Demonstration of Multi-service DC Microgrid in an Industrial Environment

N. Koch, P.-J. Alet

This report presents a lean control architecture for microgrids, with an implementation in direct current (DC) microgrids. The purpose of this architecture is to combine local objectives with system-level objectives. This patent-pending solution has been implemented and experimentally validated thanks to the commissioning of a building-scale demonstrator at Neuchâtel's wastewater treatment plant (WTP).

With the cost of photovoltaic power generation below socket parity in many places, end-users have a clear financial interest in self-consuming the power they produce. On the other hand, recognition that infrastructure costs are mainly driven by peak power, rather than energy, is leading to an increasing fraction of retail electricity prices being based on peak power. This evolution presents a challenge for end users with highly variable power profiles. Microgrids, especially with battery storage, are a promising way to manage the complexity of power networks with an increasing number of distributed, variable renewable energy sources (VRES). Through the DCSMART project, CSEM has developed a control architecture for microgrids to benefit both end users and system operations. The design has been experimentally validated by the commissioning of a demonstrator in an industrial environment.

System architecture

The architecture of the DCSMART microgrid is shown on Figure 1. It is composed of a bidirectional grid-tied inverter, DC-supplied loads, a photovoltaic installation and an energy storage system. The DC architecture eliminates conversion steps and the synchronization and balancing requirements associated with AC.

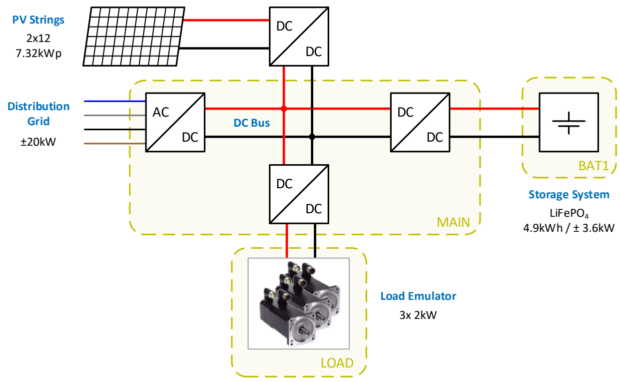

Figure 1: General topology of the microgrid.

Control strategy

The purpose of the developed strategy is to control the charging/discharging of the storage system in order to achieve local and system-level objectives:

- self-consumption to reduce energy cost for prosumers
- peak shaving on the grid power to reduce capacity charges for prosumers and peak load for DSOs
- ramp-rate control on the grid power to reduce rapid power and voltage fluctuations for DSOs.

Demonstrator

In order experimentally to validate the developed solution, CSEM has realized a building-scale DC microgrid whose key components are shown on Figure 2. This demonstrator has been commissioned at Neuchâtel's WTP. Electrosuisse inspected it and validated its safety features.

For a period of six months, the system has been intensively tested and monitored. This demonstration phase allowed to validate the correct behavior of the multi-service control strategy as well as the stable and safe operation of the hardware platform. Figure 3 illustrates the peak-shaving service performed by the battery in the event of a unit step in load consumption.

(a) *(b)*

Figure 2: Main and battery cabinet (a) and load emulator (b).

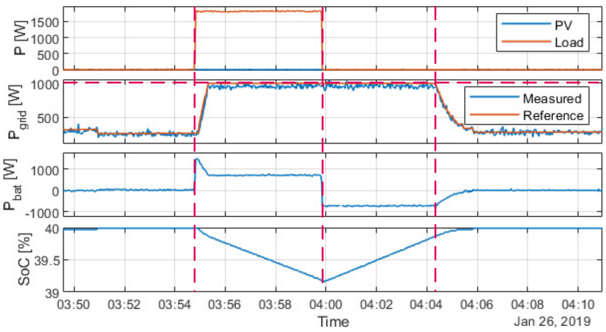

Figure 3: Load, PV, grid and battery power profiles and evolution of battery state of charge during a peak-shaving event.

Economic assessment

The economic value of the multi-service approach has also been validated. In a domestic application, the developed strategy reduces operating costs by 6% to 48% (depending on electricity rates) compared to a standard strategy with an equivalent storage capacity. For an industrial application, this reduction varies from 1.5% to 13%.

Outlook

The expertise acquired and the lessons learnt with this demonstration are already used for ongoing projects. Three improved units are currently being developed under the running European (H2020) project HYBUILD. They are compliant with the IEC 60204 standard and will be dispatched across Europe in three operational buildings for combination with heat pumps. Finally an additional unit will be deployed in an office environment at EMPA's NEST in Dübendorf.

The DCSMART project received funding with the joint initiative ERA-Net Smart Grids Plus, with support from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646039 and support from Viteos.