Exploiting flexibility under regulatory constraints in a microgrid with highly variable power profiles

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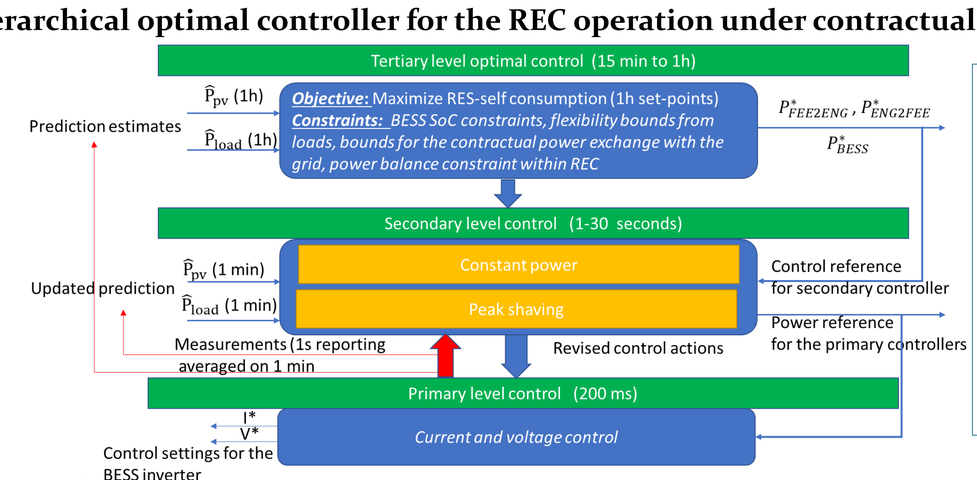
INTRODUCTION

The concept of renewable energy communities (REC) is an emerging trend in Europe with the main goal to increase the volume of locally produced power generation from renewable energy sources (RES) to an extent higher than what is currently obtained by simply clustering prosumers in a community. To increase the local self-RES consumption, one may take advantage of the flexibility of existing loads, or of a local energy storage unit, or a combination of the two based on knowledge extraction from high time-granularity measurements. Exploiting local flexibility is key for reducing the effects of the current challenges experienced by distribution system operators (DSOs) in case of high RES-induced reversed power flow, especially in low voltage feeders (e.g., overvoltage, exceed of feeder thermal limits). Furthermore, to overcome the uncertainty of incentives and regulations imposed to prosumers (e.g., from feed in tariff to net-metering, to net-billing) the proposal is for a regulatory resilient architecture called Unidirectional Resilient Consumer (UniRCon). The main contributions of this work are two-fold: (a) assume contractual bindings between the REC and the power supplier with pre-set power exchange and design a hierarchical optimal control of generation and flexibility options withing the REC in order to fulfil those contractual requirements. The solution is validated using a real hybrid microgrid architecture from the Polytechnical University of Bucharest (UPB) which was implemented in a Real-Time Typhoon Hardware-In-the-Loop (RT-HIL) experimental set-up.

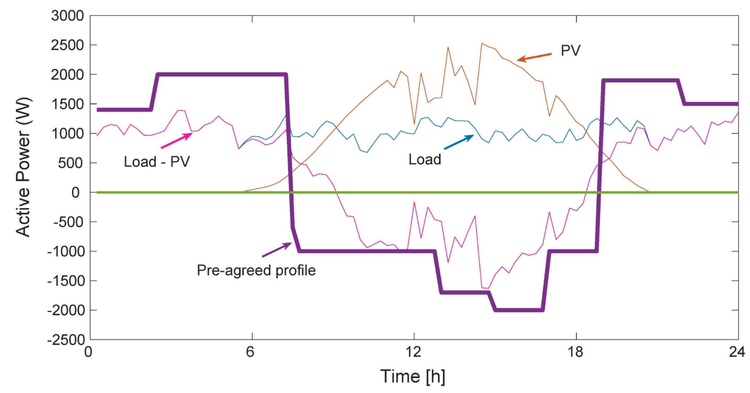
FRAMEWORK

- **Objectives**
  - Optimal operation for a hybrid microgrid (proposed REC architecture) with an internal direct current (DC) link interconnecting two UniRCon-type of microgrids both bind by pre-set power exchange contractual obligations with the utility on an hourly basis.
  - Design of a hierarchical optimal control strategy which maximizes the self-RES consumption and fulfils the contractual obligations for the pre-set power exchange profile with the grid.
- **Hierarchical optimal controller for the REC operation under contractual binds with the grid**



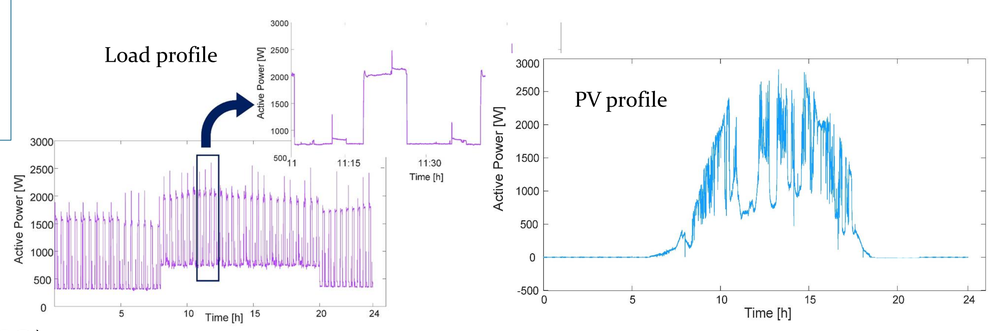
Legend:
$P^*_{FEE2ENG}$ – optimal power exchange between FEE and ENG (reference set points from the tertiary control block)
P^*_{BESS}– optimal power set point for the output of the battery energy storage system (BESS)
$\widehat{P}_{pv}$ - estimated aggregated power output from photovoltaic (PVs) RES generation of the REC
$\widehat{P}_{load}$ - estimated aggregated load demand of the REC

- **Case study:**
  - Operation for a real REC with shared BESS as a hybrid DC link enabled microgrid, called **Flexi-MLAB**.
  - Highly-variable, high-time-granularity load power and PV power generation profiles obtained from 2nd generation smart meters.
  - Pre-defined 1h power settings for REC power exchange with the Distribution System Operator (DSO) based on contractual binds.
  - Implementation and testing using Typhoon RT-HIL experimental setup and hierarchical optimal control.



Concept for pre-defined power profile under contractual bind

Note: *Load-PV refers to the net-power load obtained as the difference between the aggregated photovoltaic (PV) power production and the aggregated load demand at the point of common coupling (PCC) of REC with the grid.*

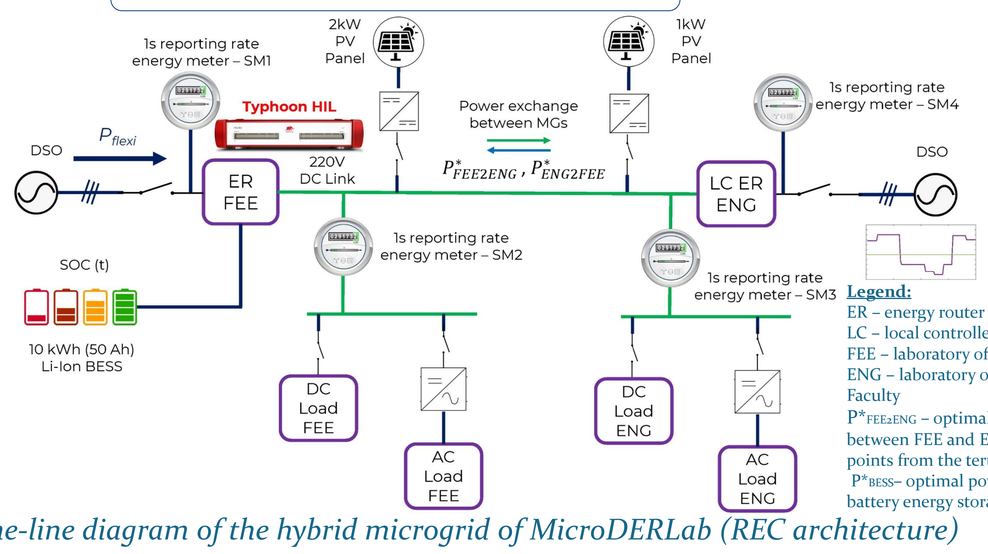


PV and Load profiles from high time-granularity measurements from 2nd generation SM

Contractual binding power profiles for optimal operation of a self-RES consumption microgrid

Scan the code for more information

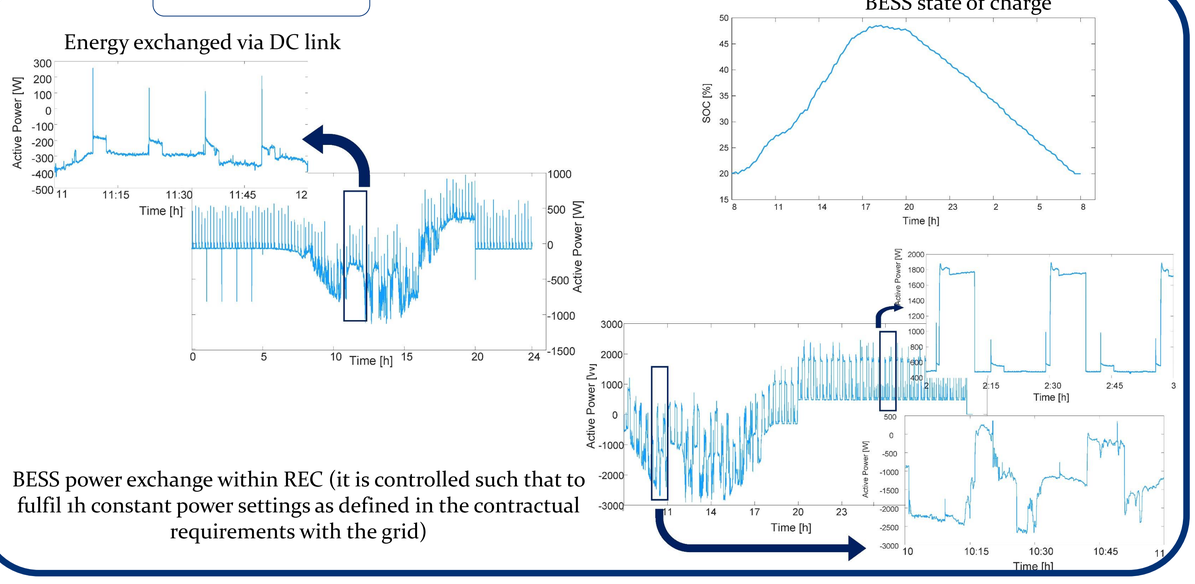
Flexi-MLAB Grid Topology



Legend:
ER – energy router
LC – local controller
FEE – laboratory of MicroDERLab
ENG – laboratory of Power Engineering Faculty
$P^*_{FEE2ENG}$ – optimal power exchange between FEE and ENG (reference set points from the tertiary control block)
P^*_{BESS}– optimal power output for the battery energy storage system

One-line diagram of the hybrid microgrid of MicroDERLab (REC architecture)

Results



BESS power exchange within REC (it is controlled such that to fulfil 1h constant power settings as defined in the contractual requirements with the grid)

Conclusions

- Two labs with prosumer behavior have been interconnected via a 220V DC link to ensure optimal operation of the resulting hybrid microgrid (proposed REC architecture), ensuring a load-only power profile from the DSO point of view.
- Numerical simulations in Typhoon-HIL using grid information and control signals available using 1s time-resolution data.
- The power profiles have been derived from historical real time measurements from 2nd generation SM with 1s reporting rate.
- The flexibility was ensured by the shared storage unit and the power exchanged between the prosumers via the DC link.
- Real time numerical simulations have been conducted for 24h continuous operation in each of the two worse-case scenarios.
- Regulatory constraints have been modeled by compulsory no-infeed operation and hourly resolution power profile.

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