C-HIL simulation scenario with OPAL-RT simulators

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This page presents a first HIL example to get started with a B-Box RCP and an OPAL-RT OP4510. Although validated with an OP4510, the provided files can be adapted to the new OP4512 or other OPAL-RT simulators.

The considered circuit, shown in Fig. 1, implements a dual-stage conversion structure, using a boost DC/DC stage in order to raise the voltage of the PV panel to an intermediate DC bus, as well as a two-level DC/AC inverter for the connection to the grid.

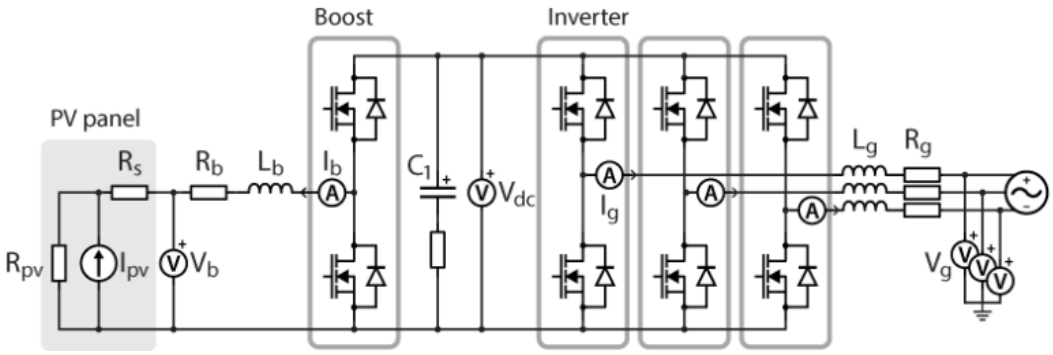

Fig. 1. Considered plant (largely inspired from the AN006).

While the real-time control is managed by the B-Box RCP (as for a real power stage), the plant is emulated in the OP4510. This configuration is often referred to as C-HIL (Controller Hardware-In-the-Loop). This scenario is depicted in Fig. 2.

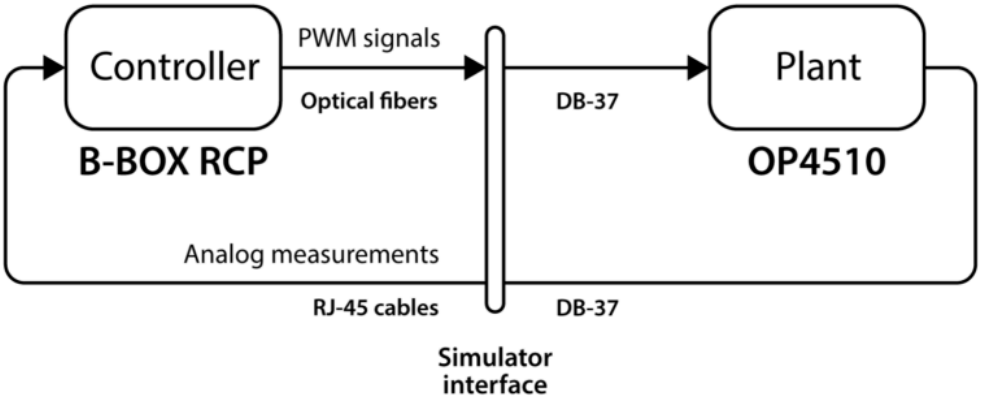

Fig. 2. C-HIL scenario.

This emulated circuit is a simplified version of the one provided in the AN006, where a more detailed introduction to the circuit and a description of the controller implementation are available.

Considered software setup

This example was created with the following software versions:

- Imperix ACG SDK 2024.1
- Matlab 2022b
- OPAL-RT RT-LAB 2024.1

Imperix supports all Matlab versions, starting from 2016a. For Opal-RT products, more information about the compatibility between Matlab and RT-LAB can be found in RT-LAB: Basic Concepts and Compatibility and RT-LAB release schedule & policy.

Downloads

The Simulink model running in the B-Box RCP and the RT-LAB project running in the OP4510 are available below.

Download **Central_PV_inverter_OPAL_HIL_BBOX.slx**
Download **Central_PV_inverter_OPAL_HIL_OP4510.zip**

Physical setup

Hardware requirements

Imperix and OPAL-RT products :

- 1x Imperix B-Box RCP
- 1x Imperix Simulator Interface for OPAL-RT
- 1x OPAL-RT OP4510

Additional components :

- 9x RJ-45 cables
- 8x optical fibers

The OP4510 has now been replaced by a new version, namely the OP4512. This example can be adapted for the newer OP4512 or other OPAL-RT simulators. Please contact the OPAL-RT Support if you need any help adapting this example for other OPAL-RT simulator platforms.
For this example, Digital Input and Analog Output IO boards are required for the OP4510. Although optional, those boards are included in the OP4510 standard configuration.

Wiring

The wiring is depicted in Fig. 3. Power supply and Ethernet connections of both the B-Box RCP and the OP4510 are not shown.

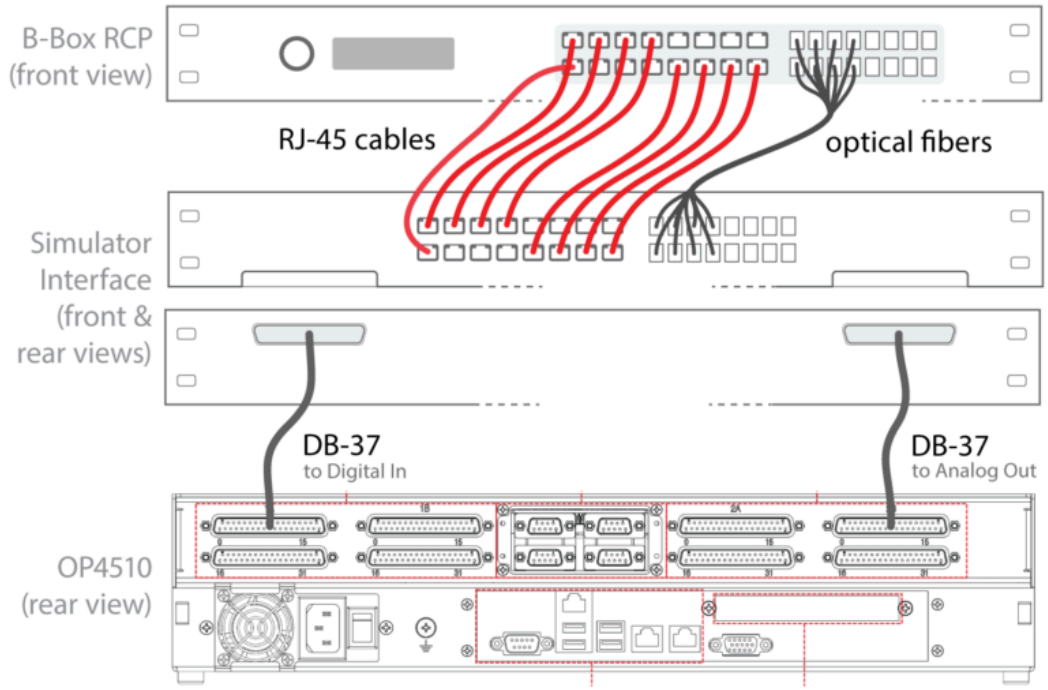

Fig. 3. Wiring between the B-Box RCP, the simulator interface and the OP4510.

This example assumes that the Digital Input and Analog Output IO boards are mounted on slots 1A and 2B, respectively. This order may vary, please check the IO boards order of your simulator.

The final setup is shown in Fig. 4.

Fig. 4. Setup after wiring, ready to run.

Step-by-step setup guide

Launch the plant simulator (OP4510)

To launch the simulator,

1. Open RT-LAB and select/create a workspace.
2. Make sure that your simulator is listed in the 'Targets' list of the Project Explorer. Then, make sure that the simulator is reachable by double-clicking on it and checking that the 'State' field is 'up'.
3. To import the project, click on File > Import > Existing RT-LAB Project, select 'Select an archive file' and set the path to this example's archive. Press 'Finish'.
4. Double-click on the project to open it.
5. To open the model's overview, expand 'Models' and double-click on the model in the project hierarchy.
6. Build, load and execute the model by clicking on 'Build', 'Load' and 'Execute' in the Operations tab on the right.

All projects must have different names in RT-LAB. Make sure that any other project or any folder in the workspace is called 'Central_PV_Inverter_OPAL_HIL_OP4510' (folder name in the archive) before importing the project.

When loading the RT-LAB project on the OP4510, another Simulink model is automatically generated and opened by RT-LAB. This new model can be used to monitor measured quantities through scopes, or set the PV panel output current (see *Ipvs* on Fig. 5).

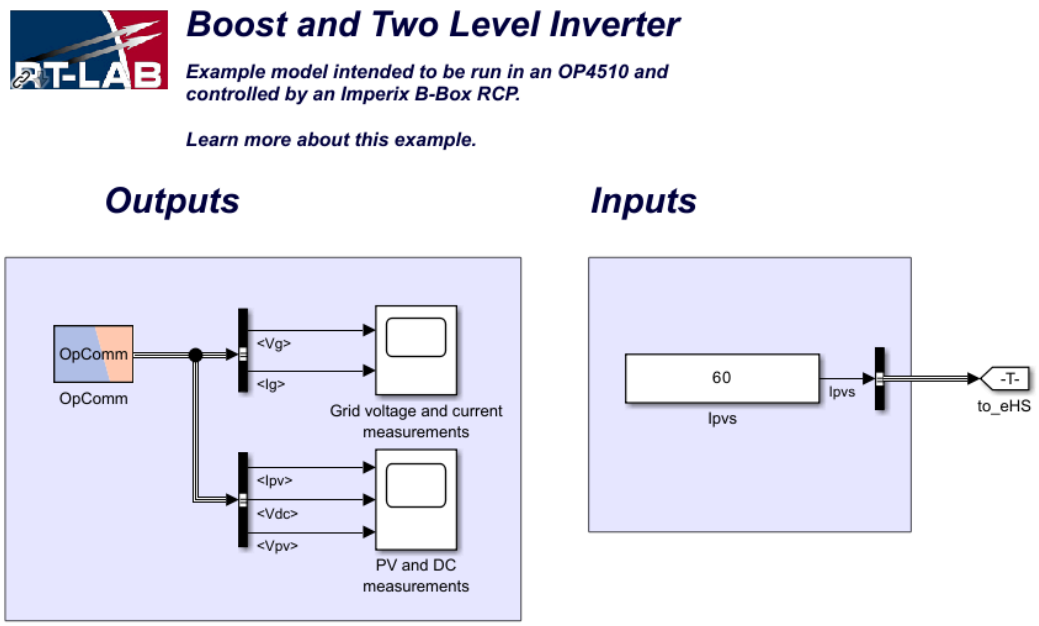

Fig. 5. Monitoring model, automatically generated and opened by RT-LAB.

Launch the real-time controller (B-Box RCP)

From the B-Box RCP point of view, there is no difference between a HIL simulation – as in this example – and controlling a real power converter: the controller receives analog measurements produced by the simulator and generates in return PWM signals through optical transmitters.

To launch the controller,

1. On the B-Box front panel, set the gains of channels 0-3/12-15 to 4 and the gain of channel 8 to 2. More information about the front panel configuration can be found in the PN105.
2. Open the Simulink model and check that 'Automated Code Generation' is selected in the Configuration block.
3. Press Ctrl+B to build the code. Cockpit will automatically launch at the end of the build process.
4. In Cockpit, select the B-Box based on its IP address and press 'OK' to open the project.
5. Add scopes to monitor the signals of interest (e.g. Vg,abc, Ig,abc).

When ready to operate, enable the PWM in the project sidebar on the left.

Results

Expected results are shown in Fig. 6. One can easily verify that injected current is in phase with the grid voltage, while the PV current and DC bus voltage follow the desired references.

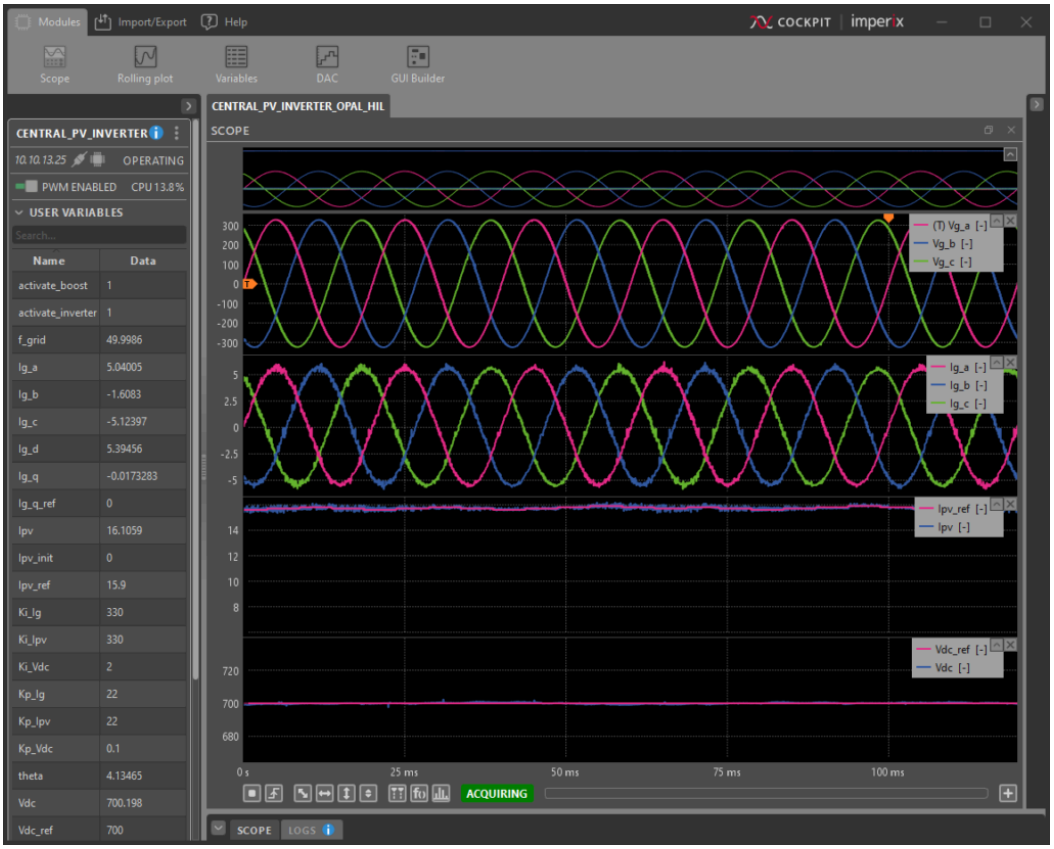

Fig. 6. Expected results in Cockpit.

Additional useful hints

Sensitivity and gain

The Imperix model is ready to operate with a real power stage (e.g. using imperix products): appropriate sensors are already selected in the ADC blocks, explaining why the considered sensitivity can vary among the measured quantities. Those variations are already taken into account in the power circuit from the RT-LAB project, where gains for the analog output have been set adequately.

The programmable gains (x1, x2, x4 or x8) set in the ADC Simulink blocks must match those set on the B-Box front panel.

The sensitivity and/or the selected sensors can be freely changed. However, make sure that the gain set in the power circuit in the OPAL-RT Schematic Editor matches the sensibility set in the Simulink model, or vice-versa.

Interface power supply

As indicated in the datasheet, the Simulator Interface for OPAL-RT is supplied with 12V through the pin #17 of the DB-37 connector. If the interface is not working properly, it is recommended to check that voltage.

In case this voltage is not sufficient (i.e. < 12V), the interface can be supplied with an external DC source via the GND and 12V pins (see Fig. 7).

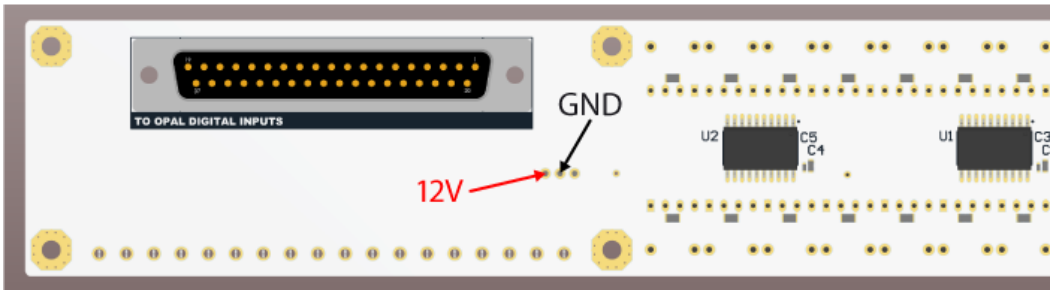

Fig. 7. Power supply pins on the interface.

Use other IO channels

Used channels can be easily changed. For instance, if channel 9 must be used instead 8 for the Vdc measurement, the following changes can be followed:

1. Change the Input channel number accordingly in the Imperix ADC block in the B-Box Simulink model.
2. Physically, move the RJ-45 cable from RJ-45 port 8 to 9 on the B-Box front panel and on the interface. Ensure that the programmable gain of channel 9 is correct (2, in this example) on the B-Box front end.
3. In the Simulink model of the RT-LAB project, move from the top-level to the 'SM_eHS' subsystem and double-click on the 'eHS' block. This will open the power circuit model in the OPAL-RT Schematic Editor. From there, select the Vdc voltage sensor and click on 'AO' in the right side panel. Then, change the pin parameter from 'Slot 2B Channel 08' to Slot 2B Channel 09'.