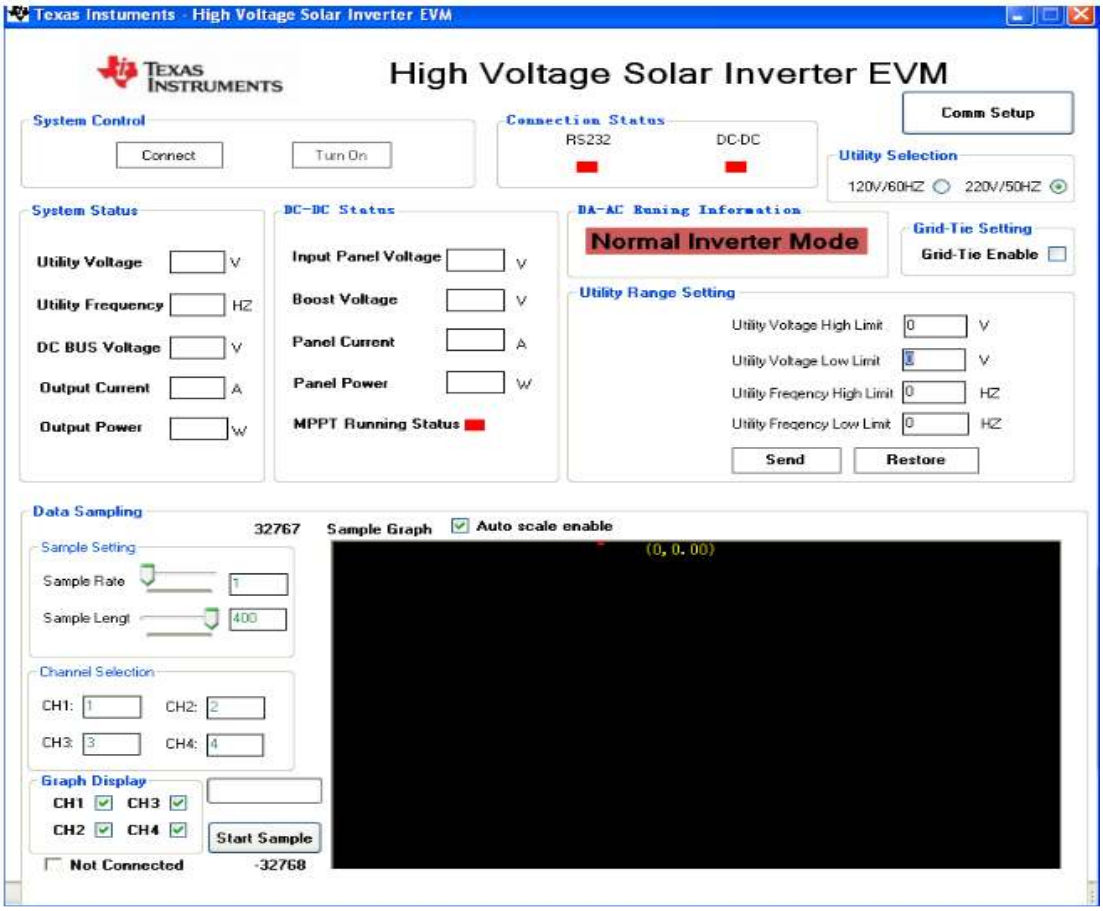


Figure 4 HV Solar Inverter GUI

2) Set up the GUI communication by clicking on the *Comm Setup* button. Then choose the COM port: COM51, for example. Then click OK.
Note: the COM port will be different for different PCs. You can check the COM port number in the PC hardware resources window.

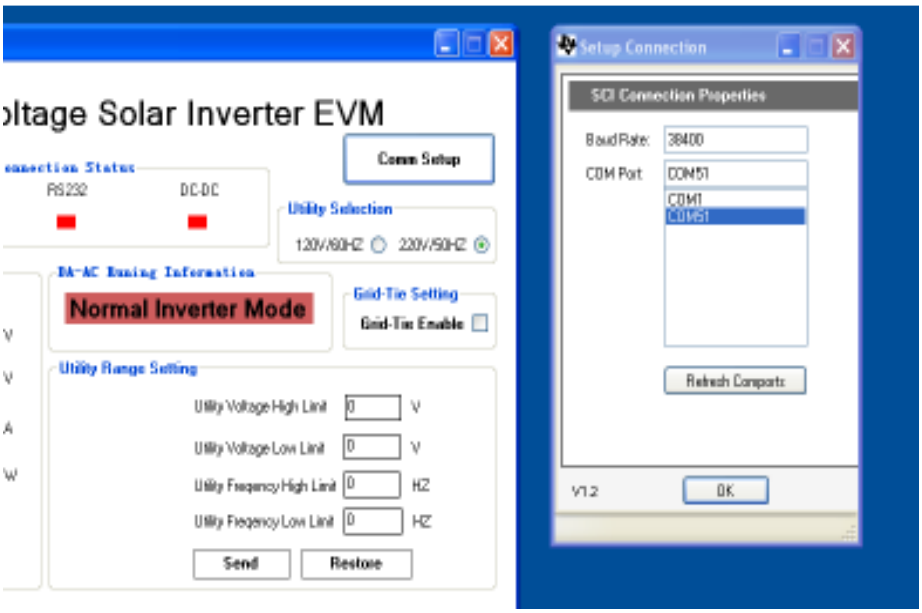


Figure 5 HV Solar Inverter GUI Setup

3) Connect the Solar Inverter System and the GUI by clicking the *Connect* button. If the boards are connected successfully, the connect status textbox will be shown in green with the connected warning. Or the connect status textbox will be in yellow with the disconnected warning. The GUI should now be connected to the target and be ready for use.

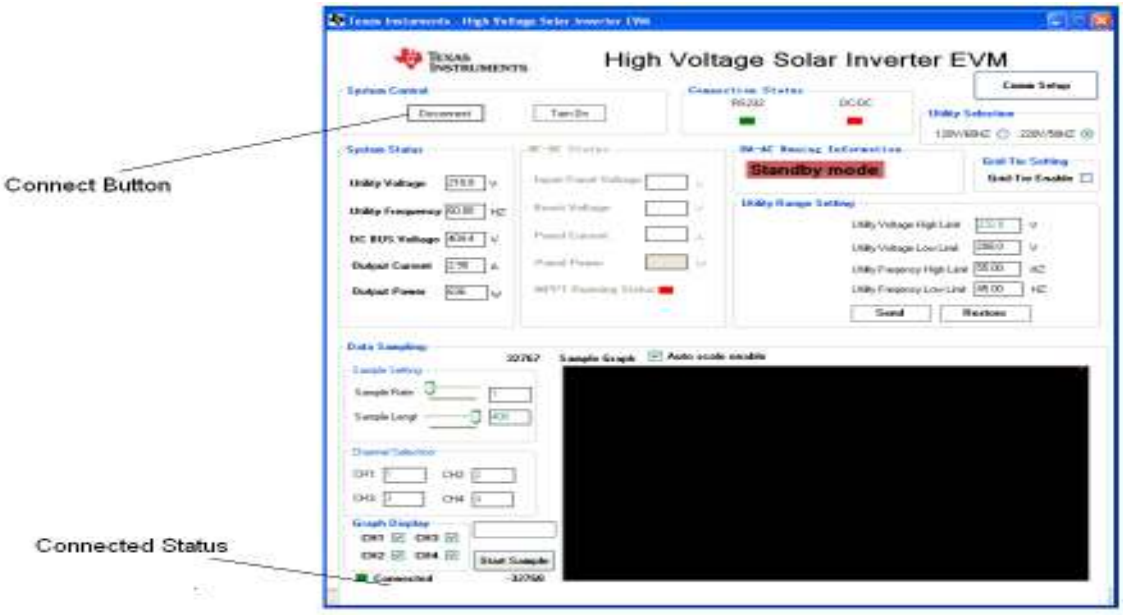


Figure 6 HV Solar Inverter GUI Connection

Using the GUI for Off-Grid Operation

- Once the hardware is set-up correctly and the application program (pre-flashed code) is tested to run with the GUI, then close the GUI, turn OFF the switches SW1 on DC-DC EVM and S1 on DC-AC Inverter EVM, and disconnect the external bias supplies from both EVMs.
- Verify that the two jumpers (J1 on DC-DC EVM and JP1 on Inverter EVM) are connected so that the on-board isolated bias supplies (small bias supply boards mounted on both EVMs) can now provide the bias power(+12V for DC-DC EVM and +15V for DC-AC Inverter EVM) when the PV panel emulator power is turned on.
- For the off-grid test, disconnect the external AC source and the isolation transformer from the load. For this off-grid test the resistive load will only be powered from the Solar Inverter. Now **turn on only one of the Solar Array Simulator DC Modules** (Agilent E4362A) with the configuration (for the panel emulator & the load resistor) described above. This will apply a maximum input voltage of 130V (open circuit voltage of each of the Solar Array Simulator DC modules E4362A) to the DC-DC input and allow the bias supplies on both EVMs (Inverter and DC-DC) to power up.
- When both the EVMs bias supplies power up connect the GUI (as described before) and monitor the GUI status. LD2 on the Inverter control card will be flashing in every 1 second. LD2 and LD3 on the DC-DC EVM will also be flashing, although at different rate.
- If the DC-AC *Running Information* shows the *Standby Mode*, then the DC-AC is ready to be turned on. To do this, click the *Turn On* button on the GUI and then power on the **second Solar Array Simulator DC Modules** (Agilent E4362A) with the configuration (for the panel emulator & the load resistor) described above. This will apply the full open circuit panel voltage (Voc) of 260V (open circuit voltage of both Solar Array Simulator DC Modules when connected in series) to the DC-DC input. The DC-AC *Running Information* on the GUI will show the *Soft-Start Mode*, and then, the *Normal Inverter Mode*. The DC-AC *Running Information* will change to *Normal Inverter Mode* when the DC-DC EVM starts MPPT operation and the DC-AC Inverter delivers power to the load.
- The DC-DC EVM output should now ramp to about 380Vdc and the Inverter EVM output should be about 120V rms.

- On the GUI, verify some of the system parameters. For example, the Input Panel Voltage should be about 220V, the Panel Power should be about 165W, the DC Bus Voltage should be about 380V etc. The GUI snapshot on Figure 7 shows these parameters under this condition.
- When turning off power, ensure that the PV panel emulator power is turned off first. Then wait for a few minutes before disconnecting the GUI.

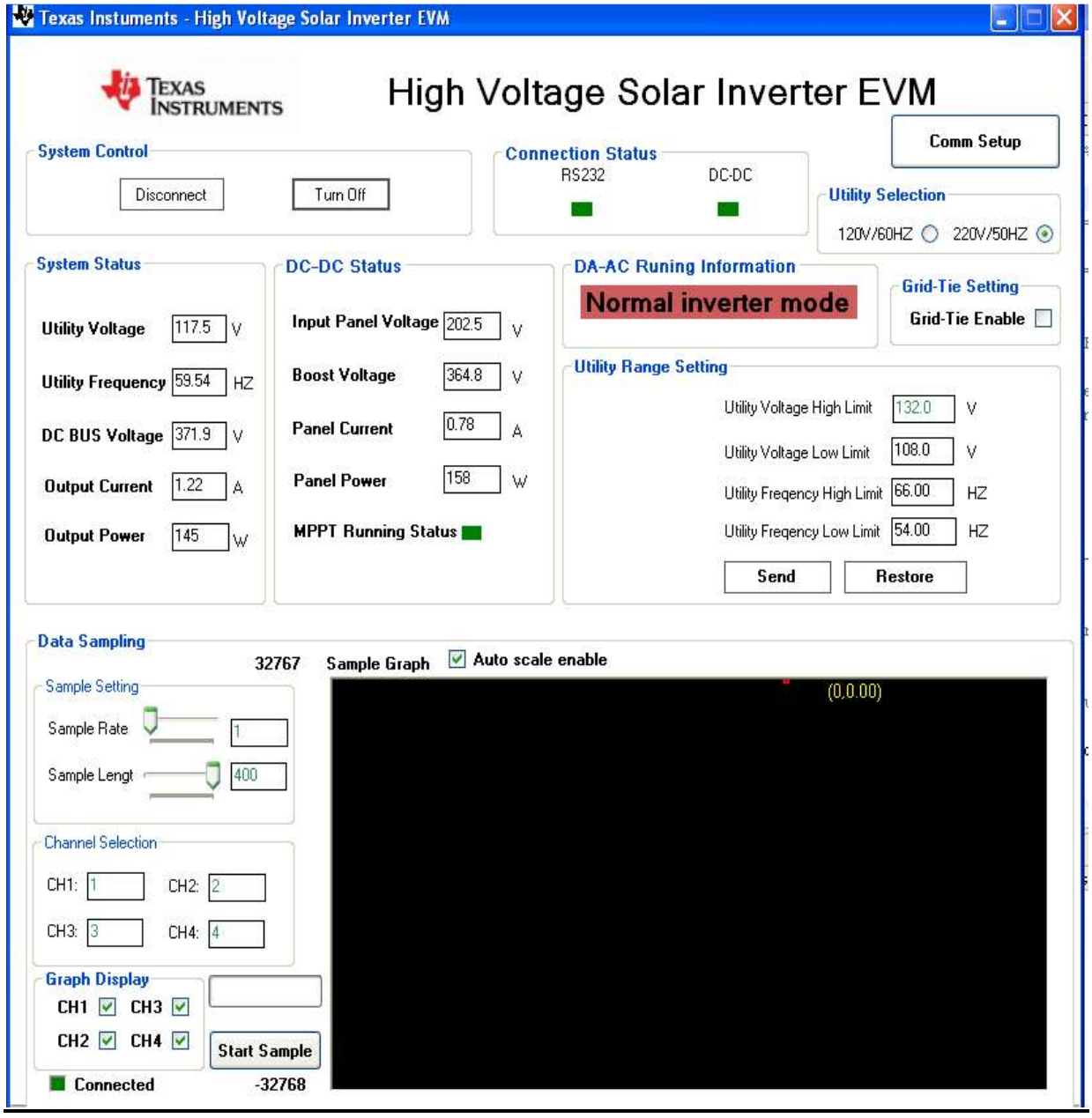


Figure 7 HV Solar Inverter GUI Snapshot for Off-Grid Operation

Using the GUI for Grid-Tie Operation

- Turn off the PV panel emulator power. For the grid-tie test, reconnect the external AC source and the isolation transformer to the load. Change the load resistor from 100 ohm to 50 ohm. Set the AC source to output 120V, 60Hz and turn it on. With 50 ohm load resistor the AC source will now deliver 100% load power of about 290W.
- Now turn on **one of the Solar Array Simulator DC Modules** (Agilent E4362A) with the configuration (for the panel emulator & the load resistor) described above.
- When both the EVMs bias supplies power up, connect the GUI (as described before) and monitor the GUI status. LD2 on the Inverter control card will be flashing in every 1 second. LD2 and LD3 on the DC-DC EVM will also be flashing, although at different rate.
- On the GUI *Grid-Tie Setting* section, click on the *Grid-Tie Enable* box. Then on the *GUI Utility Selection* section click on the *120V/60Hz* setting. ***These two selections must be done after connecting the GUI to the Solar Inverter system.*** If they are selected before connecting the GUI to the Inverter system then repeat these two selections one more time(click on these for a second time) in order to ensure the Inverter system has been communicated of the grid-tie condition and the utility setting.
- At this point, if the DC-AC *Running Information* shows the *Standby Mode*, then the DC-AC is ready to be turned on. To do this, power on the **second Solar Array Simulator DC Modules** (Agilent E4362A) and click the *Turn On* button on the GUI. The DC-AC *Running Information* will show the *Soft-Start Mode*, and then the *Normal Inverter Mode*. The DC-AC *Running Information* will change to *Normal Inverter Mode* when the DC-DC EVM starts MPPT operation and the DC-AC Inverter delivers power to the load.
- For this grid-tie test, the PV panel emulator is set up to deliver 165W of power. Therefore, the Inverter will deliver about 165W of load power at 120V/60Hz and so the AC source output power will drop from initial 290W to about 125W. The AC source output will thus be 120Vrms/ 60Hz at a load current of about 1.04A rms. The waveforms in Figure 9 below show the grid voltage and the inverter output current under this condition.
- The DC-DC EVM output should be about 380Vdc.
- On the GUI verify some of the system parameters. For example, the Utility Voltage will show about 120Vrms, the Utility Frequency will read 60Hz, the Input Panel Voltage will be about

220V, the Panel Power will be about 165W, the DC Bus Voltage will read about 380V etc. The GUI snapshot on Figure 8 shows these parameters under this condition.

- To turn off the system, first turn off the external ac source. This will create an under voltage condition and the inverter will report this on the GUI. This fault condition will also shut off both the inverter and the DC-DC outputs. At this point turn off the PV panel emulator power. Then wait for a few minutes before disconnecting the GUI.

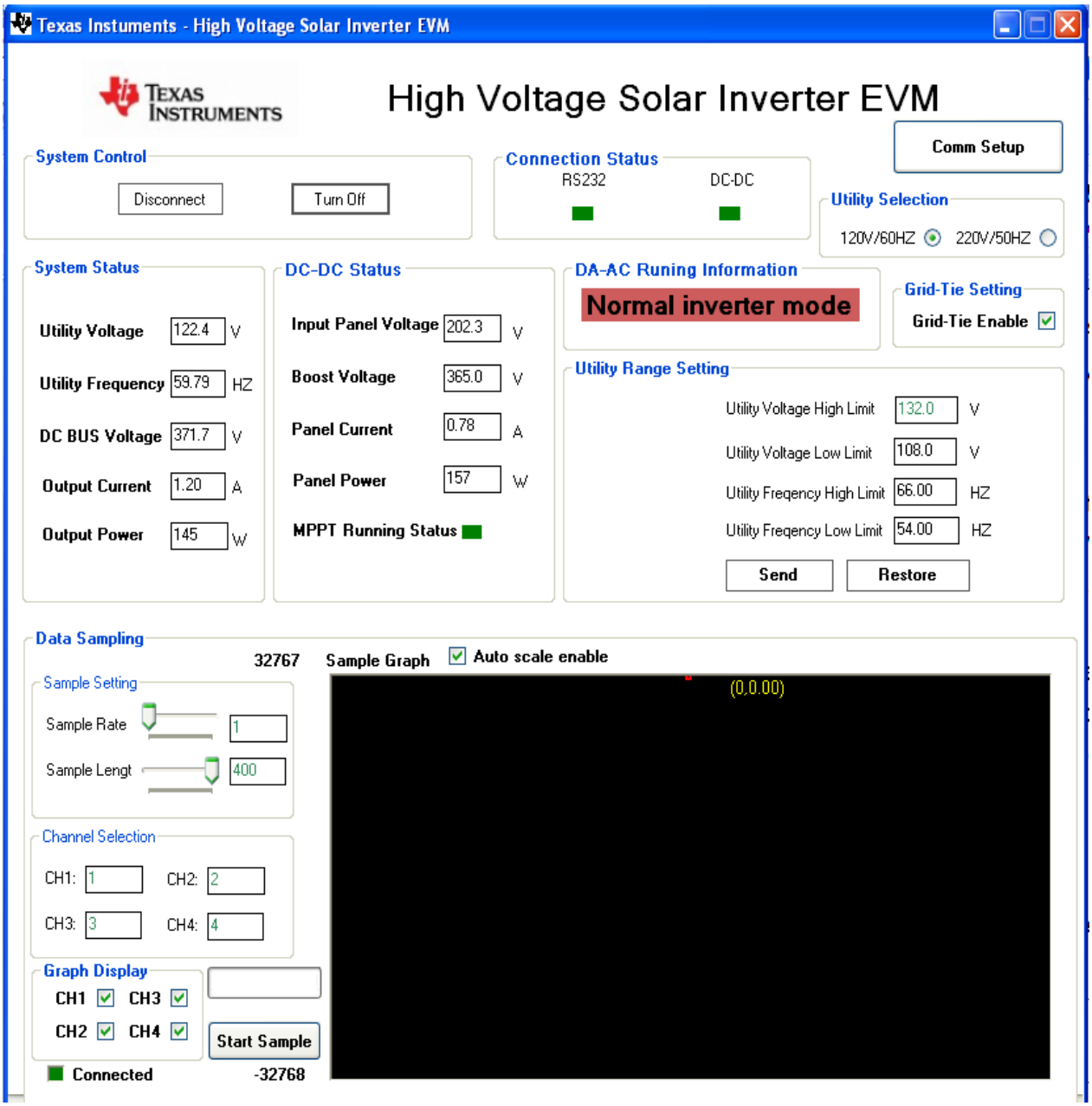


Figure 8 HV Solar Inverter GUI Snapshot for Grid-Tie Operation

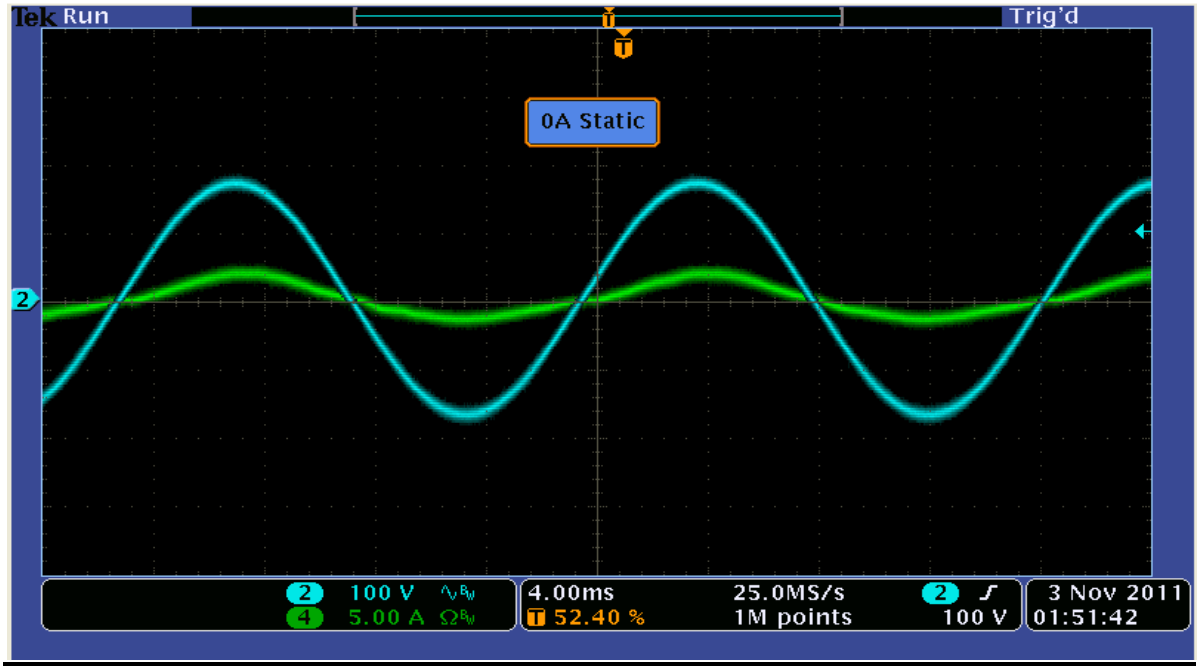


Figure 9 - Grid-Tie Test 1, Ch2: Grid Voltage, Ch4: Solar Inverter Output Current, MPPT Panel Power 165W

- Repeat the test for a higher load and higher PV panel power setting. Change the load resistor from 50 ohm to 30 ohm. Set the AC source to output 120V, 60Hz and turn it on. With 30 ohm load resistor the AC source will now deliver 100% load power of about 480W.
- Change the PV panel emulator parameter to emulate the following solar panel characteristics.

Example Panel Emulator Parameters 2		
Voc	Open circuit panel voltage	**260V**
Vmpp	Panel voltage for max power point tracking (MPPT)	**220V**
Impp	Panel current for max power point tracking (MPPT)	**1.5A**
Isc	Short circuit panel current	**1.75A**

- Repeat the steps as described for the previous load set up. For this test, the PV panel emulator is set up to deliver 330W of power. Therefore, the Inverter, when turned on, will deliver about 330W load power at 120V/60Hz and so the AC source output power will drop from initial 480W to about 150W. The waveforms in Figure 10 below show the grid voltage and the inverter output current under this condition.

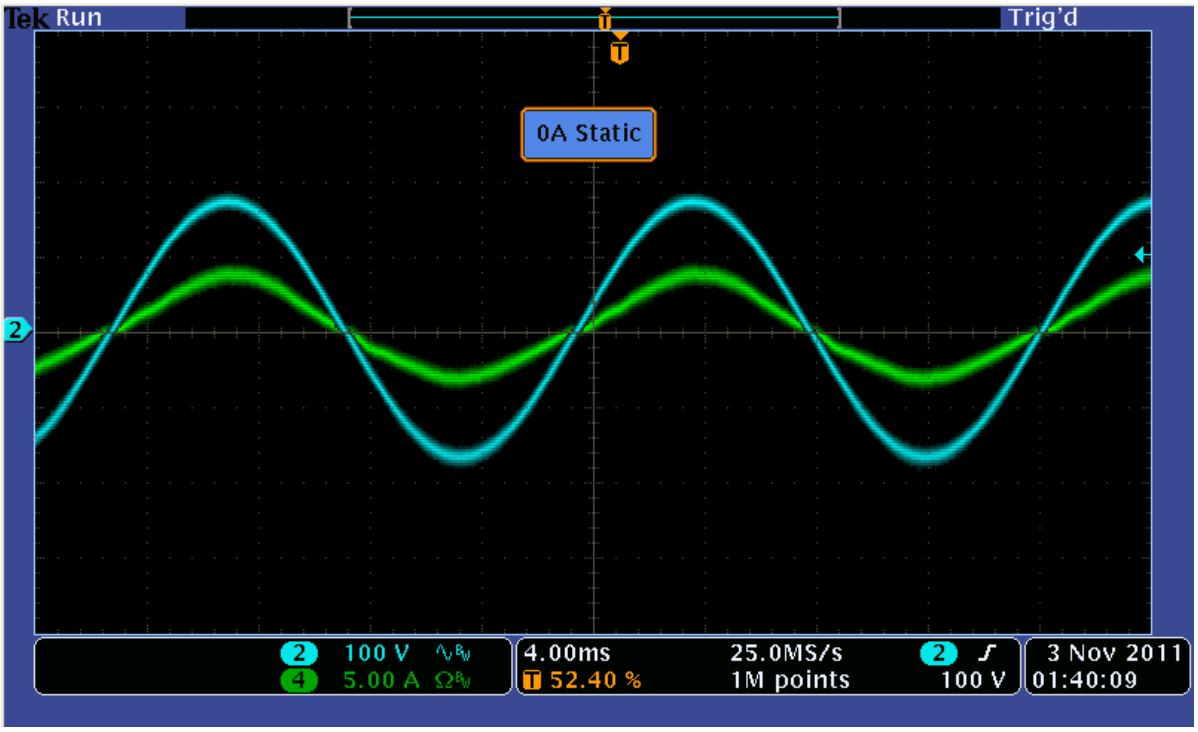


Figure 10 - Grid-Tie Test 2, Ch2: Grid Voltage, Ch4: Solar Inverter Output Current, MPPT Panel Power 330W

References

For more information please refer to the following guides:

- **HV SOLAR DC-DC User Guide & QSG –** provides detailed information on the HV SOLAR DC-DC project within an easy to use lab-style format.
  ..\controlSUITE\development_kits\HV SOLAR DC-DC\~Docs\UG_HV SOLAR DC-DC.pdf
  ..\controlSUITE\development_kits\HV SOLAR DC-DC\~Docs\QSG_HV SOLAR DC-DC.pdf
- **HV SOLAR DC-DC_Rel-1.0-HWdevPkg** – a folder containing various files related to the DC-DC schematics.
  ..\controlSUITE\development_kits\HV SOLAR DC-DC\HV SOLAR DC-DC_HWDevPkg
- **HV SOLAR DC-AC User Guide & QSG –** provides detailed information on the HV SOLAR DC-AC project within an easy to use lab-style format.
  ..\controlSUITE\development_kits\HV SOLAR DC-AC\~Docs\UG_HV SOLAR DC-AC.pdf
  ..\controlSUITE\development_kits\HV SOLAR DC-AC\~Docs\QSG_HV SOLAR DC-AC.pdf
- **HV SOLAR DC-AC_Rel-1.0-HWdevPkg** – a folder containing various files related to the DC-AC schematics.
  ..\controlSUITE\development_kits\HV SOLAR DC-AC\HV SOLAR DC-AC_HWDevPkg
- F28xxx User Guide http://www.ti.com/f28xuserguides