Enhanced control for microgrids with HIL and PHIL experiments

Radu PLĂMĂNESCU*, Alkistis KONTOU**, Panos KOTSAMPOPOULOS**
Mihaela ALBU*, Nikos HATZIARGYRIOU
***Politehnica Bucharest, Romania**
**** National Technical University of Athens, Greece**

INTERNATIONAL Microgrid SYMPOSIUMS

MicroDERLab

National Technical University of Athens

INTRODUCTION

The shift toward low-carbon and digitalized power systems increases the need for resilient and flexible microgrids. With high shares of inverter-based renewable generation, maintaining stability and optimal control becomes a major challenge. Real-time digital simulation, with Hardware-in-the-Loop (HIL) and Power-Hardware-in-the-Loop (PHIL) experiments, enables realistic validation of control algorithms and energy management strategies. This work presents enhanced control approaches for microgrids, leveraging HIL and PHIL experiments based on high-reporting rate measurement information for load and generation towards validation of pre-agreed power profiles with the utility company.

FRAMEWORK

- Grid implementation:
  - **Low-voltage microgrid with typical office appliances and PV generation with power profiles derived from high-reporting rate measurements and one storage unit.**
- Existing framework:
  - **RTDS and TyphoonHIL** used to emulate the parts of the system (DSO feeder side, solar PV panels, BESS, AC loads, and the energy router as SIL for testing the control algorithms.
  - Data integration and exchange framework within a **software cross-platform** capable of handling multi-vector measurement information with intelligent data analytics engine.
- Objectives
  - (a) self-consumption behavior continuously ensured; (b) contractual binding high resolution power profiles guaranteed for the supplier; (c) active MPPT for the local (PV) generation and no curtailment.
- Software implementation
  - Advanced Energy Management System (EMS) to monitor all the power profiles and to decide set-points for the assets as the microgrid structure to follow the operation imposed by the pre-agreed profile with the DSO. Validation with Power-Hardware-in-the-loop experiments.

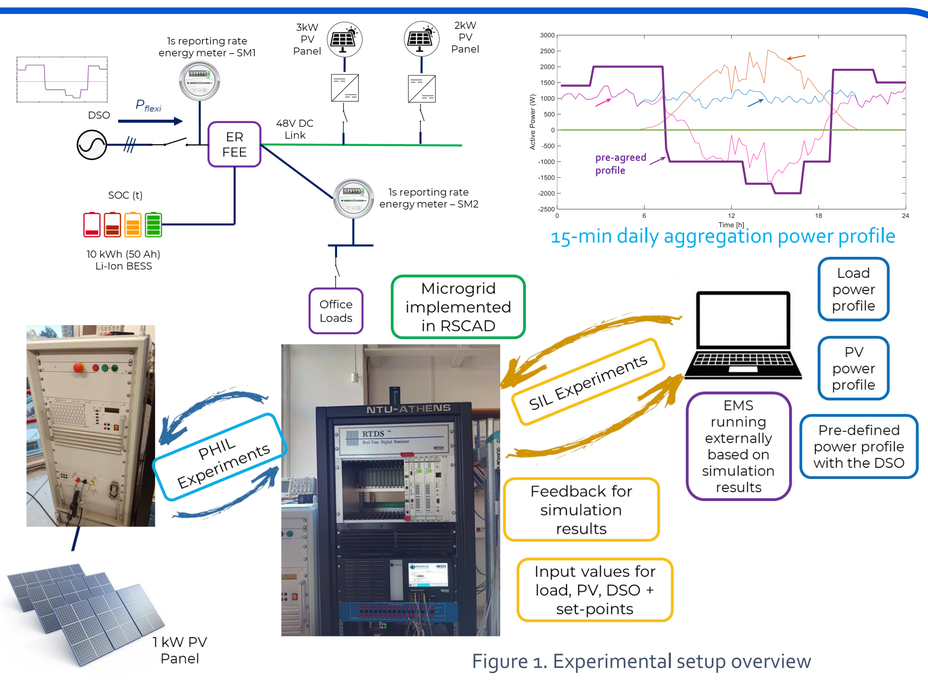
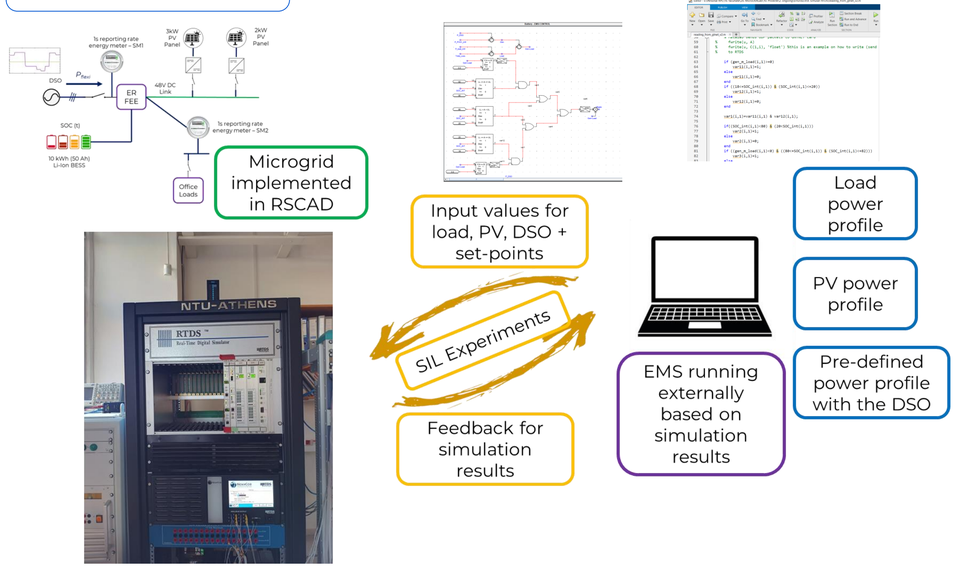


Figure 1. Experimental setup overview

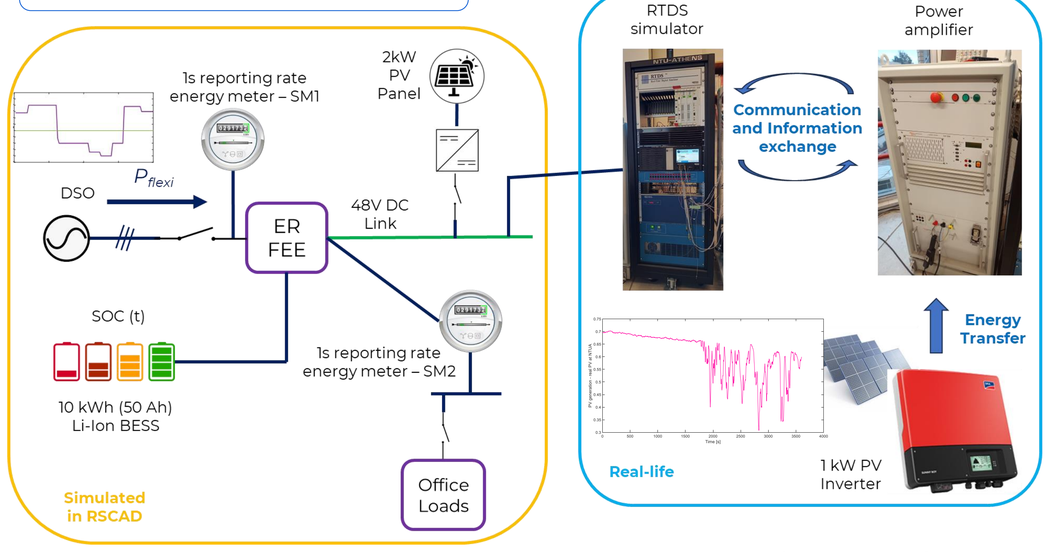
Achieving an optimal energy transfer in emerging grids using pre-agreed power profiles with SIL and PHIL experiments

SIL experiments



A Software-in-the-loop (SIL) experiment was developed to validate the EMS performance for the microgrid. Implemented in RSCAD and Matlab, the EMS processes real-time PV, load, and DSO power profiles to compute optimal setpoints, which are sent to the RTDS for execution. This setup allows comprehensive testing of EMS strategies in a controlled environment, ensuring robust and efficient real-world operation.

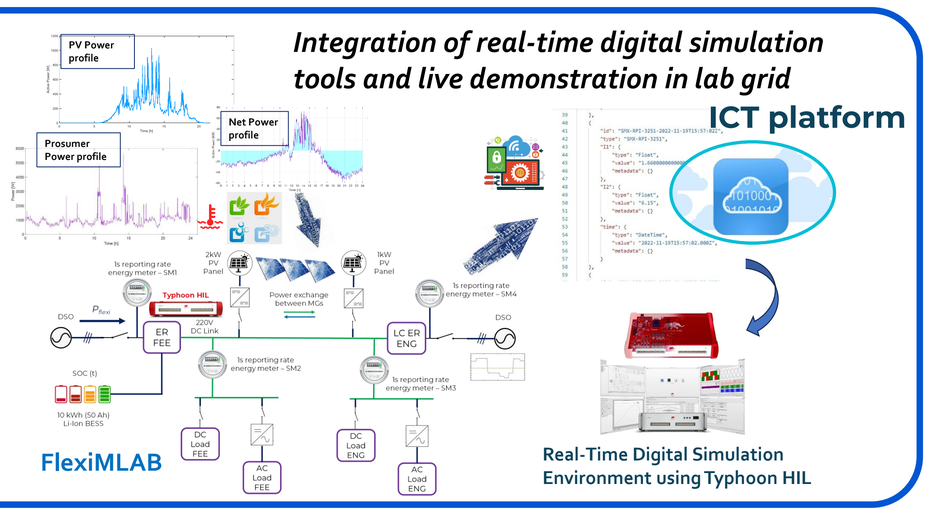
PHIL and SIL experiments



A PHIL experiment was developed to validate the real-time performance of the EMS for the microgrid. Implemented in MATLAB, the EMS processes real-time profiles of PV generation, load, and DSO signals to compute optimal power setpoints sent to the RTDS. The RTDS interfaces with physical components, such as the PV inverter, enabling realistic validation of EMS control strategies and ensuring robust performance under real operating conditions before field deployment.

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.
- 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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