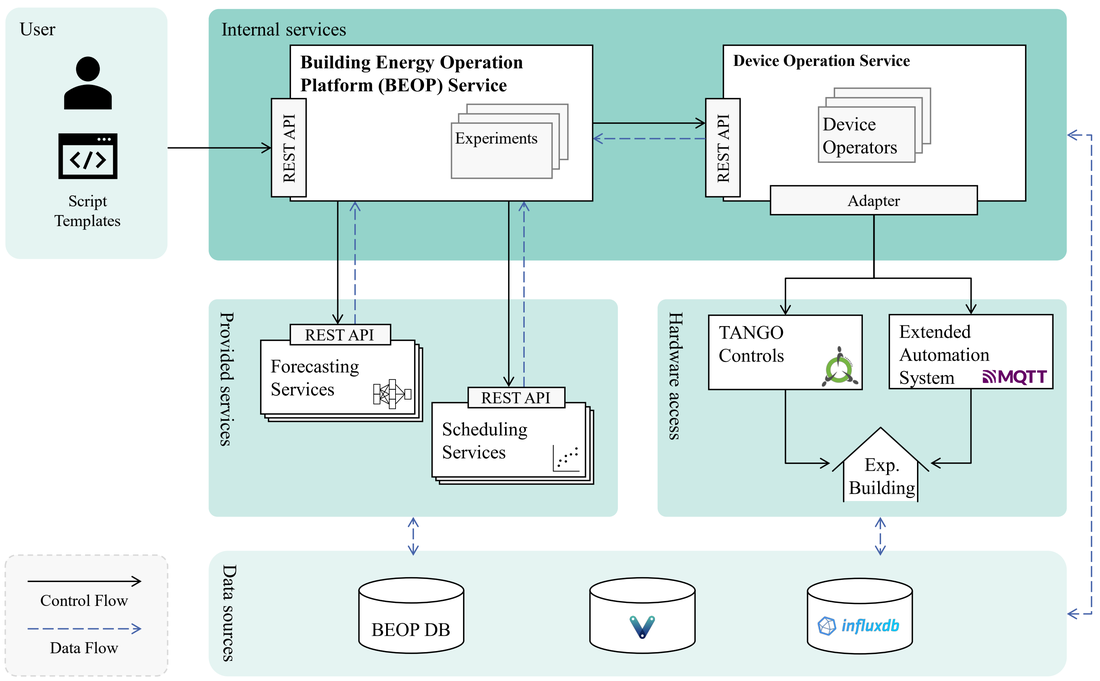
BEOP: A Framework Enabling Validation of Real-World Energy Management Systems

Sebastian Beichter, Maximilian Beichter, Alexander Nöthel, Janik Pinter, Johannes Galenzowski, Kevin Förderer, Friedrich Wiegel, Tobias Moser, Simon Waczowicz, Ralf Mikut, Veit Hagenmeyer
Institute for Automation and Applied Informatics, Karlsruhe Institute of Technology, Germany

Abstract

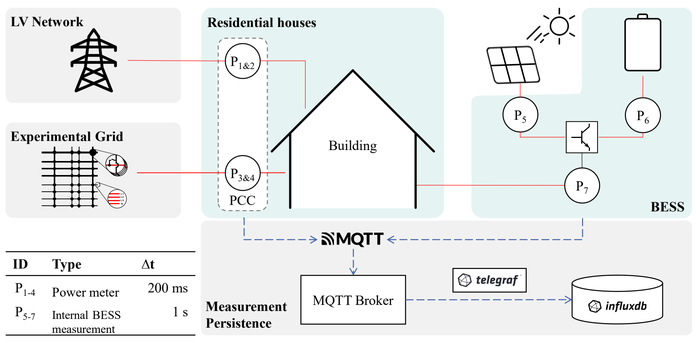
With the rise of renewable energy, electric vehicles, and batteries, residential buildings are evolving into prosumers, requiring Energy Management Systems (EMSs) to optimize self-consumption and grid support. Simulations often fail to capture real-world complexities such as fluctuating weather, hardware behavior, and communication delays. To address this, we present the Building Energy Operation Platform (BEOP), a modular and scalable framework for validating real-world EMSs. BEOP supports various EMS types, integrates hardware and software components, and allows multi-resolution performance analysis. Demonstrated through a schedule-based optimization use case, we highlight the impact of real-world factors on EMS performance and advance research in forecasting, optimization, and grid stability.

BEOP



The BEOP core including provided services and interfaces to the real hardware, describing control and data flows.

Experimental Setup

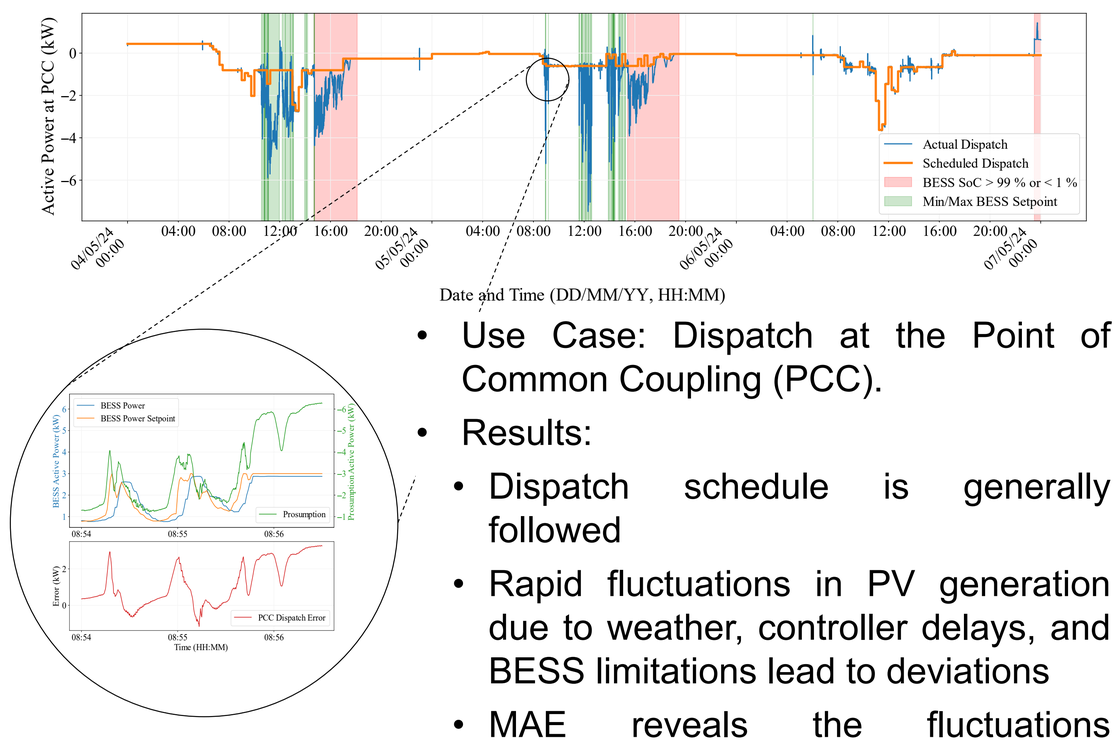


ID	Type	Δt
$P_{1\text{-}4}$	Power meter	200 ms
$P_{5\text{-}7}$	Internal BESS measurement	1 s

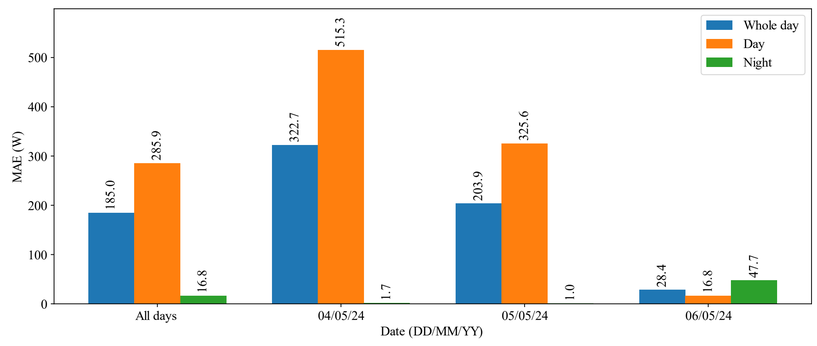
Equip-ment	Details
BESS (Battery Energy Storage System)	$E_{max} = 19{,}5\ kWh$ $P_{\max\_charge} = 3\ kW$ $P_{\max\_discharge} = -3\ kW$ $t_{measurements} = 1\ s$ $t_{control\_delay} = 1\ s$
PV	$P_{\max} = 9.6\ kWp$

Detailed experimental setup and key figures of the relevant assets.

Case Study Results



- Use Case: Dispatch at the Point of Common Coupling (PCC).
- Results:
  - Dispatch schedule is generally followed
  - Rapid fluctuations in PV generation due to weather, controller delays, and BESS limitations lead to deviations
  - MAE reveals the fluctuations especially on the first two days



MAE at the PCC, calculated with 10-second resolution. Significant deviations on days one and two when the BESS exceeded capacity, preventing the system from meeting the dispatch schedule.

Conclusion

Summary:

- Validation and evaluation of EMS strategies using real hardware
- Scalable and flexibly expandable system architecture, accommodating various components, forecast models, and optimization problems

Future work:

- Validation of additional approaches, such as rule-based control and reinforcement learning
- Quantify the objectives of each EMS strategy and evaluate their fulfillment under realistic operational conditions.
- Parallel execution of EMS strategies across multiple buildings
- Analysis of the impact of building assets on the electrical grid

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