EVBUM2673/D

SEC-3PH-11-OBC-EVB Evaluation Board User's Manual

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EVAL BOARD USER'S MANUAL

Overview

This User Guide describes how to set up and use the 3−Ph OBC PFC−LLC On−Board Charger platform. The system incorporates a 3−Ph Power Factor Correction (PFC) stage based on a 3−leg voltage source inverter and the DC−DC conversion stage based on an LLC resonant converter. Each of these two stages consist of a main board with all the necessary subsystems to run either as an OBC − cascading the boards PFC and LLC− or as separated stand−alone systems.

Features

- OBC system: Power Factor Correction and
- Input voltage − 195−265 Vac (phase)
- DC Bus 700 ±5% Vdc
- Output Voltage – 200−450 Vdc
- GUI to interface with the LLC stage

This User Guides refers to revisions 0.2 and 0.3 for the OBC LLC switch board and revisions 0.2 and 0.3 for the OBC PFC board. For additional information on the design please refer to the available technical notes for the LLC Converter https://www.onsemi.com/pub/Collateral/TND6318−D.PDF and the PFC https://www.onsemi.com/pub/Collateral/AND9957−D.PDF

HARDWARE SET−UP

The two boards are shown in Figure 3. Both boards can work and be used as stand−alone systems separately if needed.

PFC Board

Required parts

- PFC board (included)
- Set of wires and connectors (included):
  - 3−Ph (2.5 mm^2, green, grey, brown)
  - 1−Ph (2.5 mm^2, black, GND, red Vout)
  - 1−Ph internal connector (black or blue, red)
- Three−phase 11 kW AC controllable power supply

Figure 1. PFC Board Photo

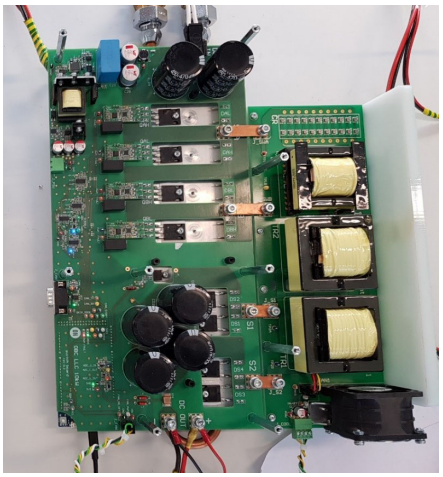

Figure 2. LLC Board Photo

Attention: The SEC−3PH−11−OBC−EVB must be powered by a controlled power supply simulating the AC mains, and is therefore exposed to high voltages. Connection to the AC mains is not supported by the boards. Only trained personnel should manipulate and operate the system. Ensure that all boards are properly connected before powering, and that power is off before disconnecting any boards. It is mandatory to fully read EVBUM2673 11 kW OBC User Manual before manipulating the board and follow the instructions while manipulating it. Failure to comply with the described safety precautions and instructions may result in personal injury or death, or equipment damage.

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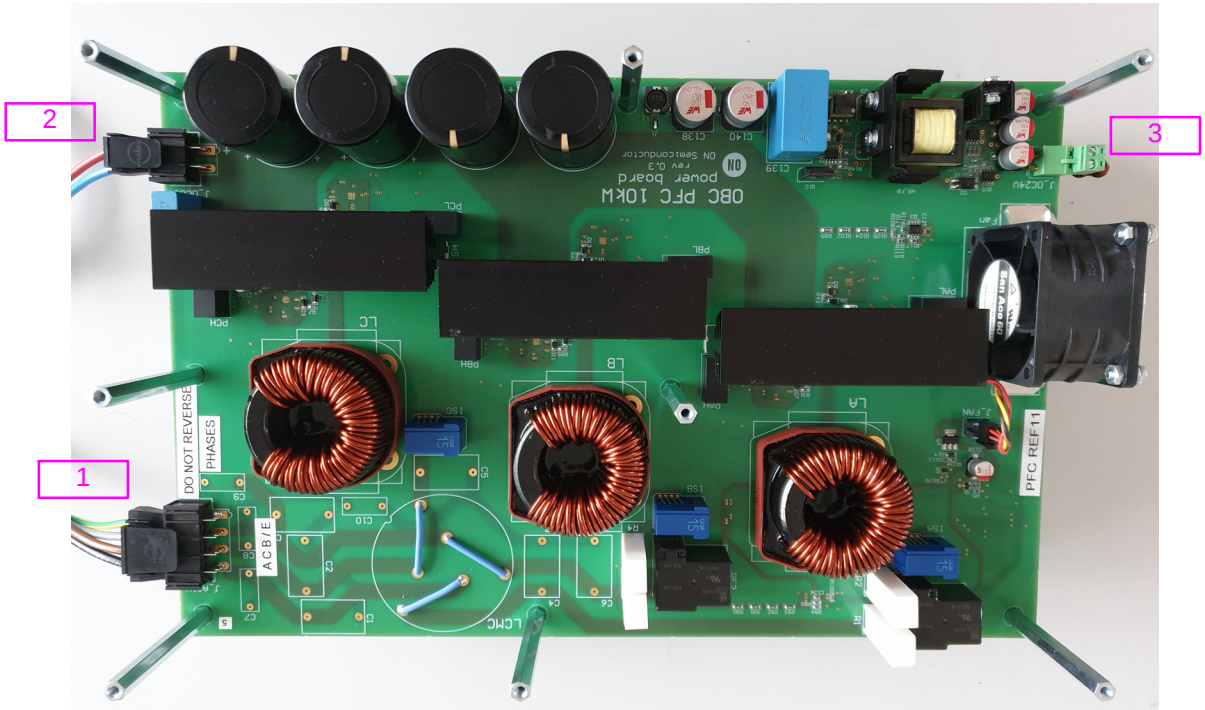

Figure 3. PFC Board Set−up

In order to get up and running the PFC board the power lines and connections marked in Figure 3 need to be plugged in and supplied.

1. 3−Ph input voltage 195−265 AC Vphase.

WARNING: When operating the PFC−3PH−11−OBC−EVB the A, B and C phases should always be connected according to the sequence indicated on the board and never be reversed (see Figure 4 below for reference).
The output of the PFC−3PH−11−OBC−EVB should be loaded ONLY when the output DC bus voltage of the PFC is stable around 700 V ±5%, which is the internally set voltage reference.

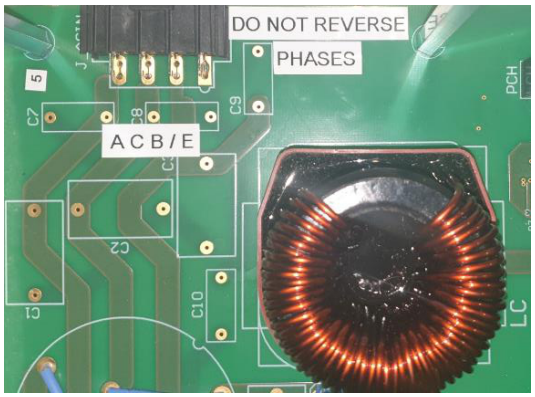

Figure 4.

2. DC link output. Vout 700 V ±5%. This connection is to be plugged to the input of the LLC board when using both boards together as an OBC system.
3. Auxiliary power. This is the connection to power the microcontroller, gate drivers, and all other low voltage ancillary systems. The higher layer needs to be connected to the lower layer as shown in Figure 5.

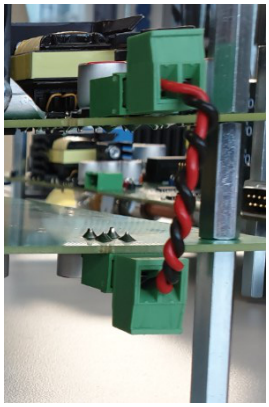

Figure 5. Low Voltage Supply Connection

LLC Board

Required parts

- LLC board (included)
- Set of wires (included):
  - 1−Ph 2.5 mm^2 (black GND, red Vin)
  - 1−Ph (4 mm^2 black GND, red Vout)
  - USB cable – USB to USB micro−B shielded (at least 50 cm)
- Ferrite clamp
- Regulated load 220−450 V (10−11 kW)
- Coolant system and hose
  - Connectors (provided):
  - Brass Hose Nozzle ¾ Inch x 19 mm Nozzle”
  - Brass Hose Nozzle ¾ Inch x 13 mm Nozzle”

In order to get up and running the LLC board the power lines and connections marked in Figure 6 need to be plugged in and supplied.

1. USB connection to the Arduino Due (Microcontroller). For proper operation of the LLC board the USB cable needs always to be connected to the Arduino Due before powering up the board.
2. DC voltage output. To be connected to a suitable load, functional range between 200 to 450 V (4 mm^2 black GND−red Vout)
3. DC bus. VDC 700 ±5% max. to be connected to a load. (2.5 mm^2 black−GND, red BUS)
4. Coolant system. The switch−board is attached to a cold plate which needs water cooling. Therefore a coolant system is required and it needs to be attached to the cool plate via one of the provided hose connectors.

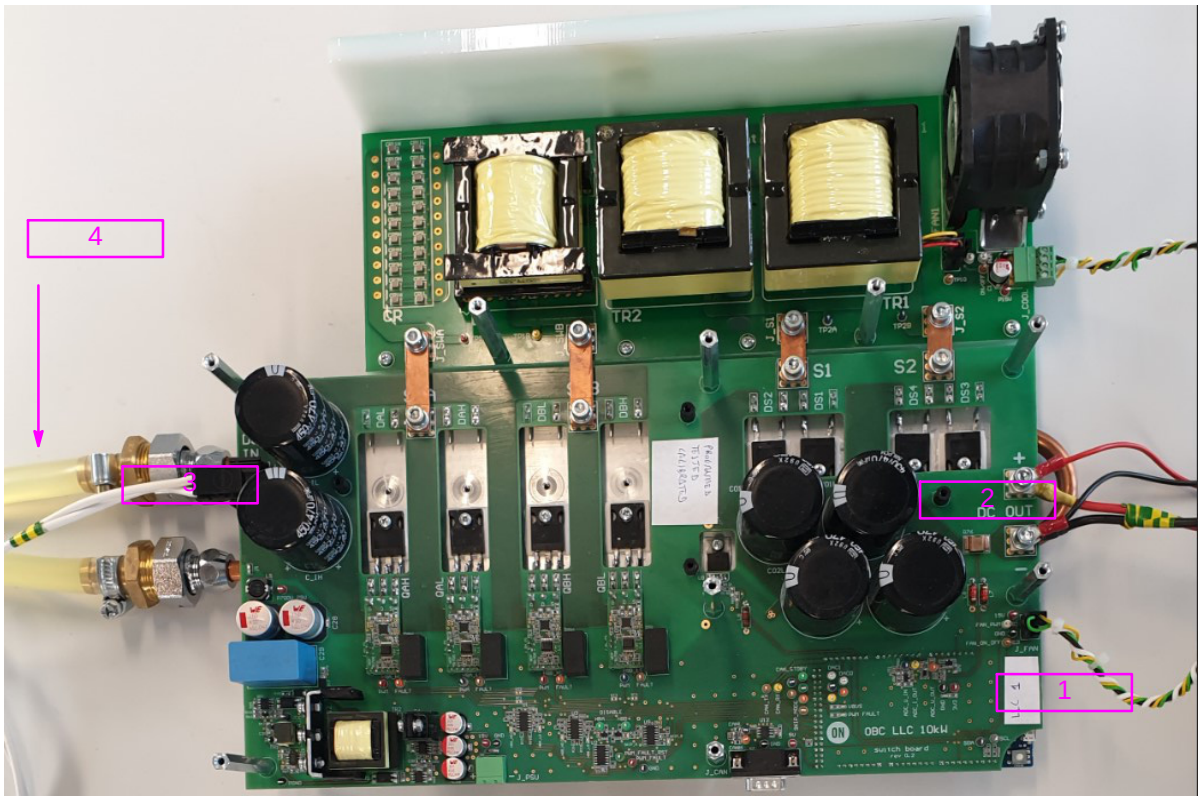

Figure 6. LLC Board Set−up

The board is fully functional and in order to run tests on the LLC board the GUI is needed. This interface, allows, among others, to set the proper output target voltage.

Table 1. SPECIFICATION AND MAX WORKING PARAMETERS

	PFC	LLC
Vin	167−265 Vac (phase) @ 50 Hz	700 ±5%
Iin	17 Arms Iphase	14.3 A @700 V
Vout	700 ±5%	220−450 V
Iout	14.3 A @700 V	0−40 Amax
fs	60−140 kHz	400 kHz

POWER−UP AND GUI DESCRIPTION

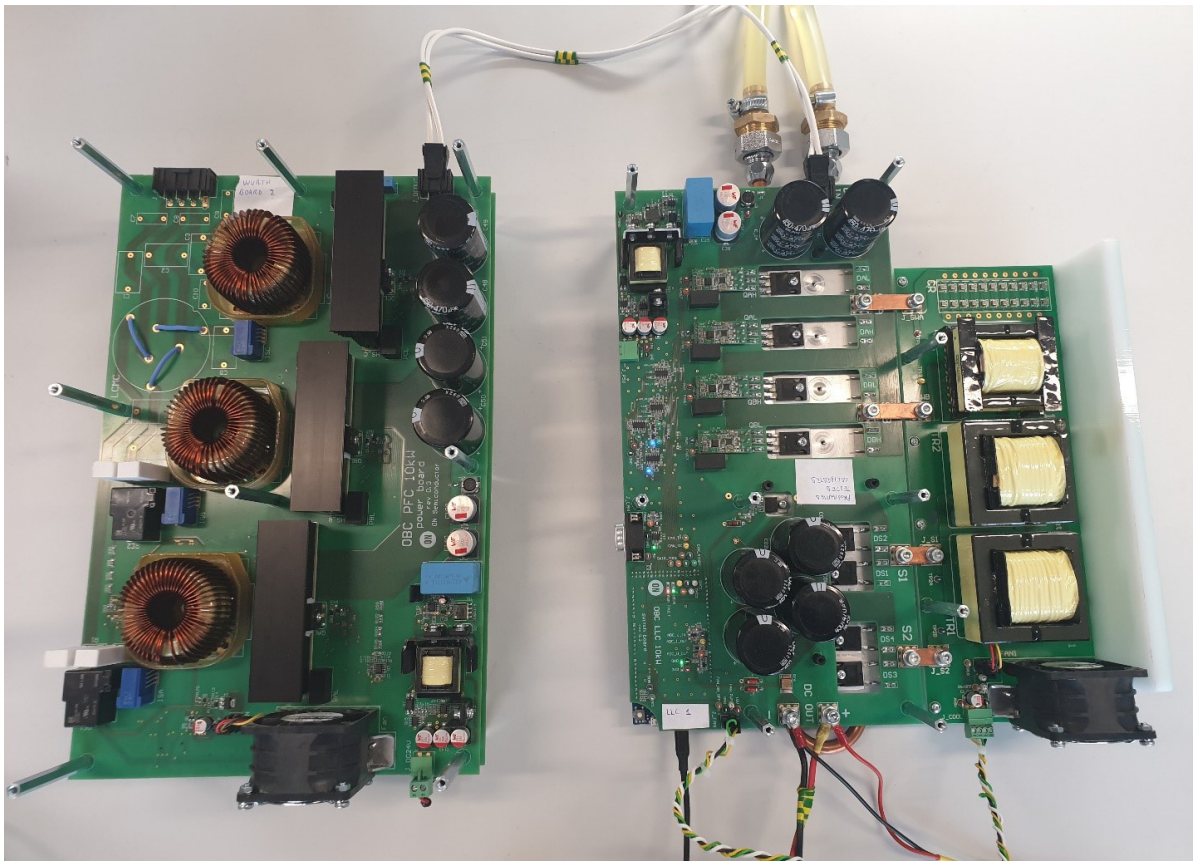

Figure 7. On−Board Charger System. PFC and LLC Boards

PFC

In order to power the PFC board up it is only required to plug in the 3−Ph supply voltage (195−365 Vac phase and 10−11 kW) and the system will self−regulate itself to deliver 700 V ±5% at the output. **Please ensure that the three phases sequence are plugged according the instructions in Hardware Setup section and the indicators on the board.** User can perform voltage and current measurements directly on the hardware. There is no need to connect USB to the Arduino Due for this board. **The output of the PFC−3PH−11−OBC−EVB should be loaded ONLY when the output DC bus voltage (of the PFC) stabilizes around the internally set reference of 700 V ±5%.**

LLC

In order to set up the communication with the LLC board connect the provided USB cable to the USB port of the Arduino Due board. Be sure that the cable is plugged to the closest to the power jack USB connector provided on the Arduino Due board, and then connect the other side to the PC (or laptop). In case the cable is missing in the box, you need to procure a USB to USB micro−B type. It is important to remind that such cable should be shielded and a ferrite clamp should be used on the cable. At least 50 cm long cable would be needed. The Arduino Due board gets powered through the USB connection and the LLC_GUI application is ready to be lunched. Download the GUI from the product website or contact your sales office. *The LLC board should always be used with the USB plugged into the Arduino Due and run with the GUI. Please do not power up the board without the USB cable connected.*

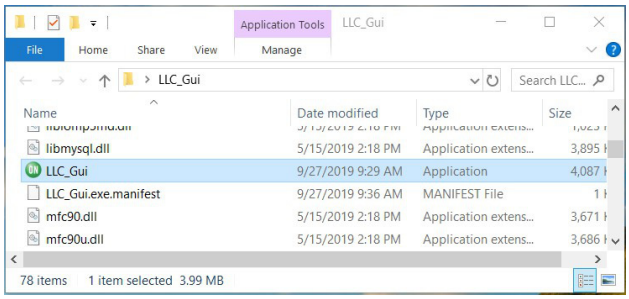

Figure 8. GUI Software Package

Scroll the LLC_Gui folder until the “LLC_Gui.exe” file is reached (Figure 8), a green ON Semiconductor symbol will help to identify it. Double click on it and the following window on Figure 9 will open. This window represents the back panel of the GUI. It is not intended for user interaction but it can be, eventually, monitored in order to see the serial

communication status. For example it can show communication error between the application and the micro firmware. It might be possible that sometimes the communication is hanging. In case of such possibility, the application has to be closed by clicking the “x” on this window and open it again.

Figure 9. GUI Back Panel

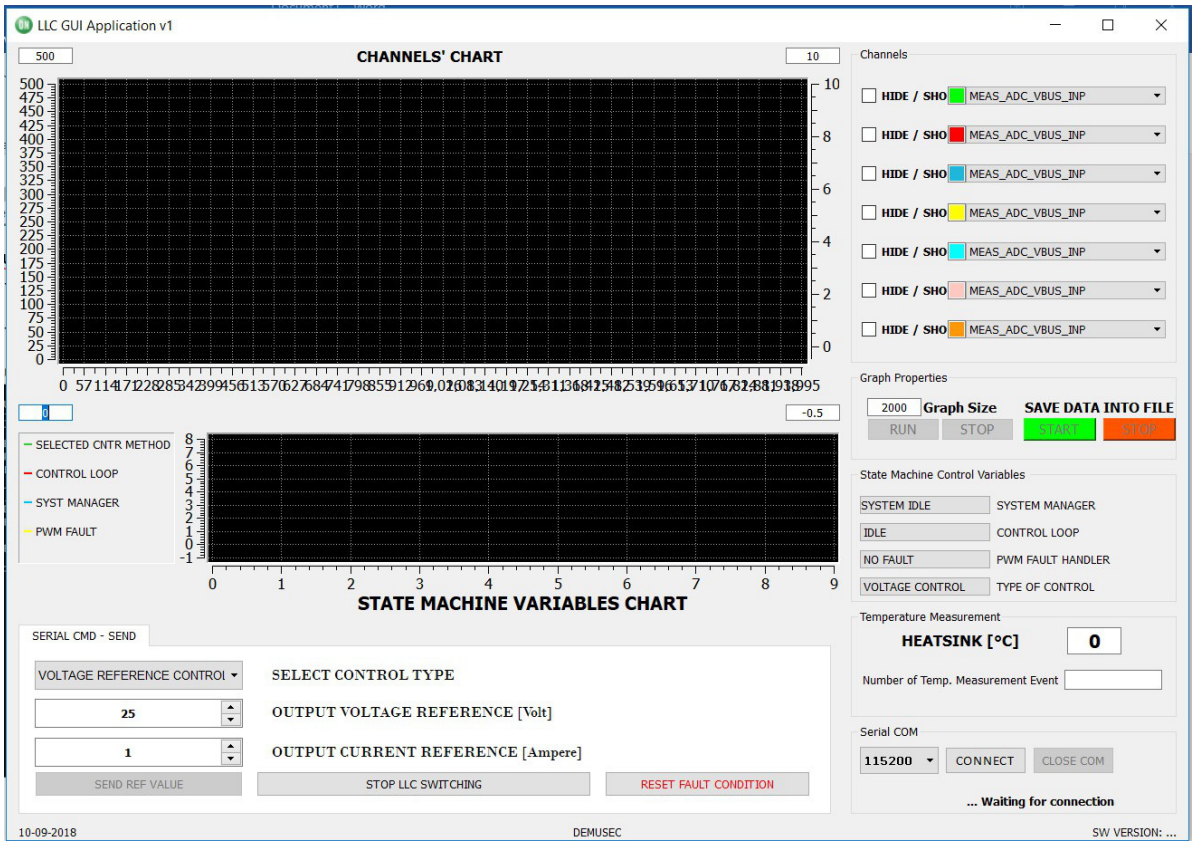

Figure 10. GUI Front Panel

Overview and Description of the Front Panel

- How to Establish a Serial Communication?

In the serial communication panel (Figure 11) the first drop−down menu selects the baud rate. The value has to be kept to 115200 and there is no need to change it otherwise the protocol will fail. The “CONNECT” button establish a connection with the microcontroller and the label “… Waiting for connection” provides a feedback about the current communication status. Once clicked, the situation will change in the following way: The label is changed into “…Connected” and info regarding the SW version of the microcontroller is provided. The correct value is “0703”. “CLOSE COM” will be available and it will guarantee the end of the communication.

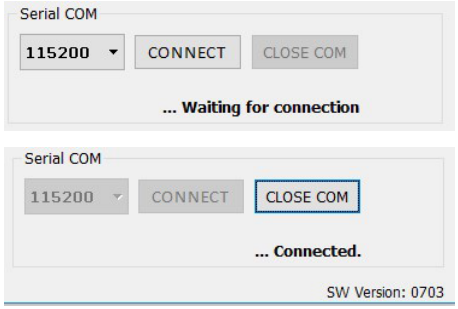

Figure 11. Serial Communication Panel

- Variables' Selector and Actual Setup:

The GUI is capable of showing up to seven software/control variables at the same time. These variables can be changed at run−time, if desired (Figure 12). Each of them has a defined color and there is the possibility to hide/restore each of them from the time−chart by checking the squared box. A preselection of variables is present:

1. "MEAS_ADC_VBUS_INP": Measured input voltage of the LLC, which should be 700 V. LLC should be operated starting from 700 V. However, such value does not represent accurately the input voltage because of the implemented HW method. (Refer to the available schematic for more information about the input voltage reading).
2. "MEAS_ADC_IBUS_OUT": Measured output bus current.
3. "MEAS_ADC_VBUS_OUT": Measured output bus voltage.
4. "DBG_REF_VOLT": Reference voltage, the one sent over the serial protocol and coming from the GUI.
5. "OUT_CMD_PERIOD": Command period, it represents the value of the internal register describing the switching speed. Higher the period, lower the switching frequency.
6. "OUT_CMD_DUTY": Command duty, it represents the behavior of the skip mode functionality. When the value goes low, it implies that the output load is either very low or the target output voltage is very low.
7. "PIREG_VOUT_REF": reference output voltage, it represent the target is supposed to be achieved and controlled by the internal voltage regulator.

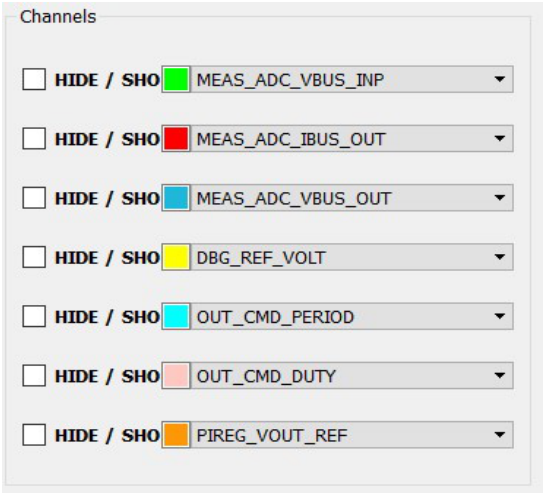

Figure 12. Variable Selector

- Chart Properties and Data Saving:

"Graph size" modifies the number of points the chart will show.

"RUN" starts the continuous variable reading, while "STOP" will arrest it.

The green "START" and "STOP" will allow storing the serial data into csv file that are collected in a folder "LLC_GUI_DATA" generated on the Desktop. The file name structure is "DATA" + the day of testing and the time.

Figure 13. Properties and Data Saving

- State Variables:

The list represents the current state of the different state machines implemented in firmware. It is beyond the scope of this document describing every possible value although their name and their value can be somehow intuitive.

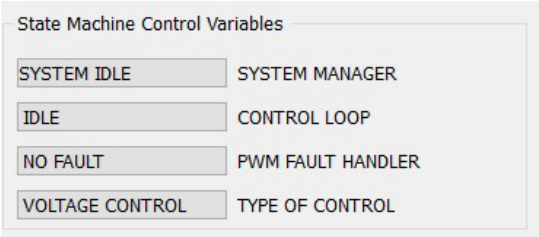

Figure 14. State Variables

- Heatsink Monitor:

The coldplate on which the mosfets and diodes are attached is also provided with an I^2C based temperature sensor. In order to operate safely, the coldplate should be attached to a chiller that provides the heat dissipation in order to keep the switches inside their safe operating conditions. The measured temperature is shown in °C and the box below the actual temperature value is showing a counter for the measurement. It might happen that the sensor is stuck because of noise issue coming from the switching; therefore, the counter will not increment its value. It is a way to monitor the activity of the sensor.

Figure 15. Heat Sink Monitor

- Command Interface:

This is the portion where the user can control the behavior of the LLC. In order to operate here, it is needed that the input voltage is provided. Then it is possible to select between a “voltage control mode” and a “current control mode”. In case of voltage control mode, the reference voltage has to used, otherwise the reference current. Once completed the selection, the “SEND REF VALUE” has to be pressed. In case it is required to stop the LLC board, it is possible to press the “STOP LLC SWITCHING”, it could be an option in case it is desired to stop a test. “RESET FAULT CONDITION” reinitialize the hardware and the software to an idle state in case a failure is detected.

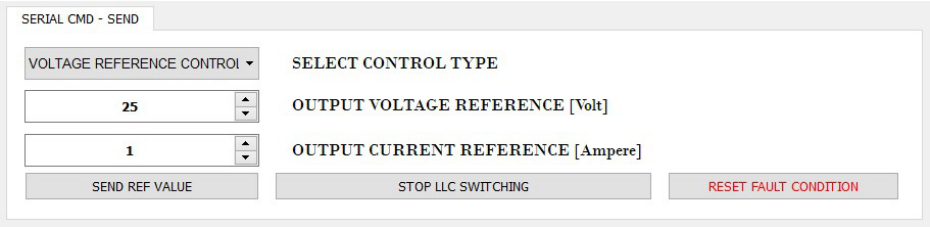

Figure 16. Command Interface

- Graph Chart :

Chart on which the data sent over the serial protocol will be collected similarly to what an oscilloscope would do. In order to understand the logic of the axes, the left side is intended to show “high” value quantities, like voltages, while the right side is intended for “low” value quantity, like currents. The Y axis range is not adjusted automatically, but it has to be changed by using the 4 boxes at the corners.

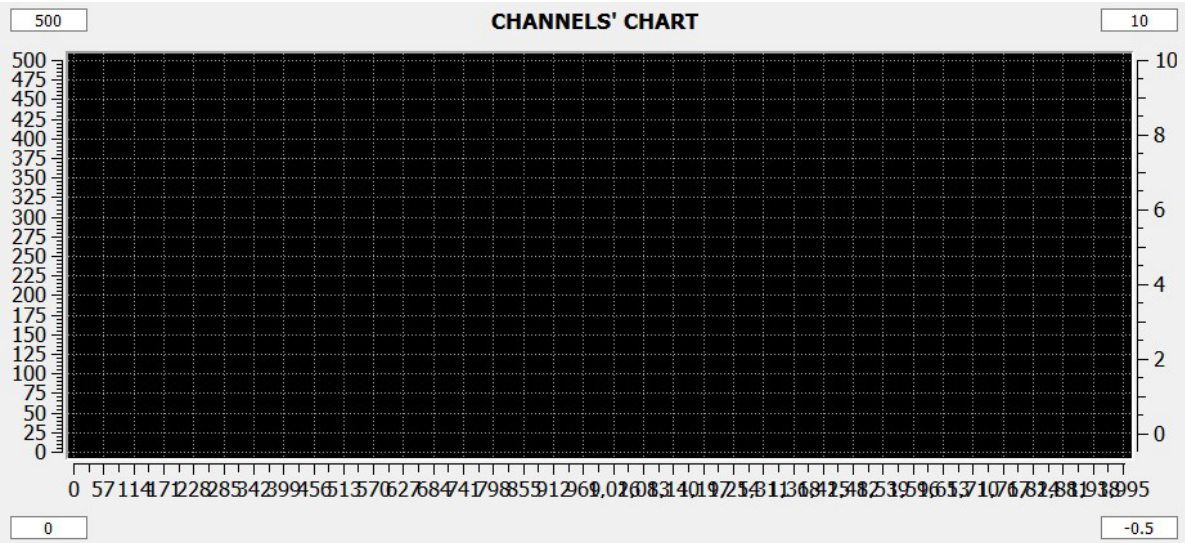

Figure 17. Chart Graph

Please, do not use "Enter" button after any box modification. Instead use "TAB". The usage of "Enter" will trigger a "SEND A REF VALUE" command that is not desired by this modification.

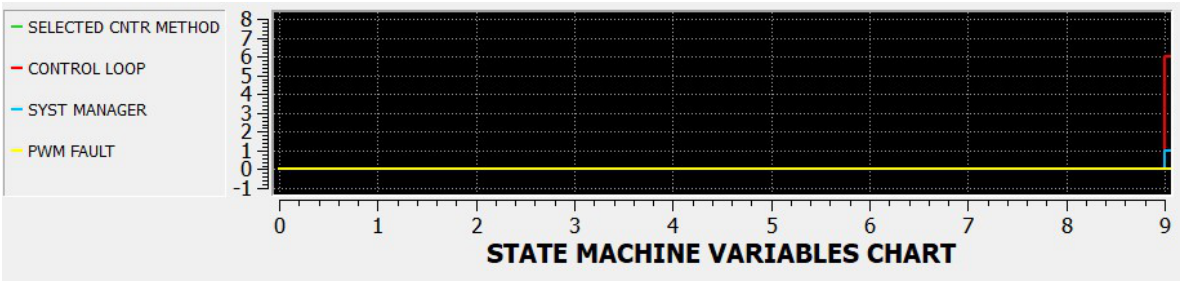

Figure 18. State Machine Variable Chart

The state chart is updating only when a transition in any of the state variables is happening. The behavior is not time related. The values shown on this graph are not saved in the text file. *In any case, these two graphs will not be filled with data until the "RUN" button is not pressed*. When sending commands, it is possible that at the first try, the command is not accepted, please send it multiple times until it is accepted. In any case, keep an eye on the serial monitor to evaluate the response of the microcontroller, normally a response starting with 0 x F… that means not acknowledged.

OBC SYSTEM OPERATION

This section describes how to run the OBC system with the PFC and LLC boards together. It also discusses the expected behavior of the board when operated according to this note.

Once provided the AC voltage to the PFC, the LLC starts to sense the input bus voltage:

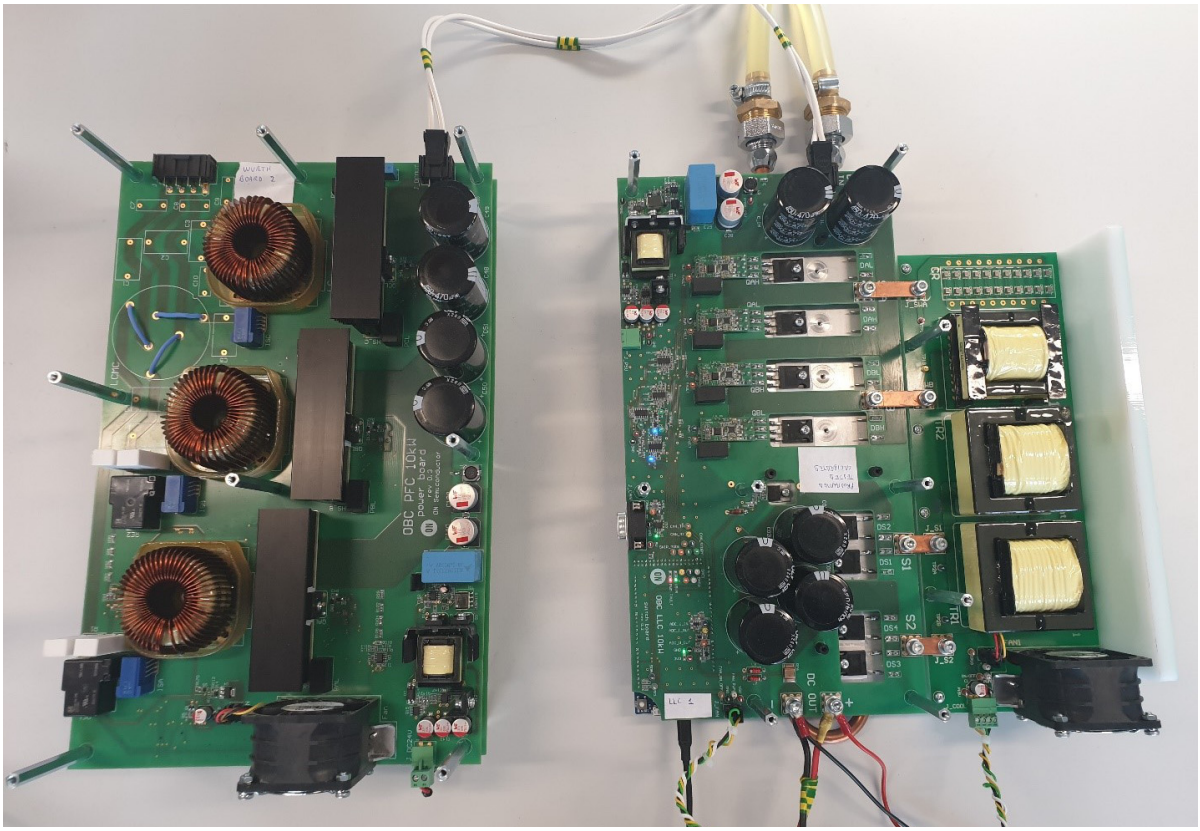

Figure 19. OBC System. Three−phase Voltage Source Inverter PFC (Left) and DC−DC LLC Resonant Converter (Right)

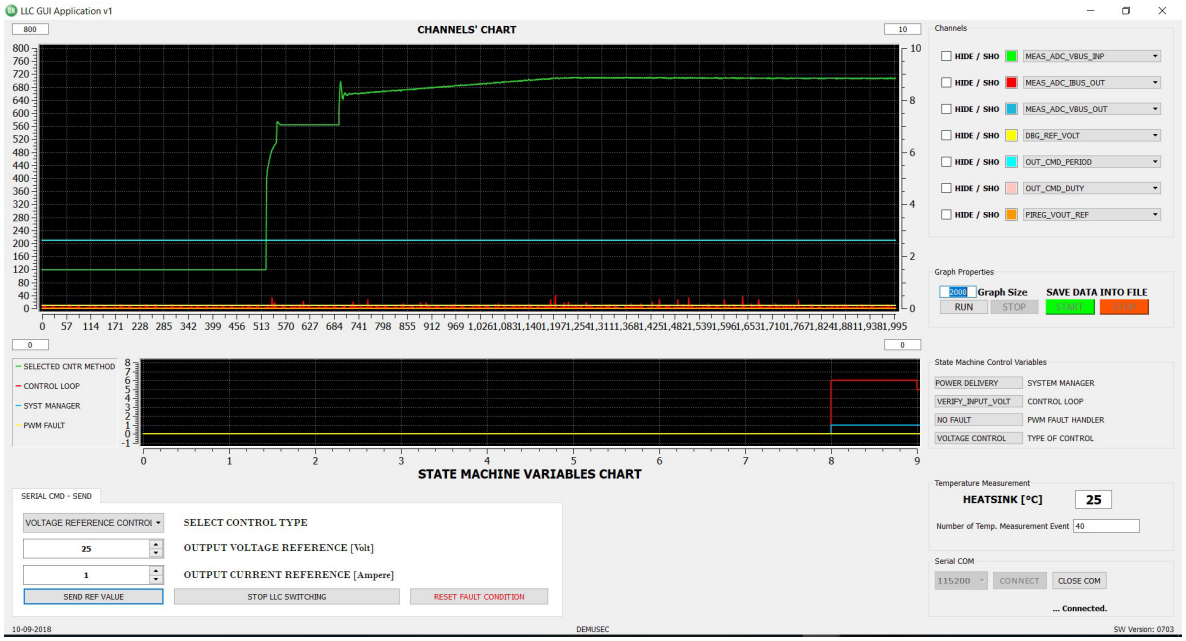

Figure 20. GUI front panel. Bus Voltage

In Figure 20 it is visible the presence of the bus voltage on the LLC. This will ensure that the board can start to operate normally. Be aware that we are talking about power boards and therefore they should be enclosed in ad hoc boxes to ensure safety precautions.

Voltage Control Mode

Let's consider first the 'voltage control mode' and let's target an output DC voltage of 220 V. Before sending the message to the microcontroller, we can set the DC load ON and, eventually, set a current load of 100 mA. It is not mandatory for operation but a small load will help starting. Once edited the fields, press "SEND REF VALUE".

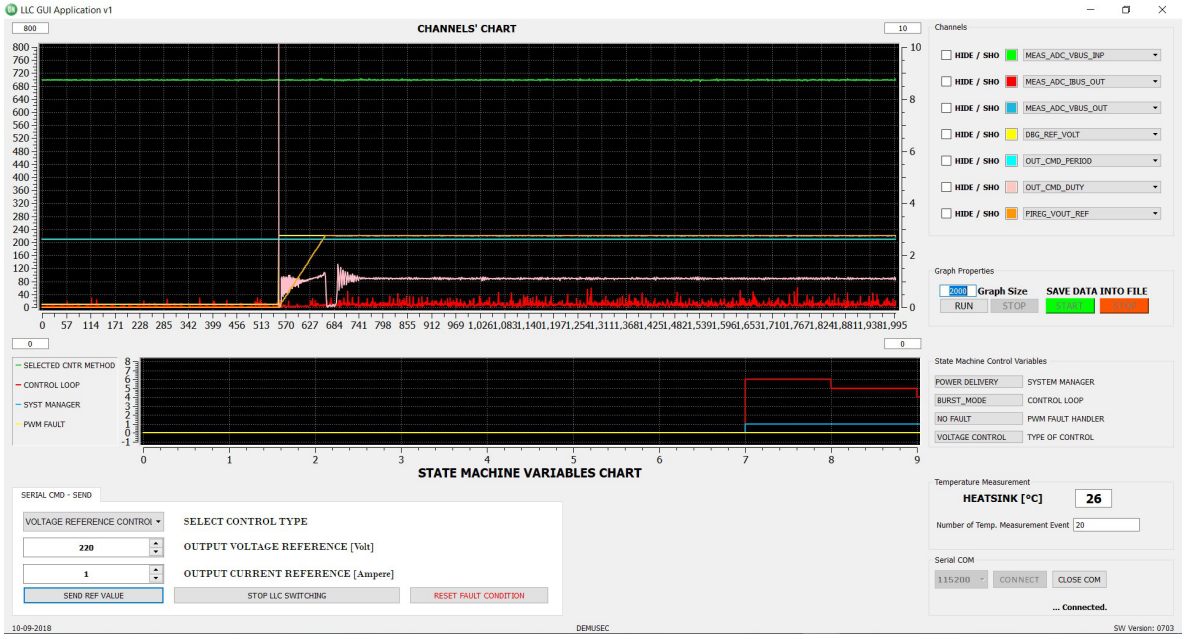

Figure 21. GUI Front Panel. OBC System Power Up

Basically, if there is no need to change the voltage working conditions, we can use the GUI only for monitoring the behavior of the firmware. For example Figure 22 shows a current load variation keeping the voltage regulated at 220 V. The current load variation is happening at DC load equipment level.

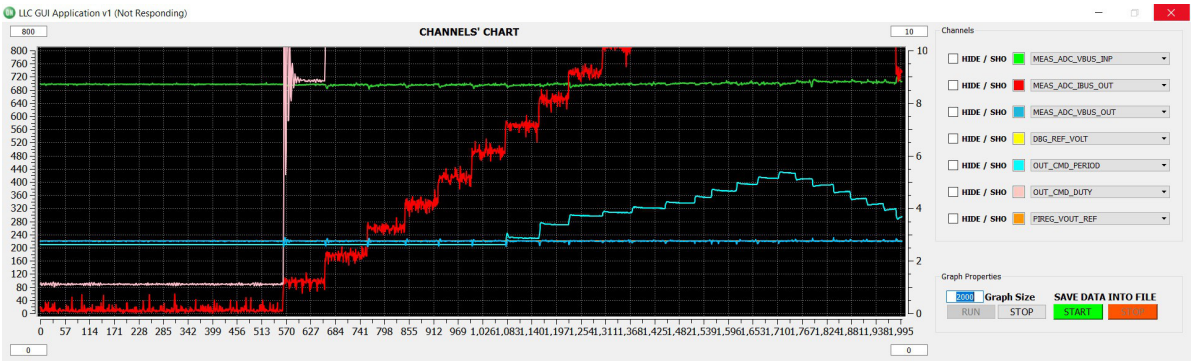

Figure 22. Current Load Variation at Constant Voltage 220 V

It is possible to see that LLC is capable of keeping the bus voltage to 220 V, while changing the load conditions. As the load current target is changed, at DC load level, first the OUT_CMD_DUTY is increasing, escaping the burst mode conditions, which means working at 400 kHz, max operating frequency of the application. In order to increase further the output current, keeping the voltage under control the OUT_CMD_PERIOD is starting to increase decreasing the switching frequency, as it should. If needed, we can update the reference output voltage by changing the voltage reference and pressing again the “SEND REF VALUE”.

Current Control Mode

In ‘current control mode’, the LLC behavior does not change. It is more important to remind how to safely operate the equipment connected to the LLC board in order to ensure the proper behavior of the application. The assumption done here is that the DC load used for the test is capable of providing a voltage control mode and a current control mode. In order to enable the current control mode on the LLC, it is needed to ensure that the DC Load is operating in voltage control mode. Therefore, the DC load should not trigger the current control mode options; an easy way to do so is increasing the current target value to a high value, like 20 Amp or more. Here it has been requested a current of 3 A, while the load is operating at 250 V (Figure 23).

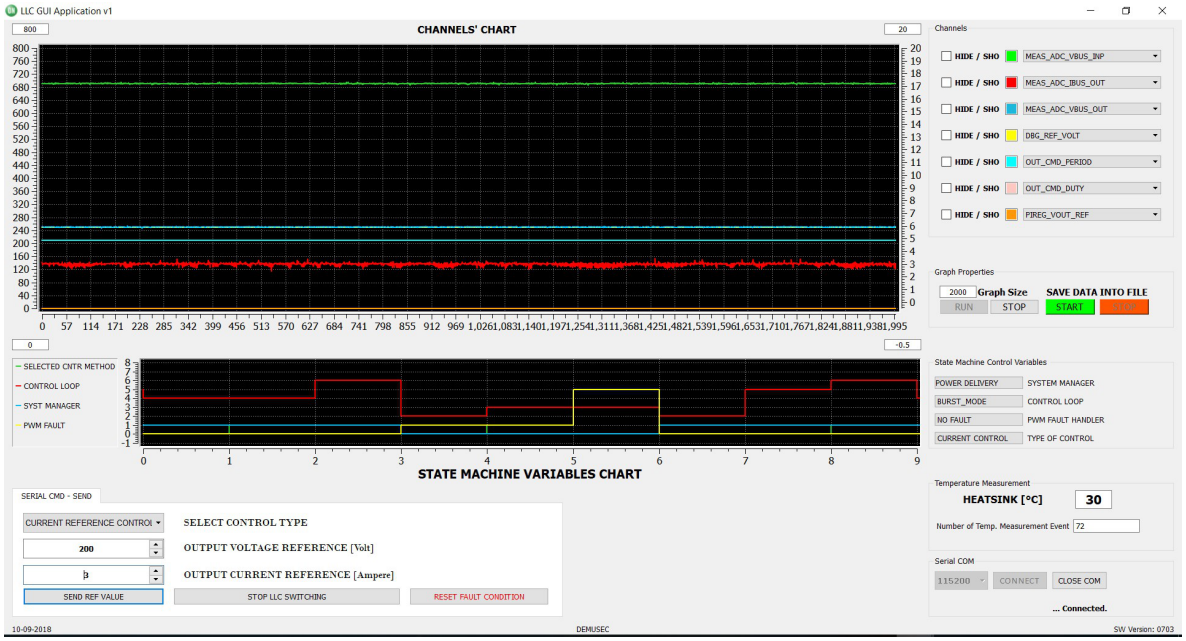

Figure 23. Operation Point : 250 V Voltage Bus and 3 A for Load

This is what happens by changing the voltage target on the DC load. It is visible in Figure 24 that the DC output voltage goes from 250 V to 320 V while the output current is still at 3 A.

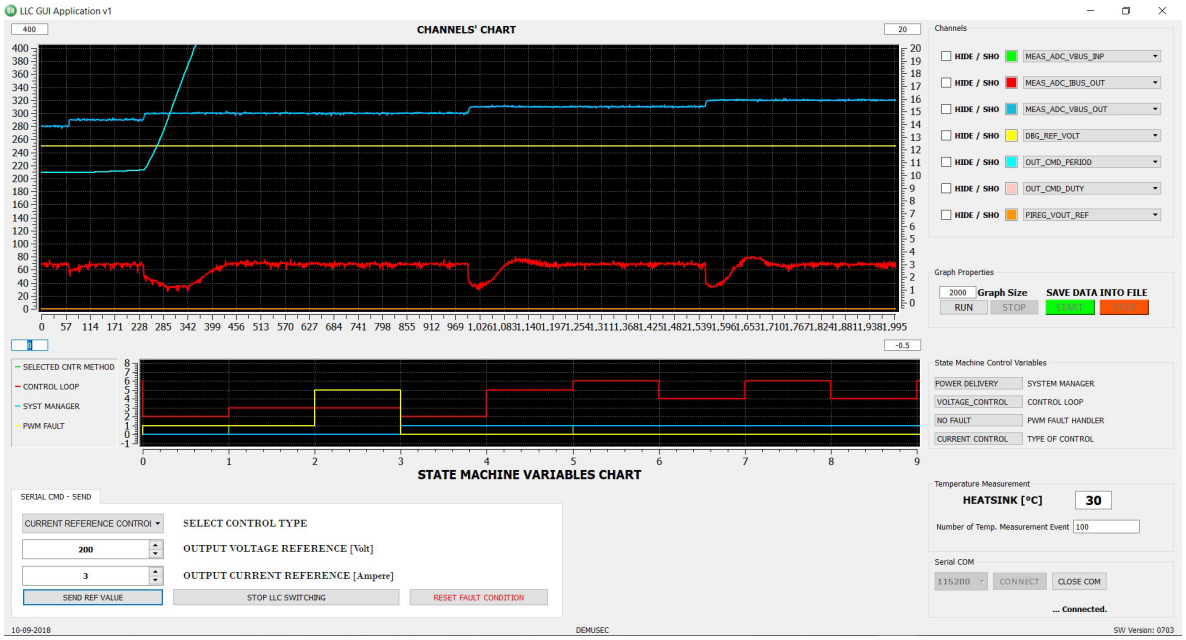

Figure 24. DC Link Voltage Increase after Defining 320 V as Set Point

Figure 25 shows current evolution when changing the current target at GUI level (here double step on the current), from 3 A to 1 A and then to 10 A.

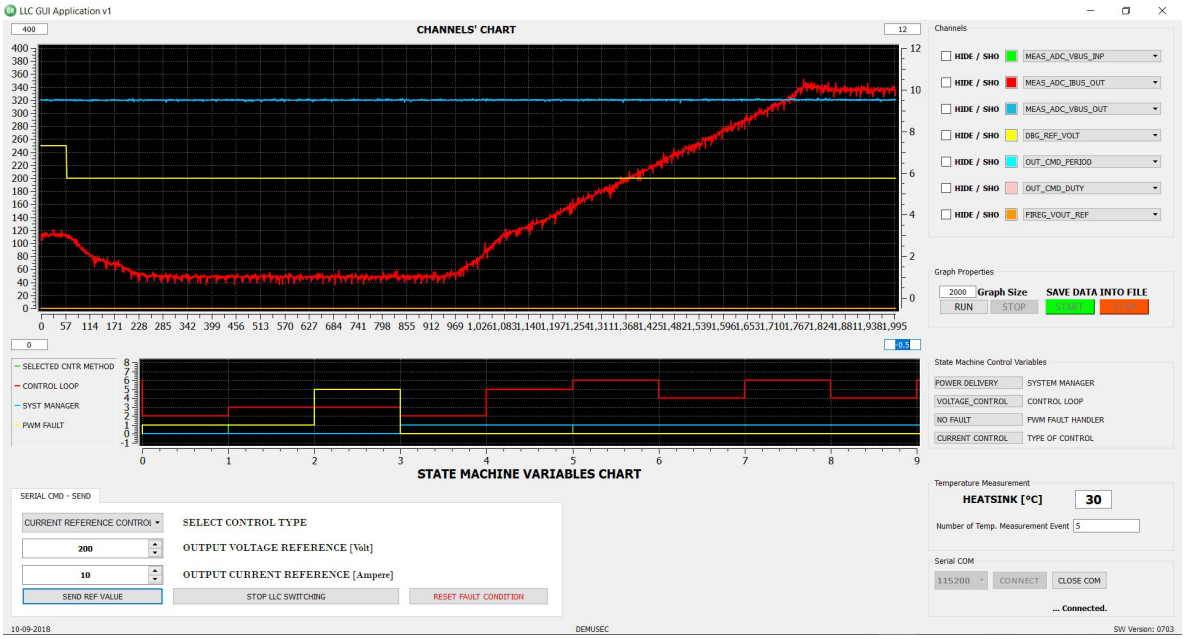

Figure 25. Current Evolution Following Multiple Set−point Variations. 1) 3 A, 2) 1 A and 3) 10 A

The output voltage stays the same while the current is regulated. The PI parameters are left intentionally ‘soft’ to show the regulation reaction compared to the voltage control mode.

Figure 26. Load Conditions for Current Control Mode. Beginning of the Mode (Above) and End of the Mode (Below)

Power Down

To stop the test it is better to reduce the load and then remove the input voltage, at PFC level. In any case, if a sudden turn off is happening at load level, an over current protection will be triggered on the boards. Such fault, in case of abnormal conditions, makes the turning off a safe procedure.

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