Set-up and Operation of a Low-voltage DC Micro-grid Demonstrator

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CSEM is developing system architectures for isolated or grid-connected micro-grids. This project demonstrates how photovoltaic generation and electrical storage can be integrated with loads in a building. All components are interconnected in direct current (DC). A CSEM controller manages this micro-grid. It can be industrially implemented in applications ranging from commercial buildings to rural electrification.

Reduced costs of photovoltaic (PV) and storage systems make them attractive for individuals and companies to build micro-grids able to completely or partially satisfy their electrical energy needs. On the other hand a reliable and cost-effective system integration is required to guarantee the operation of such micro-grids and its possible interface with the public distribution grid. Distributing power in direct current (DC) instead of alternating current (AC) avoids multiple DC/AC converters and the associated losses, improves the power quality, and reduces the complexity of the whole system

In this project a robust DC micro-grid control strategy, which requires no communication infrastructure, is being developed. A demonstrator has been realized (Figure 1); it consists in a DC micro-grid where a PV source, loads and a storage system are directly connected. The whole micro-grid is interfaced with the AC grid through a single power converter.

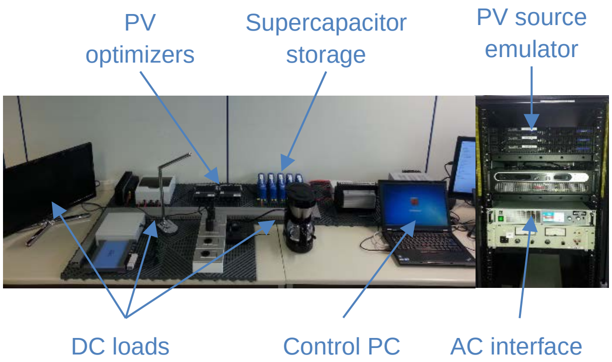

Figure 1: DC micro-grid demonstrator.

The selected storage technology is supercapacitors for two main reasons: first is the high performance in terms of efficiency and lifetime (up to one million full cycles) and, second is their state of charge (SoC) being simple to estimate.

The controller consists in a Python script running on a laptop, which sets and controls the power exchanged at the AC interface. The strategy consists of the following steps:

- Requesting power from the AC interface converter when the storage reaches its lower state-of-charge set point;
- Reinjecting back to the AC grid the excess of energy when the storage reaches its upper SoC set point;
- Setting a 0 power reference of the AC interface converter when the storage is between its lower and upper SoC set points.

The control strategy is implemented by a voltage controller which sets the current reference of the AC interface converter as a function of the storage SoC.

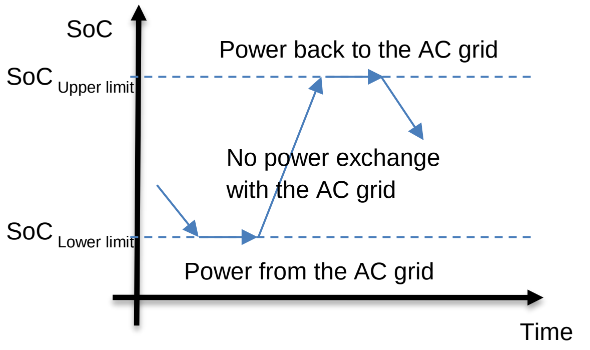

Figure 2: Control strategy of the interface converter.

Design rules for the controller have been developed to guarantee power quality on both the DC micro-grid and the AC grid. With the right bandwidth, the controller limits the power ramps towards the AC grid independently from the power oscillations in the DC micro-grid.

This ramp-rate functionality has been validated with a variable irradiance profile for the PV source derived from the EN 50530 standard for inverter testing. In Figure 3 the oscillations in PV power (due to irradiance variations), and in power exchanged with the AC grid are shown under different settings of the voltage controller. PV power ramps of 3.5 W/s (Figure 3 top) and 35 W/s (Figure 3 bottom) are mitigated down to 2.8 W/s and 10.5 W/s respectively with a fast dynamic control ("setting 1"), and down to 2.2 W/s and 5.9 W/s with a slow dynamic control ("setting 2").

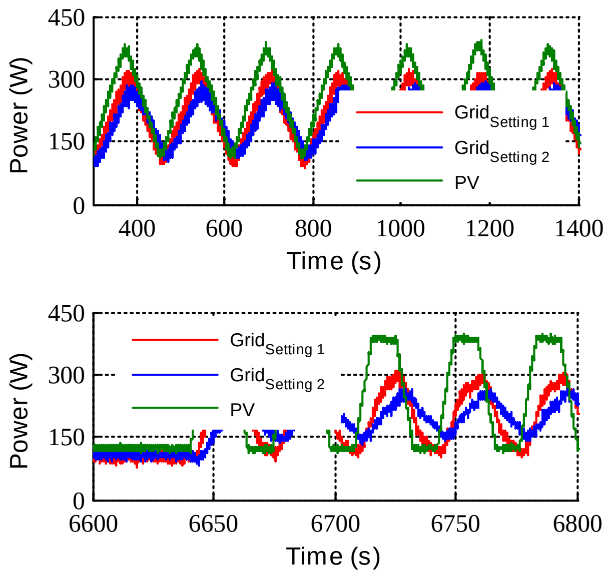

Figure 3: System response under a variable PV power profile.

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