Center for Combined Smart Energy Systems (CoSES)

The idea and the possibilites

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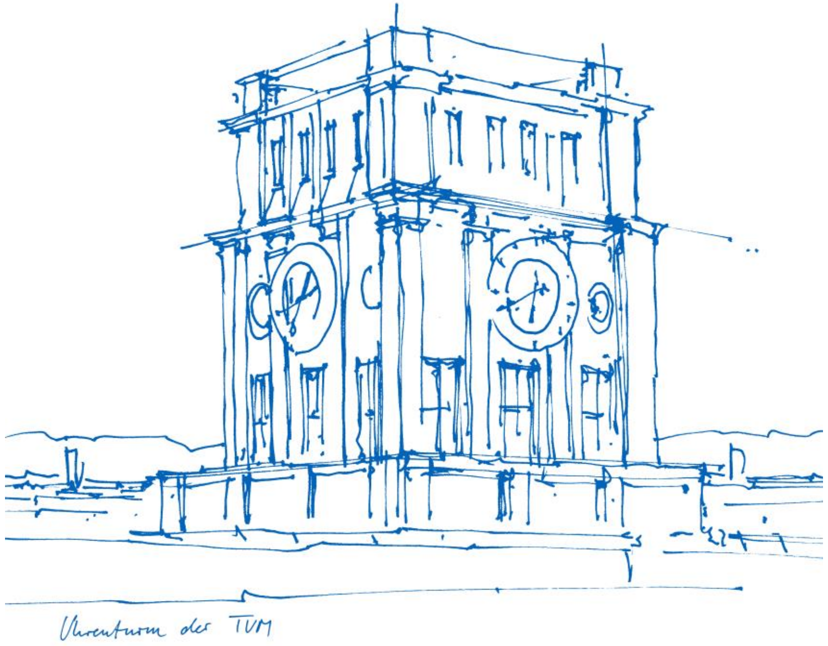
Munich Institute of Integrated Materials, Energy and Process Engineering (MEP)



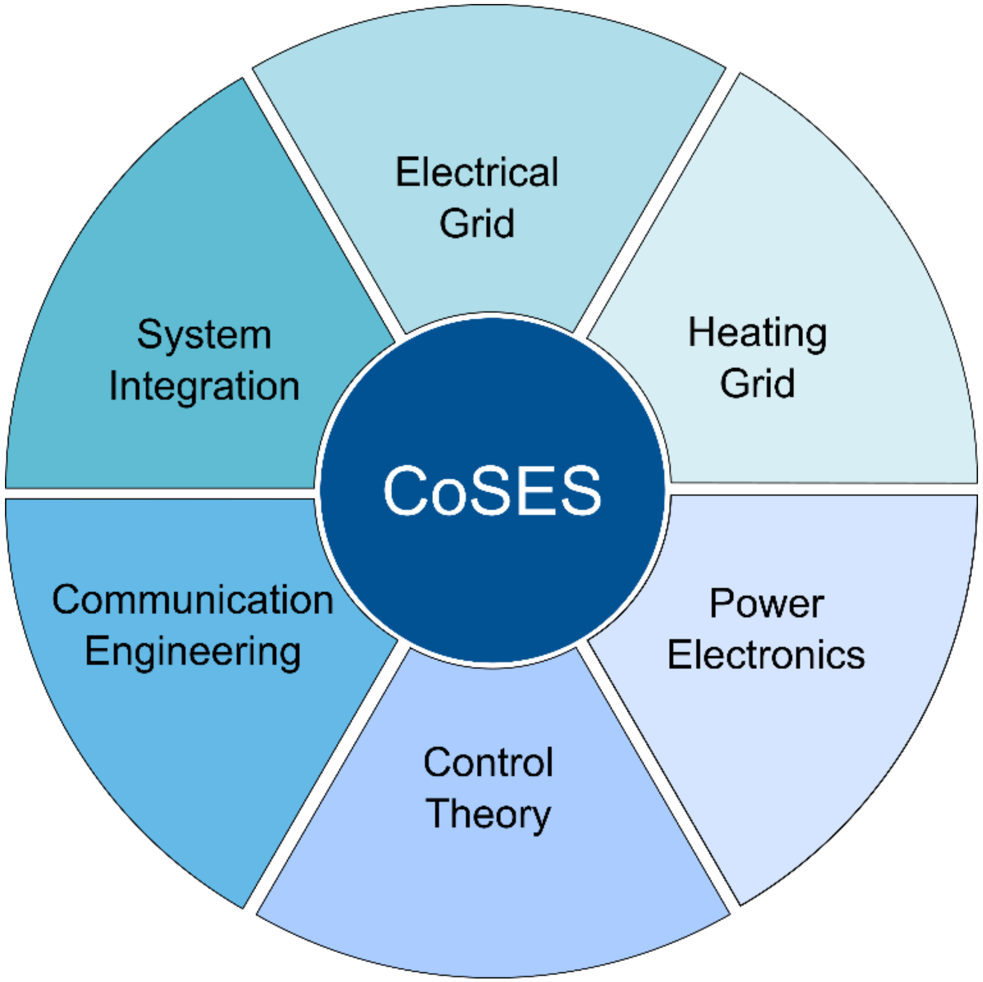
Motivation

Energy transition revolution

- Changing energy supply conditions
- Reduced controllability of renewable energy sources
- Infrastructural changes in grid necessary

Interdisciplinary research

- Smart grids – product of cross-interaction between fields
- Synergy among separate focus groups



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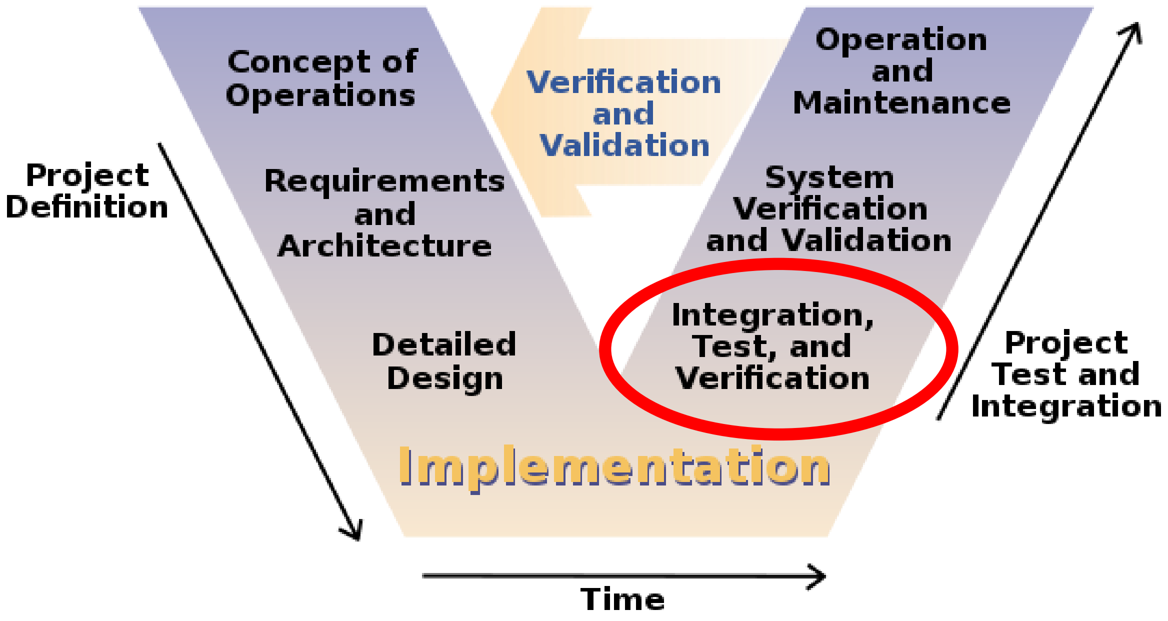
Realistic validation

- Closer to market readiness
- Greater confidence in the results



Source – Wikipedia, V-model of systems development lifecycle

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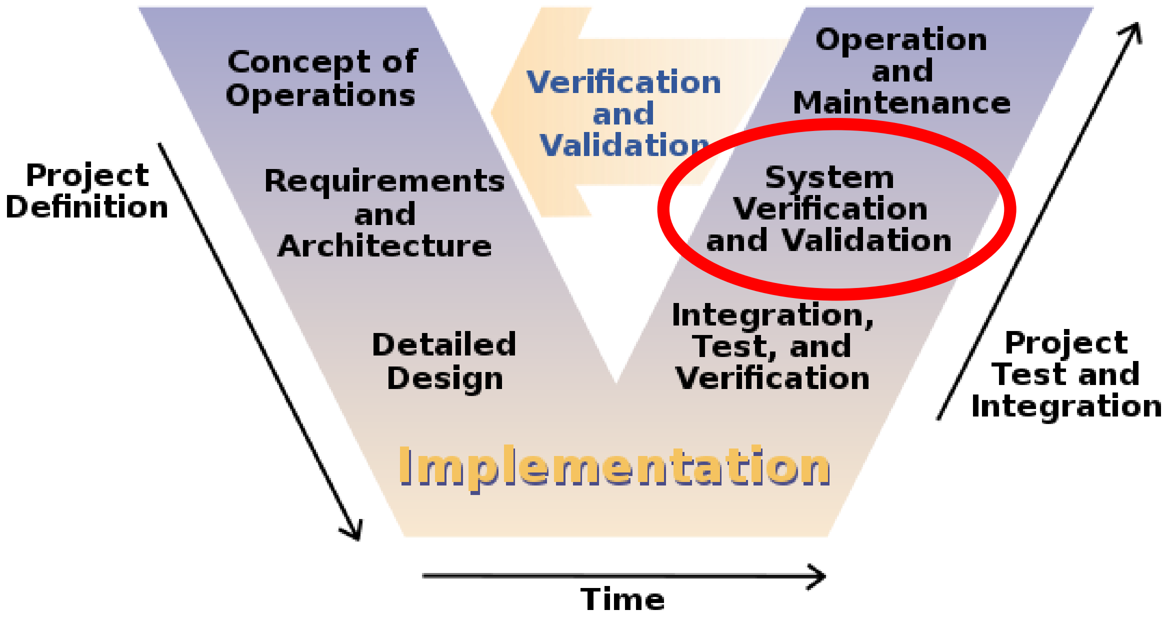

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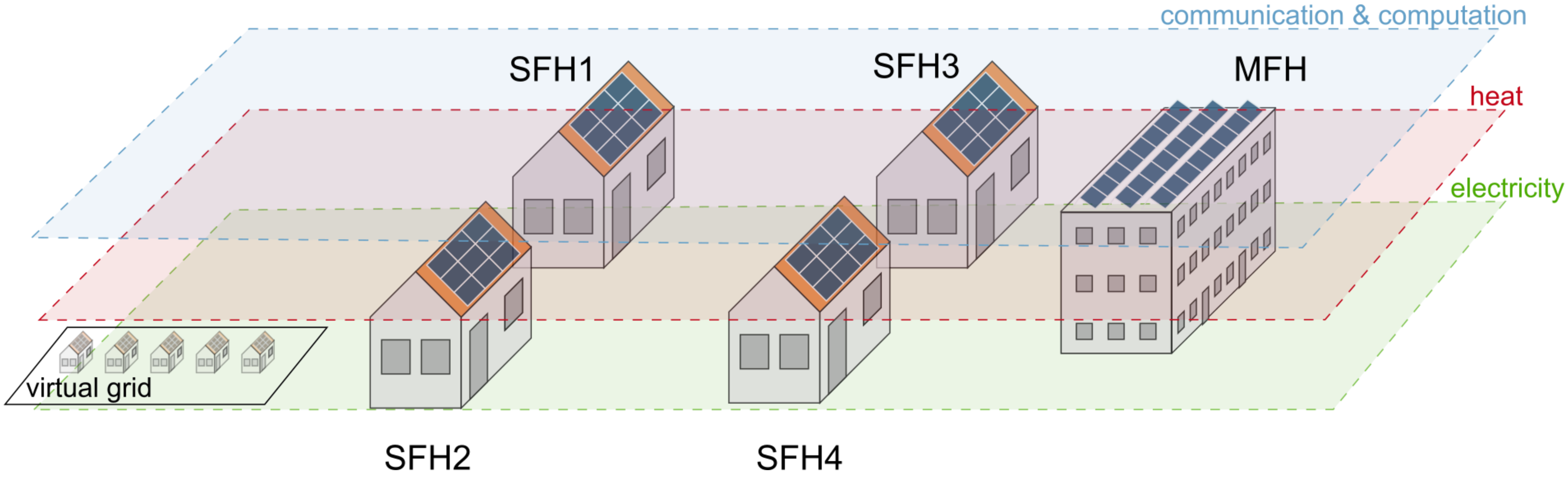
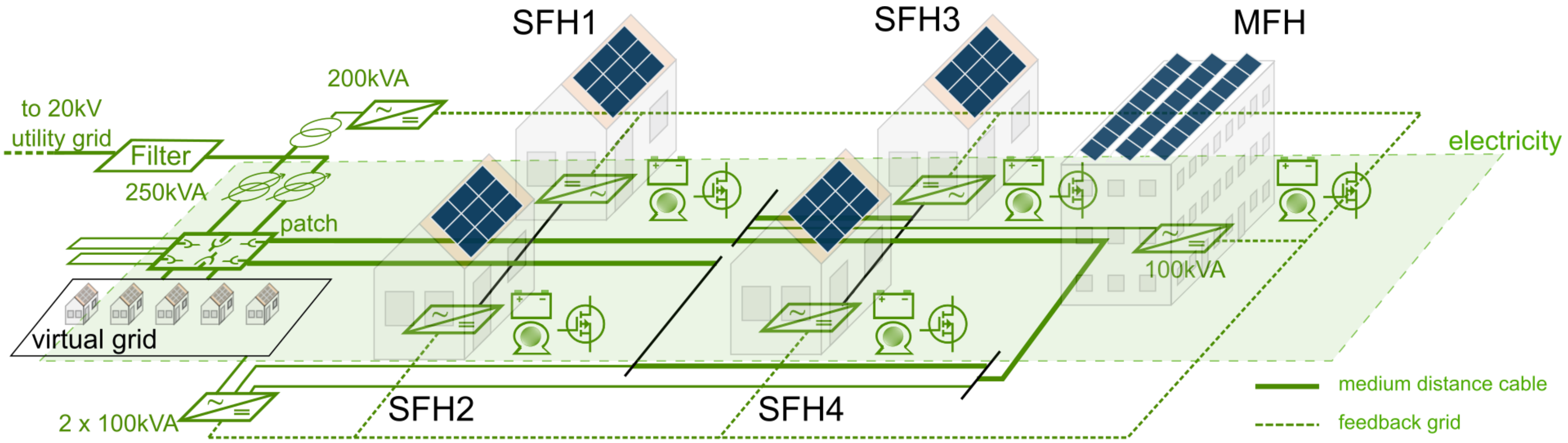
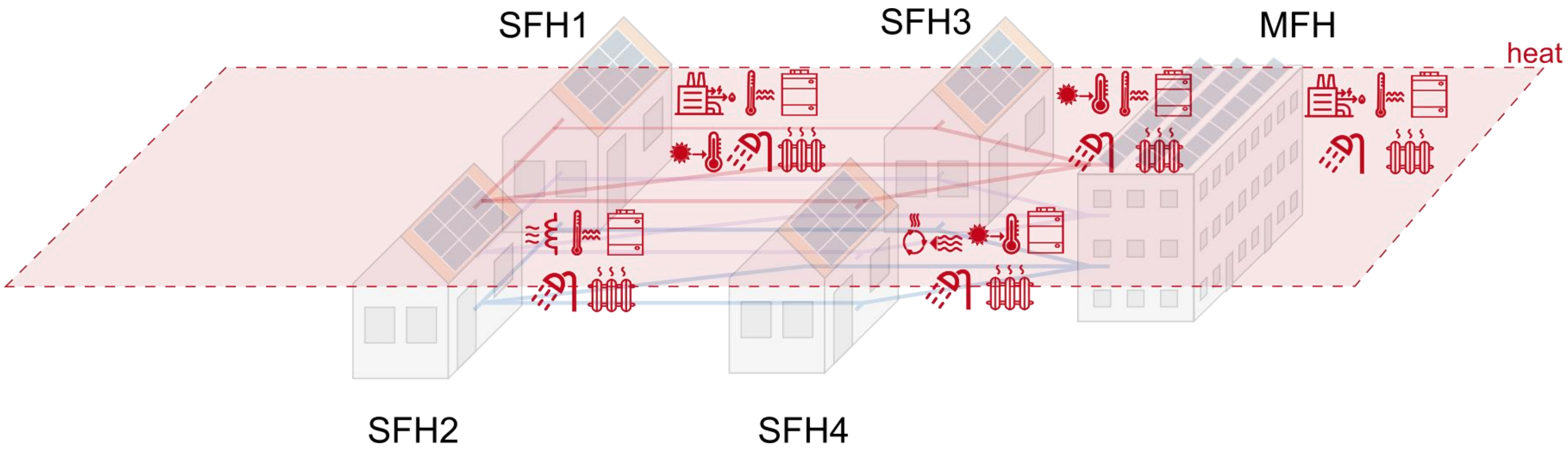
CoSES: Overall Layout



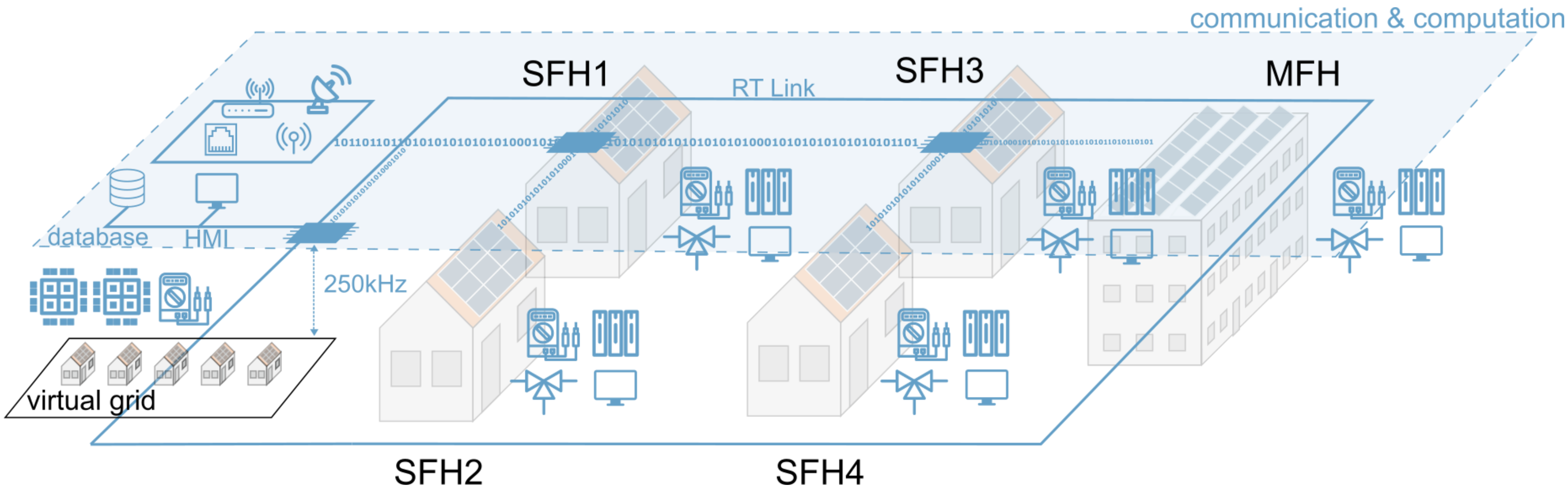
CoSES: Electrical Grid



CoSES: Heat Grid



CoSES: Communication Grid



Laboratory: Guiding Philosophies.

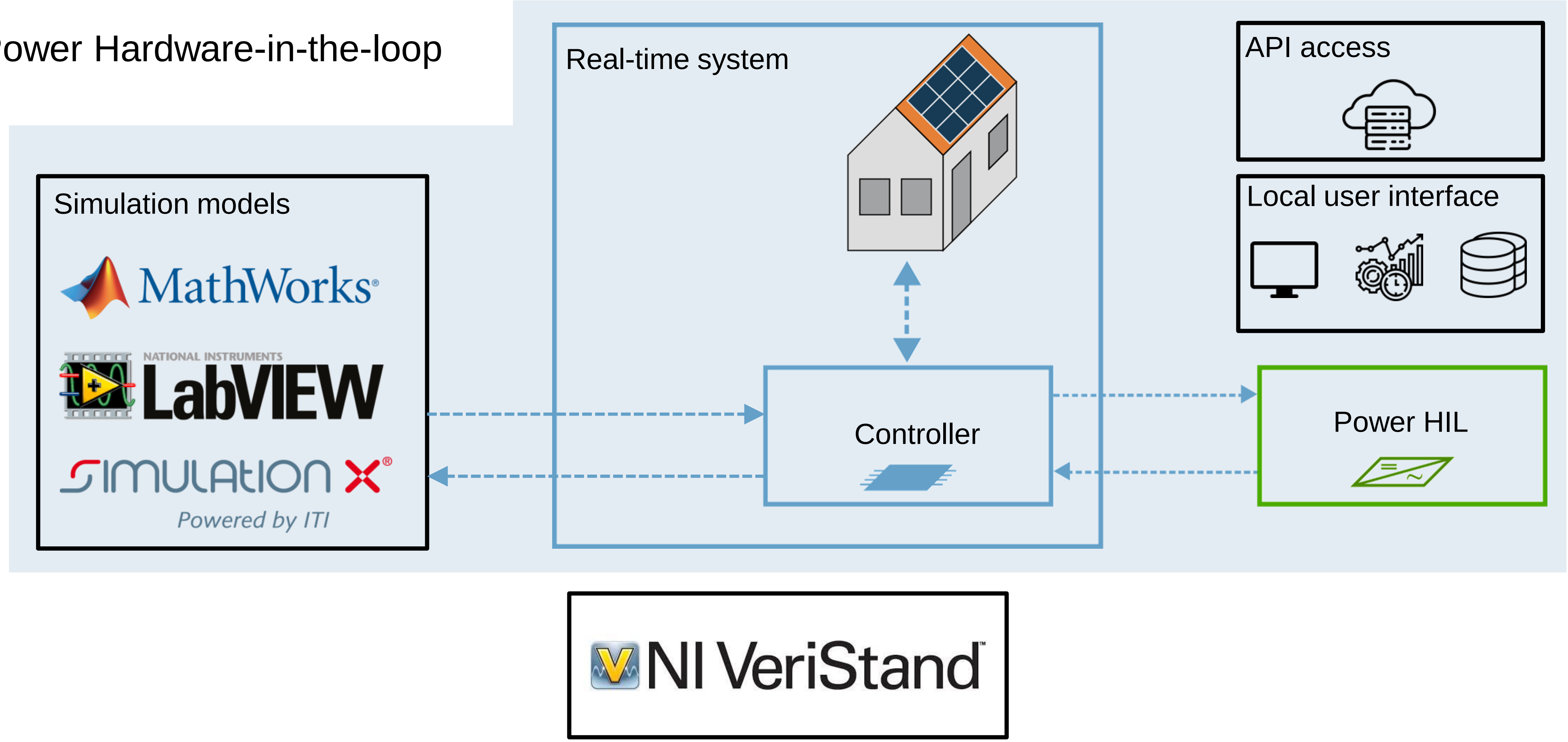
- Cable parameters – Never 100% accurate.
- Whole set of measurements – Rarely available everywhere.
- Massive centralized computation power to throw at a problem – Not practical.

- DER manufacturers will not let you interfere with internal controller for direct control.
- CHP and Heat pumps do not modulate 0-100%.
- Most heat grid components deviate significantly from datasheet performance.
- Nobody knows how to control “Real” bi-directional heat grids.

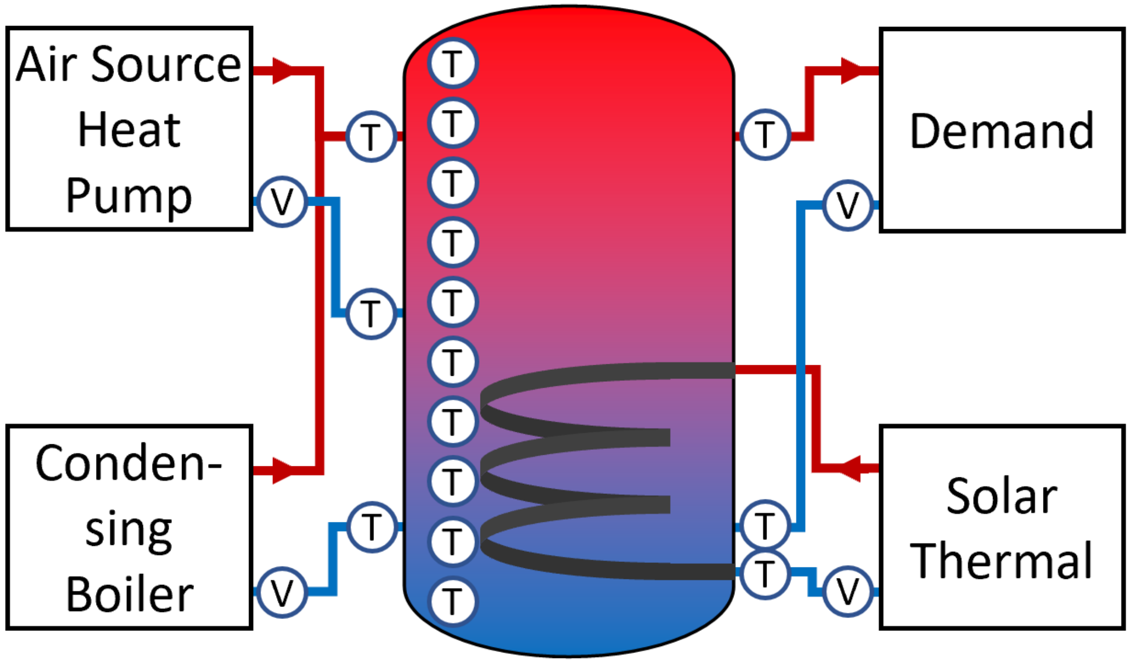
- Real interface between optimization and control – and it is a problem!
- Things are rarely useful if not easily reproducible.

CoSES: Experiment Design

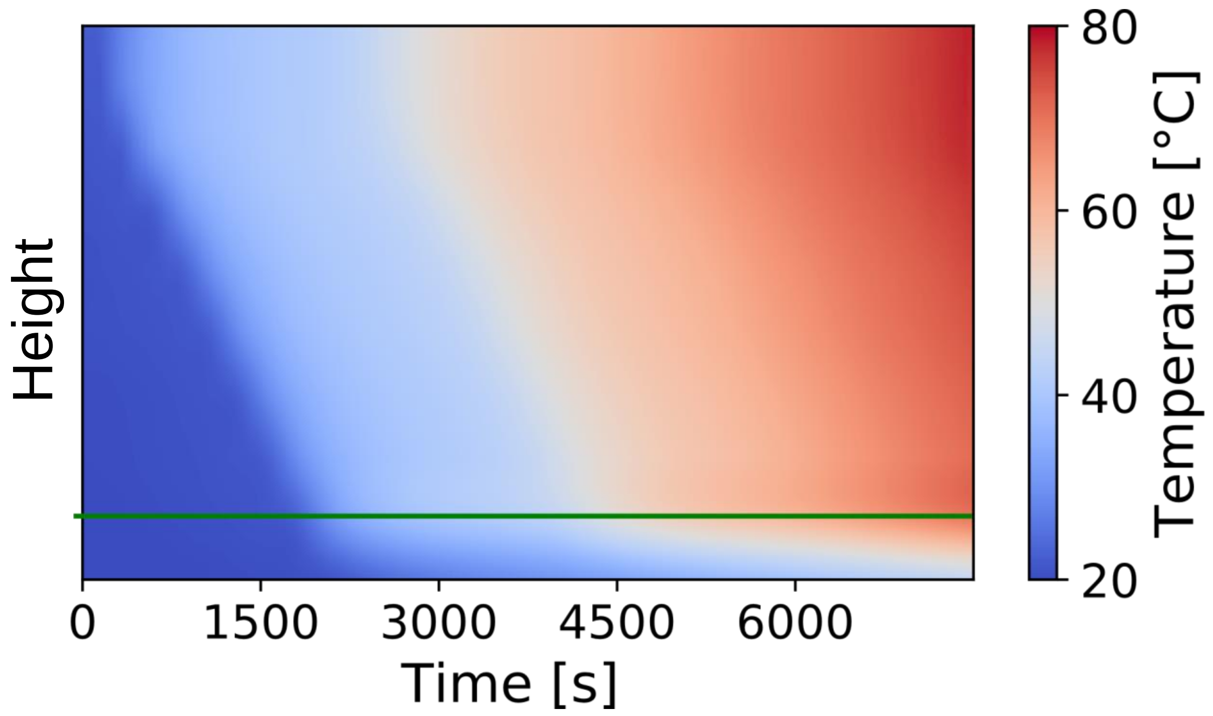
Sector coupled Power Hardware-in-the-loop



Study #1: Experimental Model Validation of a Thermal Storage

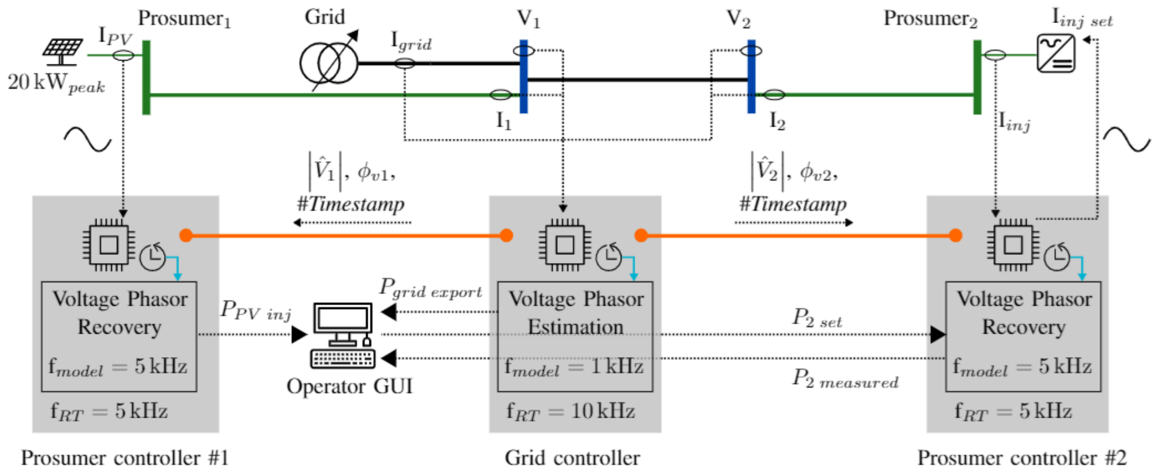


Charging with Condensing Boiler

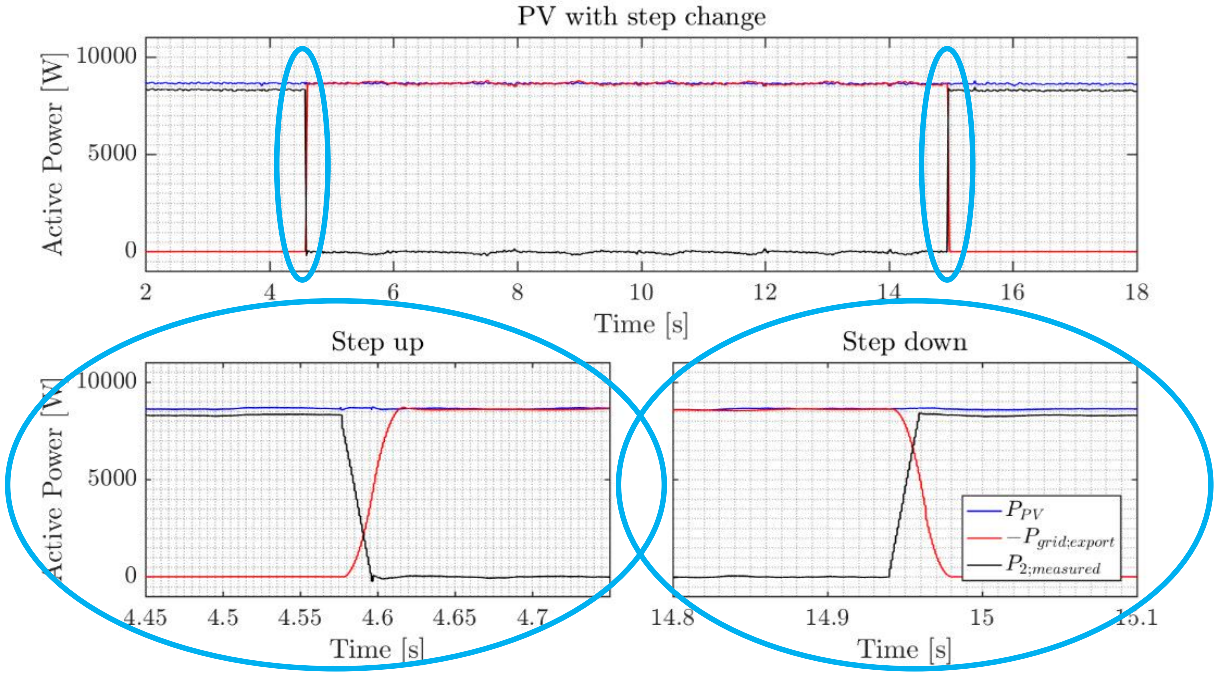


https://www.sciencedirect.com/science/article/pii/S030626192201813X

Study #2: Grid Connected Self Consumption of PV



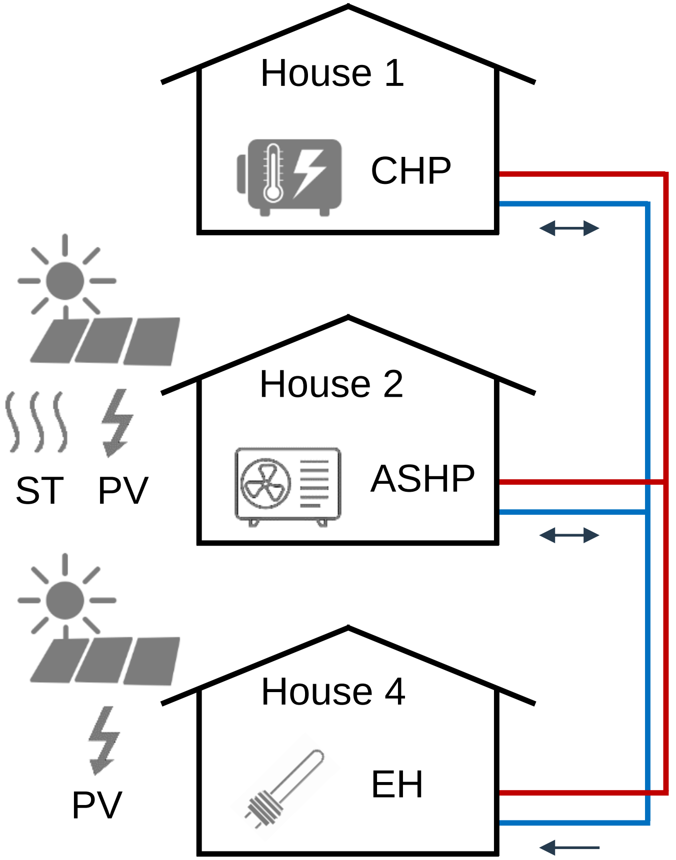
Schematic of the PHIL experiment for **matching the PV production** as a dynamic load to make **net export zero** in **grid connected mode**.



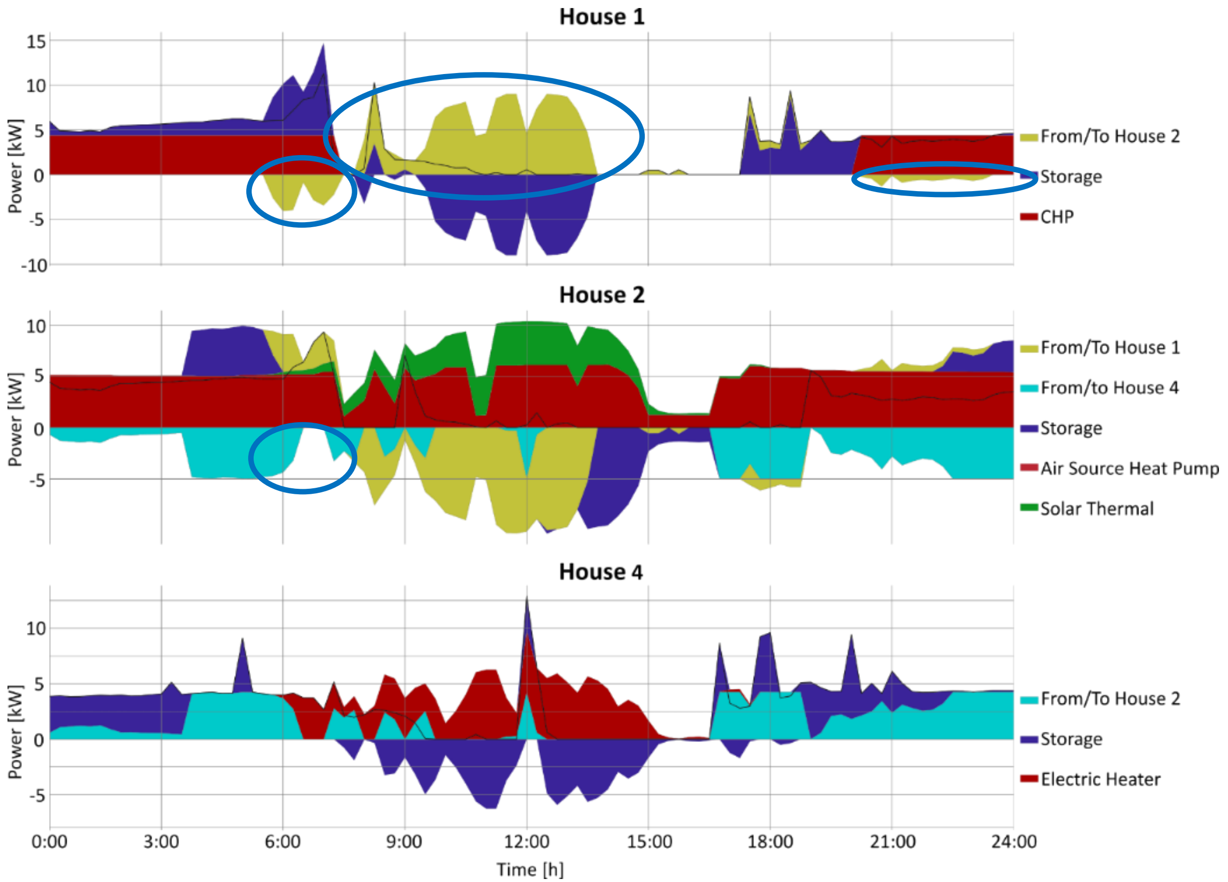
Grid export with Prosumer#2 matching the PV Power

https://www.sciencedirect.com/science/article/abs/pii/S0378779622005818

Study #3: Optimal prosumer operation in district heating grids



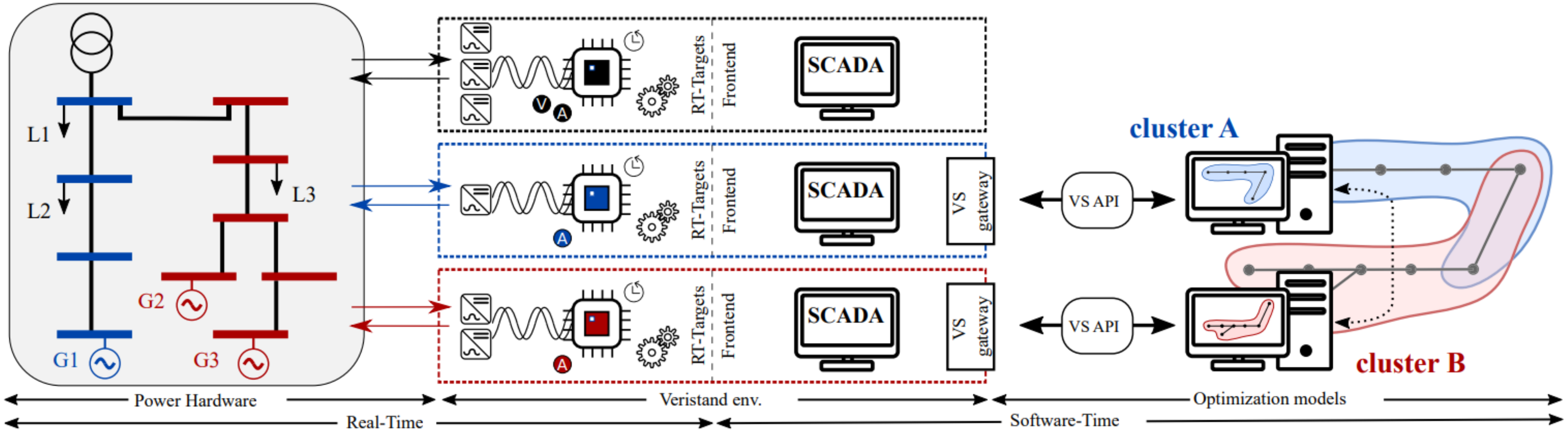
Cost optimization of 3 houses over 24 hours in 15 minute steps



https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4003819

Study #4: Experimental validation of decentral optimal power flow.

1. ADMM based Decentralized OPF
2. Different clusters do not share their internal costs
3. Clusters exchange only tie-line voltages
4. The OPF execution rate is close to real-time (20 sec)
5. The OPF is implemented in Julia that communicates with NI Veristand through JSON using TCP Connection



https://ieeexplore.ieee.org/document/9916705

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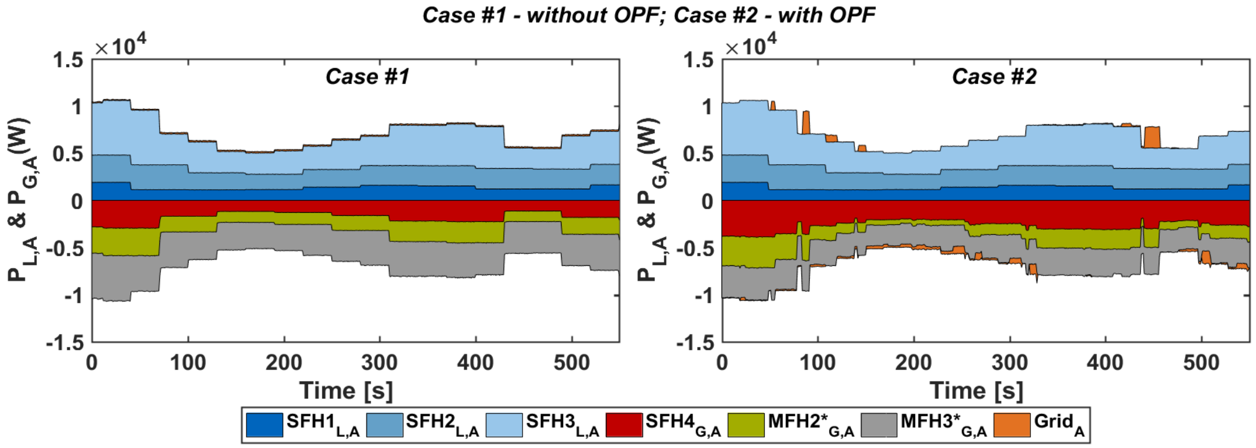

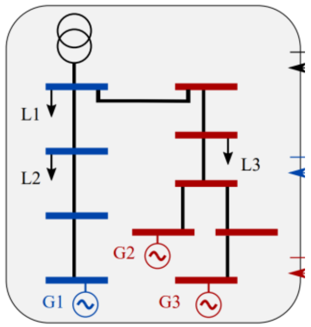

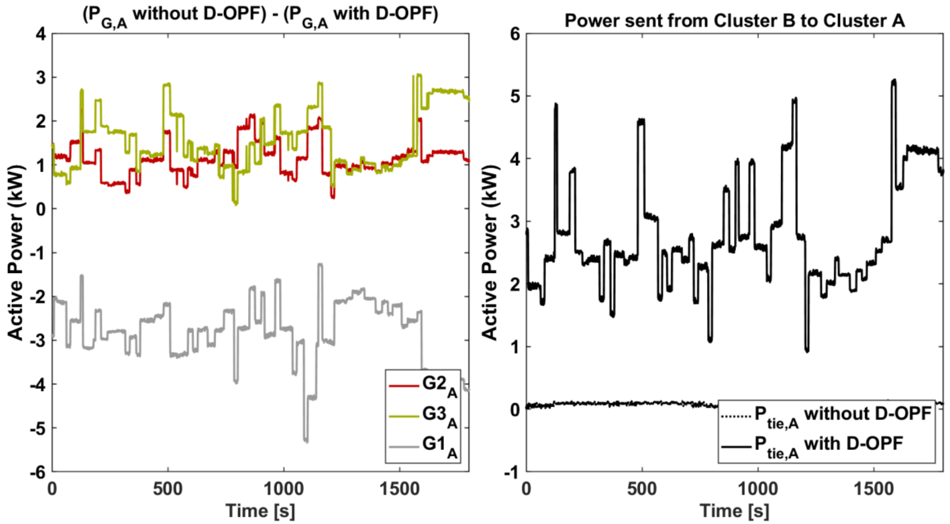

Cluster A
Cluster B

Features:

- Grid connection – Munich LV grid
- LV network – 70 & 95mm^2 cables
- Generators & Loads – Egston
- Control algorithm– Simulink & LV
- OPF algorithm – Julia
- Messaging– JSONs + LV API

Components:

- 3 x RT Embedded controllers
- 2 x PCs for distributed optimisation
- 46 x V, I measurements
- 6 x Power amplifiers
- 1 x Veristand RT environment

Center for Combined Smart Energy Systems

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Selected publications

1. V. S. Perić et al., "CoSES Laboratory for Combined Energy Systems At TU Munich," 2020 IEEE Power & Energy Society General Meeting (PESGM), 2020, pp. 1-5, doi: https://doi.org/10.1109/PESGM41954.2020.9281442

2. A. Mohapatra, T. Hamacher, V. S. Peric, „PHIL Infrastructure in CoSES Microgrid Lab“, *2022 IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe)*, 2022, doi: https://doi.org/10.1109/ISGT-Europe54678.2022.9960295

3. M. Mayer, A. Mohapatra and V. S. Perić, "IoT Integration for Combined Energy Systems at the CoSES Laboratory," 2021 IEEE 7th World Forum on Internet of Things (WF-IoT), 2021, pp. 195-200, doi: https://doi.org/10.1109/WF-IoT51360.2021.9596000

4. Sezgin, Erhan; Mohapatra, Anurag; Peric, Vedran S.; Salor, Ozgül; Hamacher, Thomas (2021): Fast harmonic analysis for PHIL experiments with decentralized real-time controllers. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.17061944.v1, Accepted in PSCC 2022

5. Cornejo, Martin; Mohapatra, Anurag; Candas, Soner; Peric, Vedran S. (2021): PHIL implementation of a decentralized online OPF for active distribution grids. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.17065193.v1, Accepted in PESGM 2022

6. Thomas Licklederer, Thomas Hamacher, Michael Kramer, Vedran S. Perić, Thermohydraulic model of Smart Thermal Grids with bidirectional power flow between prosumers, Energy, Volume 230, 2021, https://doi.org/10.1016/j.energy.2021.120825

7. Zinsmeister, Daniel; Licklederer, Thomas; Adldinger, Stefan; Christange, Franz; Tzscheutschler, Peter; Hamacher, Thomas; Perić, Vedran, „A Prosumer-Based Sector-Coupled District Heating and Cooling Laboratory Architecture“, Smart Energy, Volume 9, 2023, doi: https://dx.doi.org/10.1016/j.segy.2023.100095

8. Iván De la Cruz-Loredo, Daniel Zinsmeister, Thomas Licklederer, Carlos E. Ugalde-Loo, Daniel A. Morales, Héctor Bastida, Vedran S. Perić, Arslan Saleem, „Experimental validation of a hybrid 1-D multi-node model of a hot water thermal energy storage tank“, Applied Energy, Volume 332, 2023, doi: https://doi.org/10.1016/j.apenergy.2022.120556

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