Resilient DC LV communities – UPB demonstrator

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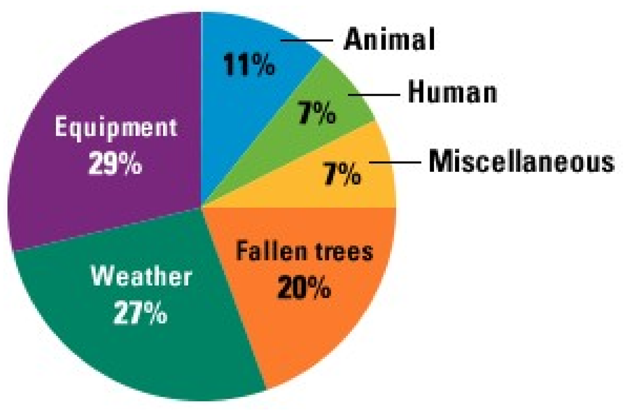
Abstract

This work presents the architecture and operational features of a demonstrator developed at the premises of MicroDERLab Research Group at UPB that consists of two interconnected DC low voltage microgrids aiming to serve several research projects that focus on resilient DC LV communities. The architecture of the demonstrator uses a case-driven approach to validate and demonstrate the toolkits to be developed. Concretely, the demonstrator aims to facilitate the experimental assessments of several applications from monitoring and active power management of energy consumption in prosumers' world, to aggregation of measurement data for modelling, planning, integration, operation and evaluation of distributed Energy Storage Systems. One of the major innovation of the proposed architecture consists in the extension of the functionality of the Unbundled Smart Meter (USM), the so called SMX side that processes all the information coming from the micro-controller of the energy router (ER). Simulated results of a distributed and adaptive energy management system to be tested on this demonstrator are also presented, while briefing a number of use-cases in line with several business models that led us to this design.

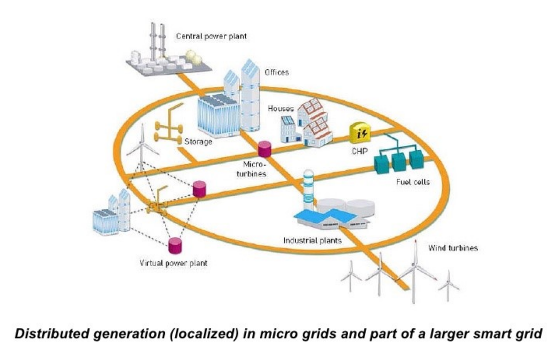
Background

Extreme weather is proved to play a major role in the cause of power outages (about 80% of the cases according to a report of Climate Central's analysis of 28 years of power outage data in the USA [1]). A study commissioned in 2012 by the Congress of USA concluded that the estimated cost from storm-related outages to the U.S. economy is between $20 billion and $55 billion annually [2]. Another case study in Europe concerning the Swedish power critical infrastructure estimated an economic loss on the electric power service alone to be around 3 billion euros due to a heavy storm in 2005 [3]. Both latter studies concluded that power delivery systems are the most vulnerable to weather events. Thus, improving the overall efficiency and condition of the low voltage part of the power system can only serve to improve its resiliency and help a fast recovery from outages (weather-related or not).



Source: WE Energies

Smart Grid / Micro Grid



Source: www.resilience.org

Business and resilience assumptions on the design of the system

The proposed architecture is based on the technical philosophy that the new prosumer at the LV side of the grid shall be seen by the DSO as a **"consumer-only"** entity from DSO point of view [4]. Storage plays a key role in migrating the prosumer's behavior back to the design assumptions of the legacy power distribution system.

Key features of the resilient by design microgrid's architecture:

- almost risk-free RoI over the lifetime of the system;
- increased self-consumption of local generation, close to unity factor;
- increased resilience of the microgrid in case of grid outages;
- easy scaling-up potential at community level ("plug-and-play" expansion plan);
- decoupling the need for synchronization (grace to the DC bus);
- smooth connection to the main grid with no need for planning or changes in the current SoA architectures & operation of DSO's grids.

Operation use-cases for resilience

Use case 1: when a disturbance occurs on the loads side of the MG or there is a large deviation from the predicted PV power production, the operation of the MG(s) remains stable with the support of the grid former and grid balancing reactions of the energy router (ER role), while the power set points for the DSO remain unchanged ("non-disturbed" DSO).

Use case 2: whenever a disturbance occurs on the DSO side, which may reduce the MG's scheduled power demand from the DSO, the internal balancing mechanism of the MG being able to compensate it using the same mechanisms (battery/storage plus distributed low-level control).

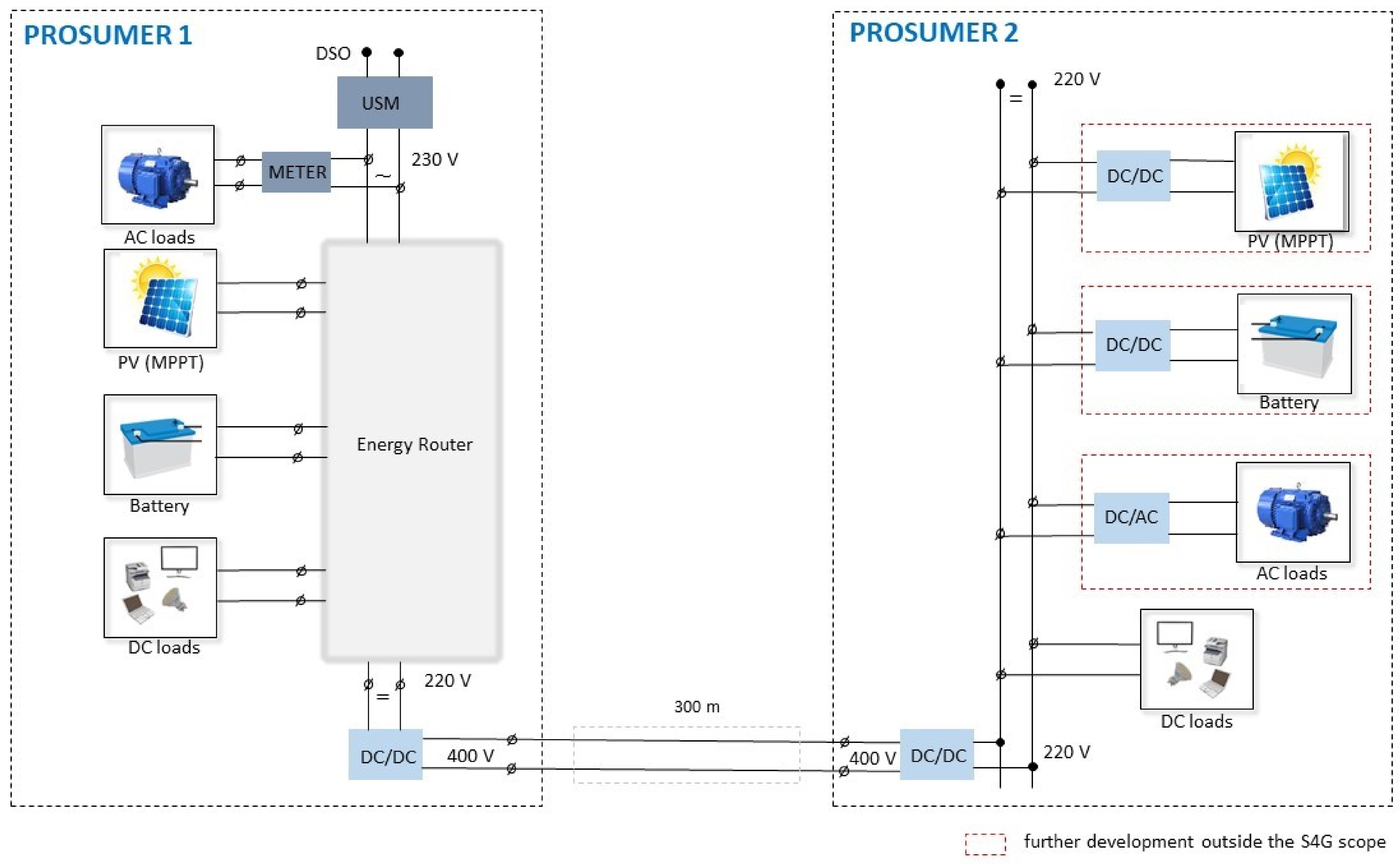
Use case 3: an extension of the use case 2 where there is a total loss of the scheduled power to be provided by the grid (DSO).

USM role

The proposed architecture places a major innovative role to the Unbundled Smart Meter (USM). To be noted that the information facilitating the microgrid control is mediated by the USM where the smart meter functionalities are adequately grouped into two separate (unbundled) components:

a) one for metrological / billing purposes, handling "hard real-time" function, and called the Smart Metrology Meter (SMM); usually SMM is the already exiting smart meter.

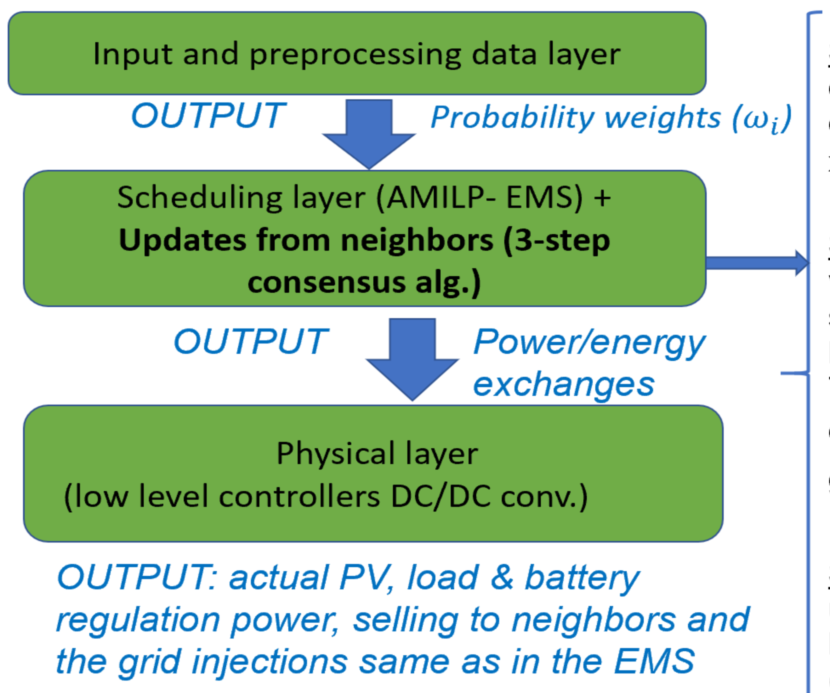
b) one Smart Meter eXtension (SMX) providing the flexibility needed for new functionality



to be deployed during the meter lifetime and to support the future evolution of the smart grid and energy services. The SMX is a Linux machine, able to read from the SMM all relevant instrumentation values (using DLMS protocol) and stores data in a text file, to be later processed/used, including for developing a local load profile [5].

Energy management system for resilient communities

The solution makes use of a smart metering infrastructure with minimum requirements for communication between the operational nodes. The algorithmic implementation is based on a 3-steps general consensus formulation, summarized below [6].

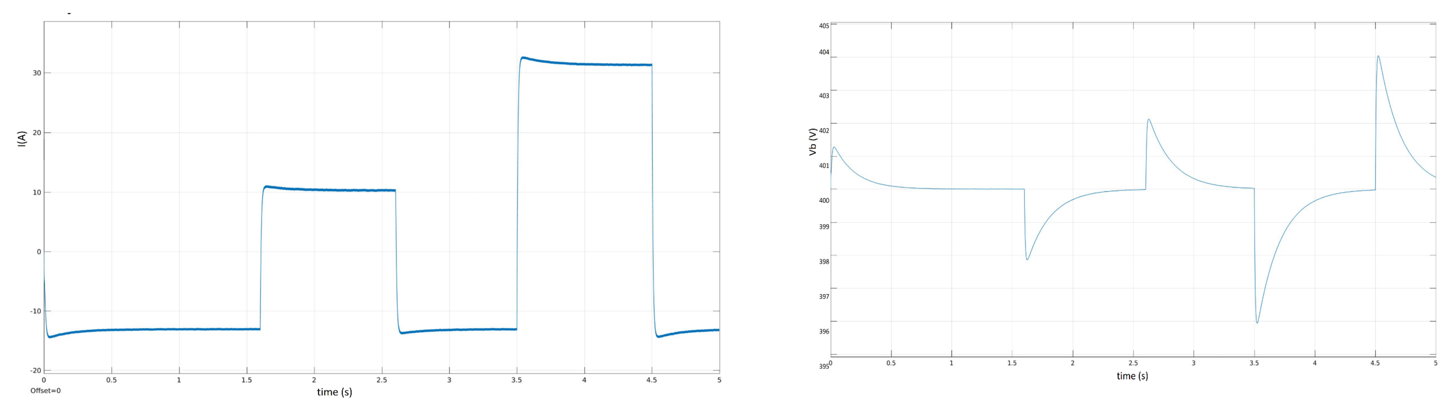


Step1: each ER minimizes its own objective function and obtains a new set of local variables x_i^{k+1} (completely decentralized step).

Step2: the components of the global variable z^{k+1} are updated. For this step we need the communication between adjacent ER to be recalled. This step implies averaging all entries of $x_i^{k+1} + \frac{1}{\rho} * \mu_i^k$ that map to the same global index (adjacency nodes).

Step 3: the Lagrange multipliers μ_i are updated according to the difference between the local and global variables (completely decentralized step).

The adaptive distributed EMS plays a key role in ensuring adaptability and learning capabilities using a prediction and learning module for pre-processing of information.



BESS: current and voltage waveforms

Simulation scenario is as follows: @t=0 – normal/scheduled operation to supply only Load1; @t=1.6 s -> connect Load2; @t=2.6 s Load2 is disconnected due to internal disturbance in the MG. Load2 is 25% of Load1 + Load2; @t=3.5 the scheduled power intake from the grid is disconnected (disturbance in the grid) & @t=4.5 s, the power infeed (from the grid) is restored to the scheduled value.

Conclusions

This work elaborated on several design and operational use-cases for a Lab/Campus scale demonstrator of DC LV power distribution. The design paradigm, features and assumptions were analyzed following a set of features that characterize resilient systems.

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Acknowlegements

This work has received funding from two on-going projects funded by the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 708844, LCE - 731155 Storage4Grid Project and LCE