Leveraging flexibility for a microgrid with highly variable power profiles under regulatory constraints

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INTRODUCTION

The evolving power distribution system increasingly relies on decentralized, intermittent Renewable Energy Sources (RES), requiring real-time data on load and generation profiles for optimal control. In this context, self-RES consumption communities (SCCs), or renewable energy communities (RECs), are emerging in Europe. These communities aim to boost local RES-based generation beyond what individual prosumers could achieve, aligning with the goals of the "Clean Energy for All Europeans" initiative. The work will showcase scenarios of operation for a real test-site (FlexiMLAB) having its core infrastructure composed by two microgrids tied together with a DC link, acting as two UniRCon (self-consumption and no power injection into the grid).

FRAMEWORK

- Grid implementation:
  - Hybrid microgrid with an internal DC link interconnecting two resilient prosumers and one BESS, operating with regulatory constraints.
  - Low-voltage microgrid with typical office appliances and PV generation with power profiles derived from high-reporting rate measurements.
- Existing framework:
  - **TyphoonHIL** used to emulate the parts of the system (DSO feeder side, solar PV panels, BESS, DC and AC loads, the interconnection DC link and the energy router as SIL for testing the control algorithms for Flexi-MLAB.
  - Data integration and exchange framework within a **software cross-platform** capable of handling multi-vector measurement information with intelligent data analytics engine.
- Objectives
  - Minimization of negative effects on utility side as for the intermittent generation and load variability is achieved by new **contractual binding power profiles**.
  - Operation of a SCC with regulatory constraints in terms of ensuring self-consumption, maximal PV generation without curtailment and **pre-set power exchange** with the utility.

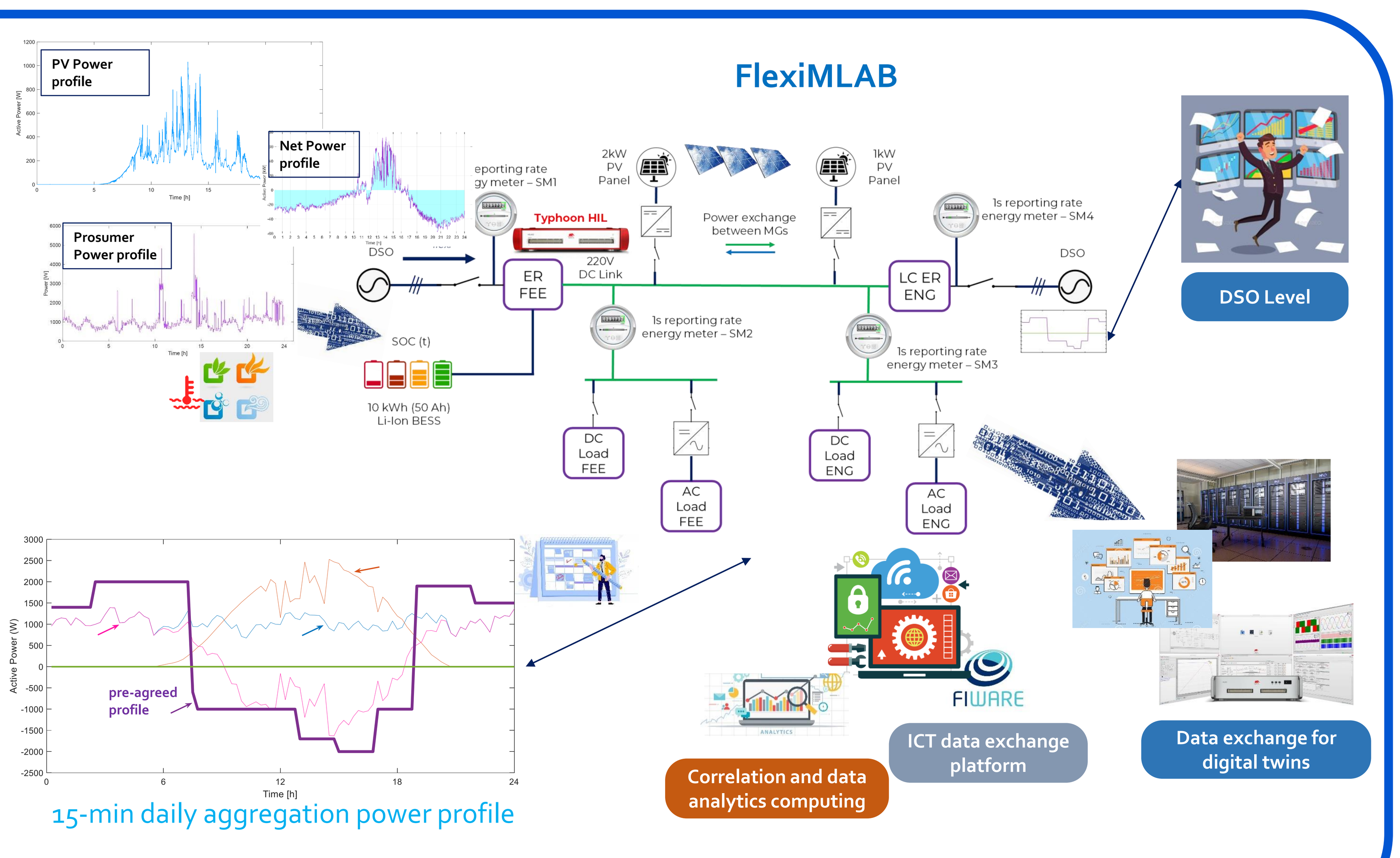


Figure 1. FlexiMLAB microgrid topology and services

Achieving an optimal energy transfer in emerging grids using pre-agreed power profiles with HIL and SIL experiments

Assessment of Flexibilities

User flexibility – Flexibility of energy use

T_use = usage time interval	delta_T_shift = [min, max] = time interval willing to shift	Energy_shift = Total energy shifted = P_nom*T_use	Probability of shifting = probability to be willing to shift

Flexibility of the Power Profile

Power profile variability index (based on statistical analysis)
Using R2, 1-CV(RMSD) and GoF

User flexibility

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(x_i - y_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \qquad CV(RMSD) = \frac{1}{\bar{y}_p}\sqrt{\frac{\sum_{i=1}^{n}(x_i - y_i)^2}{n}} \qquad GoF^* = 20lg\frac{P_{max}}{|\bar{P}_i - P_{max}|}$$

Flexibility index of the Power Profile = User flexibility index * Variability index

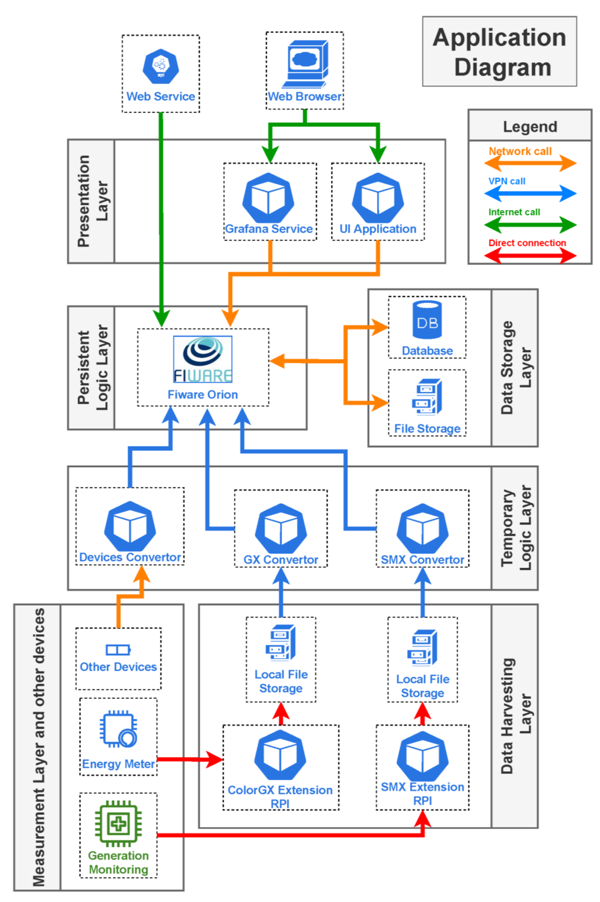
Controllability of the Power Profile

Controllability index of the Power Profile = (Flexibility index of the power profile) * Nominal (installed) Power

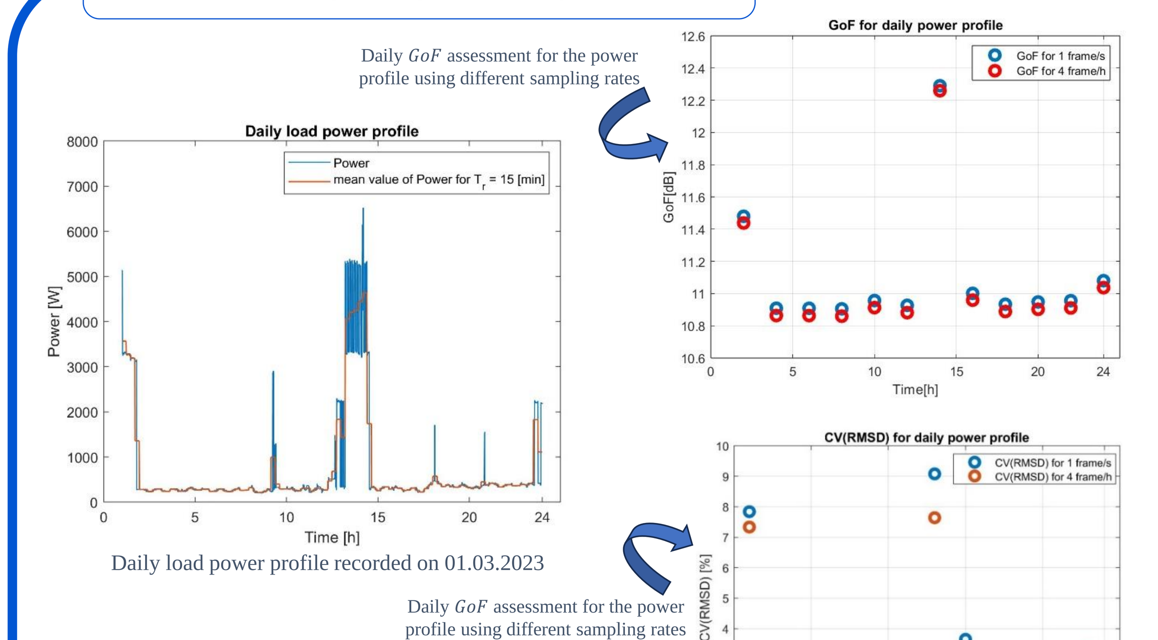
FLEXIBILITY
- Variability index (per year) – in 95% of cases (min, max, mean, distribution)
- User Flexibility index

Platform architecture

Multi-vector, heterogeneous sources data integration framework



Variability of power profiles

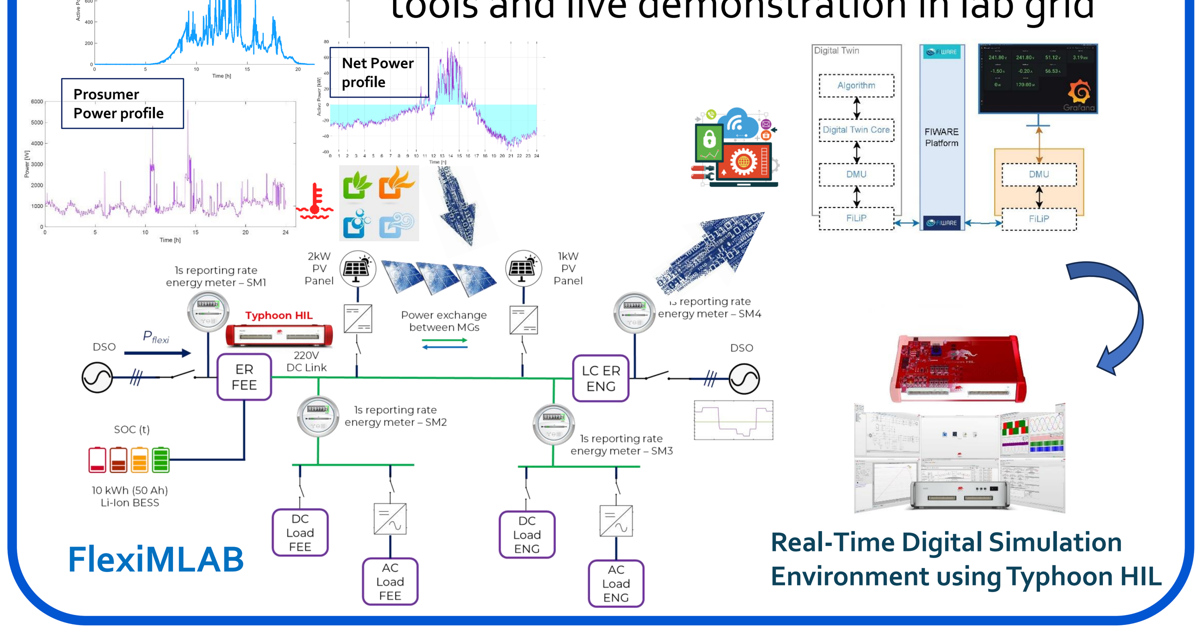


A. P. Brîncoveanu, R. Plămănescu, A. -M. Dumitrescu and M. Albu, "Measurement and Information Uncertainty for Highly Variable Power Profiles," *2024 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*, Glasgow, United Kingdom, 2024, pp. 1-6

R. Plămănescu and M. Albu, "Exploiting Flexibility Under Regulatory Constraints in a Microgrid with Highly Variable Power Profiles,", presentation during the *5th International Conference on Solar Technologies & Hybrid Mini Grids to Improve Energy Access, 4 – 6 September 2024, Palma de Mallorca, Spain.*

Digital Twin and HIL experiments

Integration of real-time digital simulation tools and live demonstration in lab grid



HINTS FOR FUTURE WORK

- Maintain and update a robust data integration and exchange framework within a software cross-platform using a standard format capable of handling multi-vector measurement information, including power profiles with a high-reporting rate (1 frame/s) and environmental conditions data from sensors with a time resolution of 1s or lower.
- Develop an intelligent data analytics engine that can process and correlate information from various sources (energy transfer parameters, environmental and contextual conditions). Develop and adapt data analytics algorithms to extract meaningful insights from the integrated information, enabling real-time anomaly detection, predictive maintenance, and energy control.
- Establish an integration mechanism of heterogeneous data with real-time (heterogenous) digital simulation tools for modelling and simulation of energy transfer in emerging power grids.

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