Sector-coupling emulation for PHIL laboratories

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CoSES Team

Prof.
Thomas Hamacher

Director

Dr. -Ing.
Anurag Mohapatra

Group Lead

Approx. 10 internal and external doctoral candidates, several guest researchers and student assisstants.

Photo: CoSES Team Retreat, 2024, Berchtesgaaden

CoSES: at a Glance

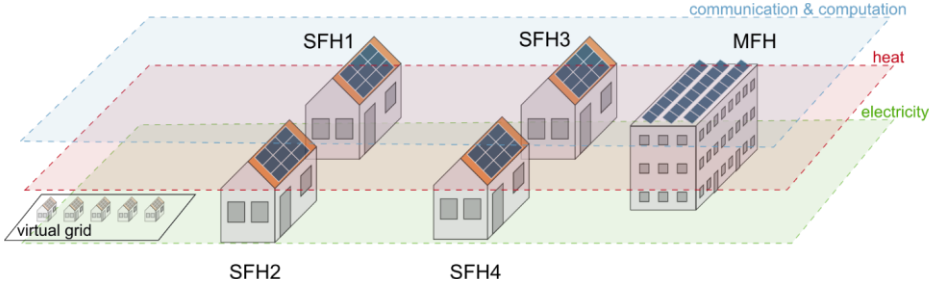
Sector-coupled microgrid at TUM

- Reconfigurable 1.5 km power grid
- Real district heating grid

- Upto 250kVA PHIL emulation
- 4th and 5th generation heat prosumers
- PV, BESS, EV chargers, HP, CHP, Boilers

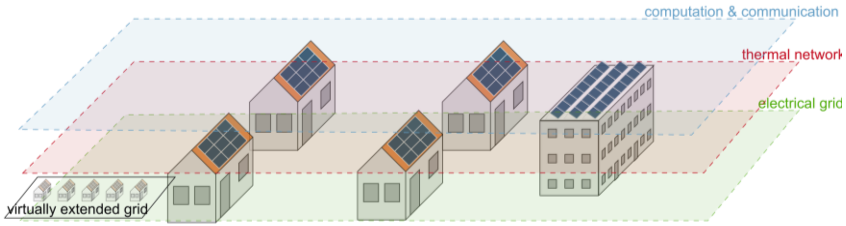
- Decentralised control systems
- Unified programming interfaces

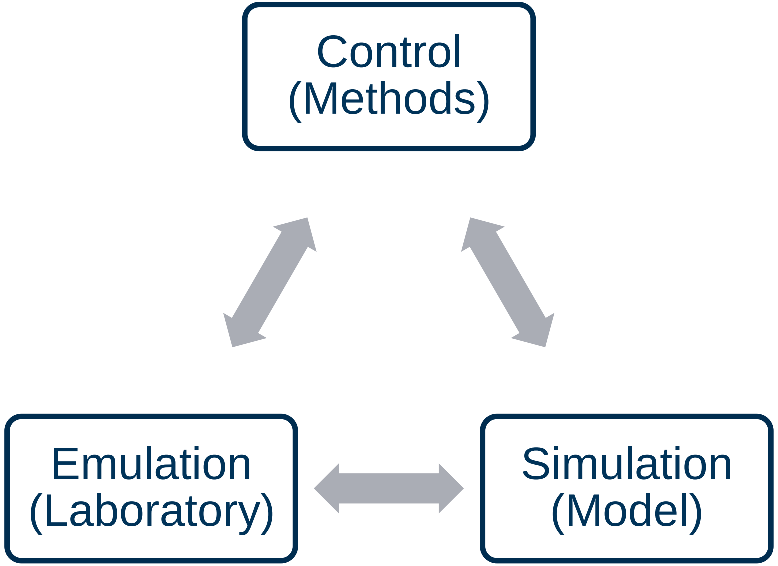
- API access to the lab



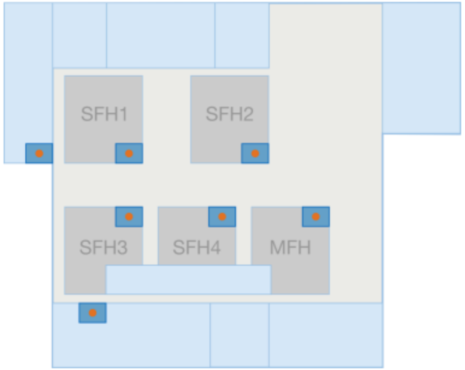
CoSES: Research and Expertise

- Active Distribution Grids
- Bidirectional District Heating & Cooling Networks
- Smart Management, Communication & Control





CoSES: Energy technology of five buildings in one lab



Video Presentation:

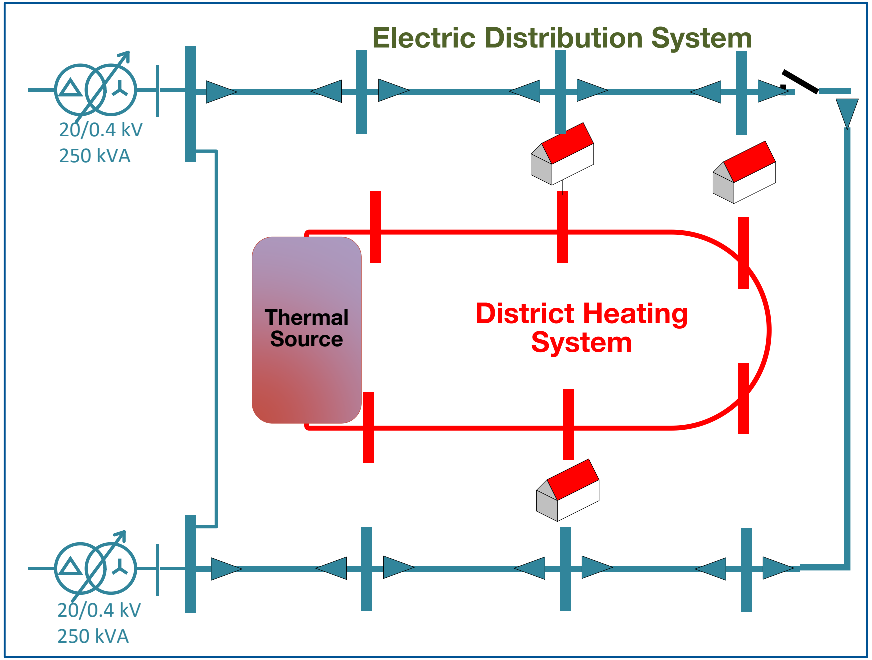
[Licklederer2022]

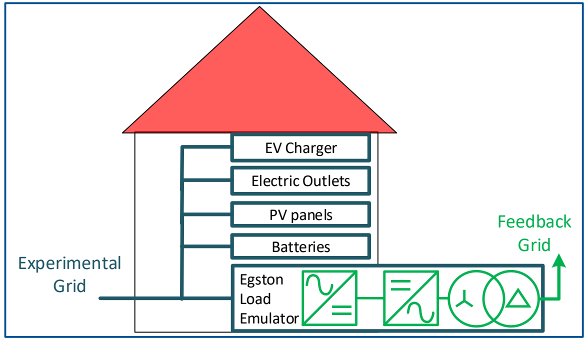
Detailed info in our publications on the lab:

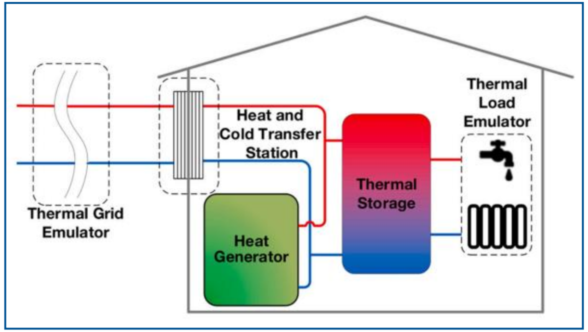
[Zinsmeister2023]

[Mohapatra2022]

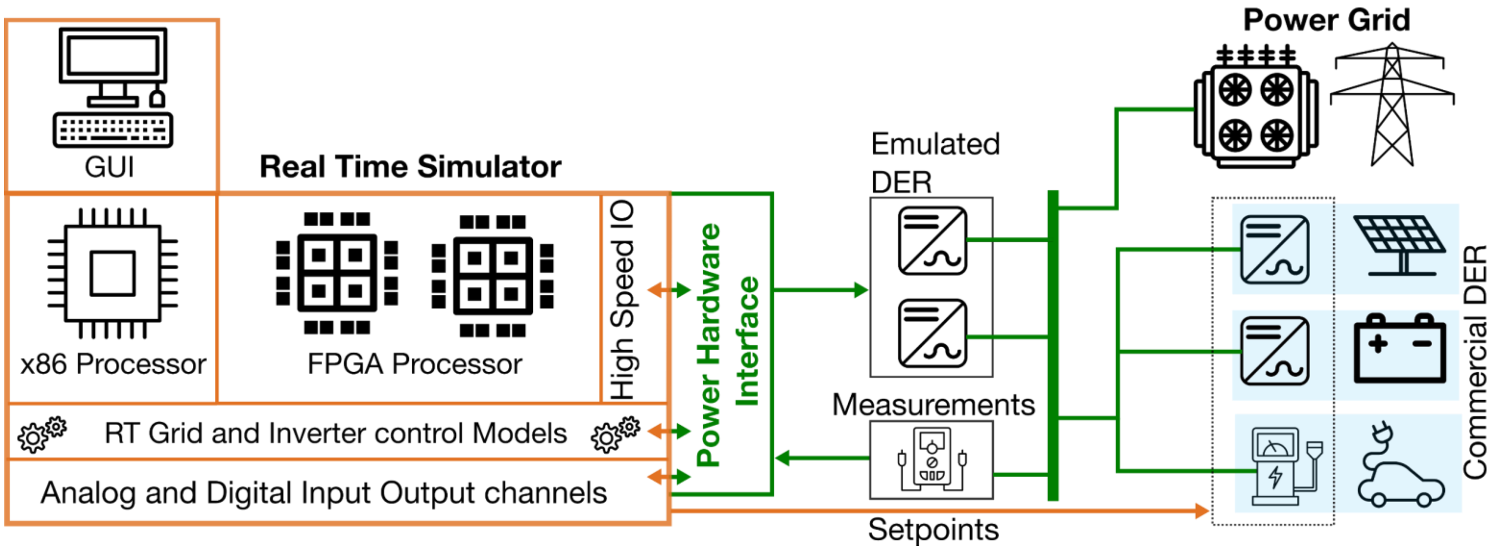
CoSES: Schematic overview





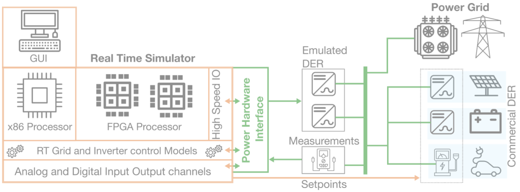


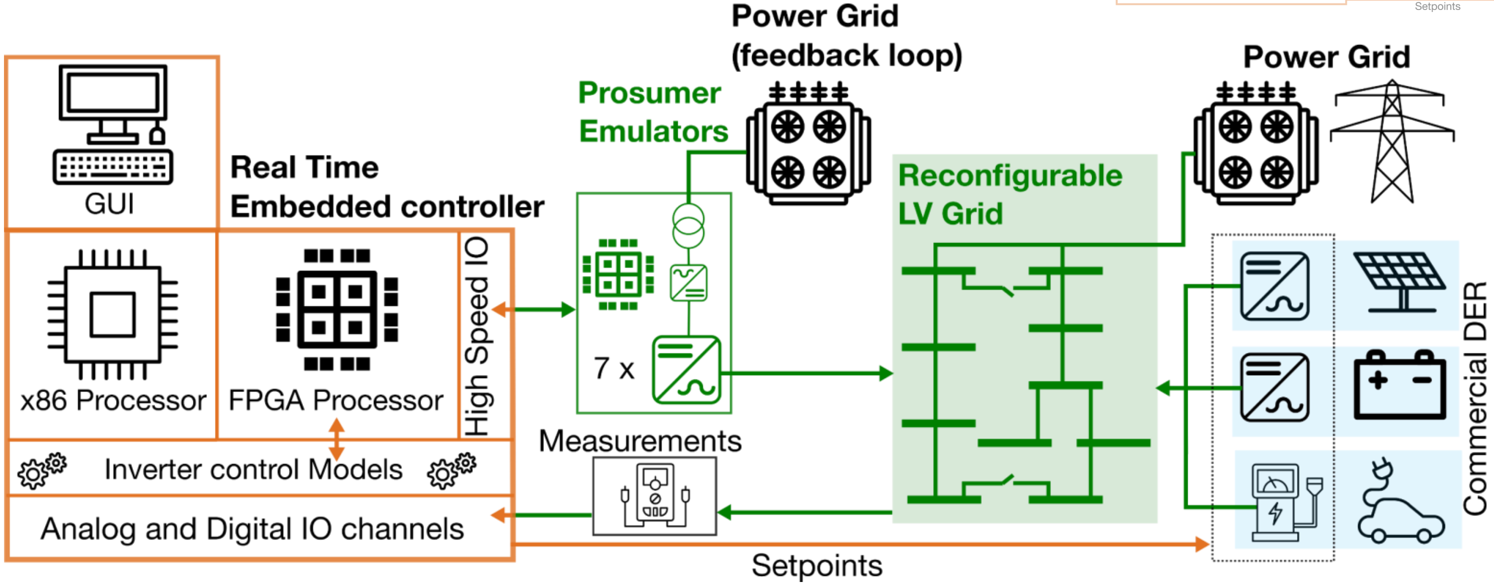
CoSES: Power-system in the loop



Standard power system laboratories

CoSES: Power-system in the loop

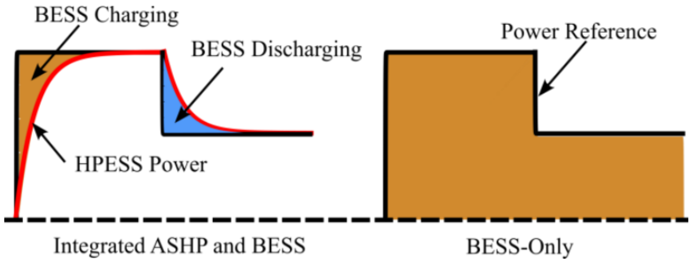




CoSES: Power system in the loop

Virtual DERs for sector coupling

- Heat pumps can be used for frequency response services
- Heat pumps are a control nightmare in the field



- How exactly should power system laboratories „research“ sector-coupling through heat-pumps?
  - Lack of expertise in heat-pump modelling
  - Lack of access to requisite real hardware
  - Unable to bypass any device safety features for fast control

SPIEGEL Business

Why heat pumps often consume too much electricity

They are intended to make residential buildings more climate-friendly and less dependent on gas. But many heat pumps are planned incorrectly, and customers are often left with high costs. What consumers should pay attention to.

By Henning Jauernig
18.03.2022, 13:00 • from DER SPIEGEL 12/2022

Virtual DERs for sector coupling

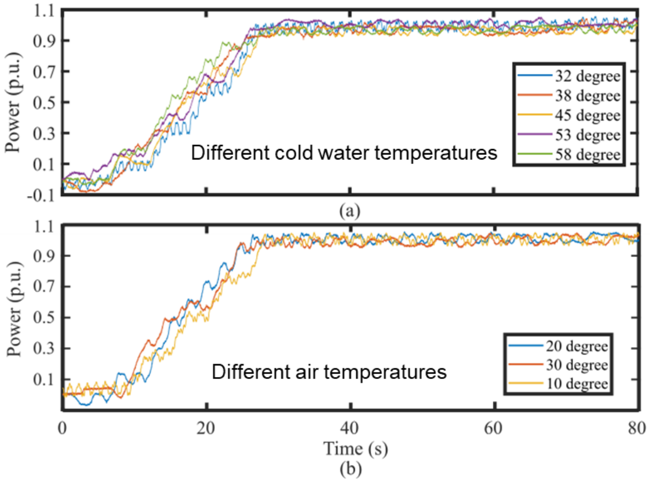
Wolf Air Source Heat Pump

(19 kW_{heat}, 9 kW_{cold})

+

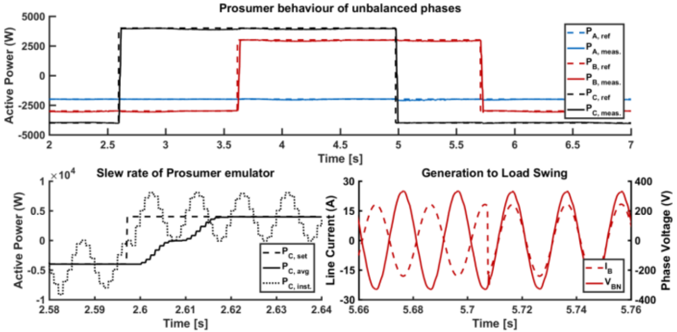
HVAC climate generator

Speed-power response of the CoSES ASHP (normalized):



Virtual DERs for sector coupling

- High bandwidth PHIL emulation.



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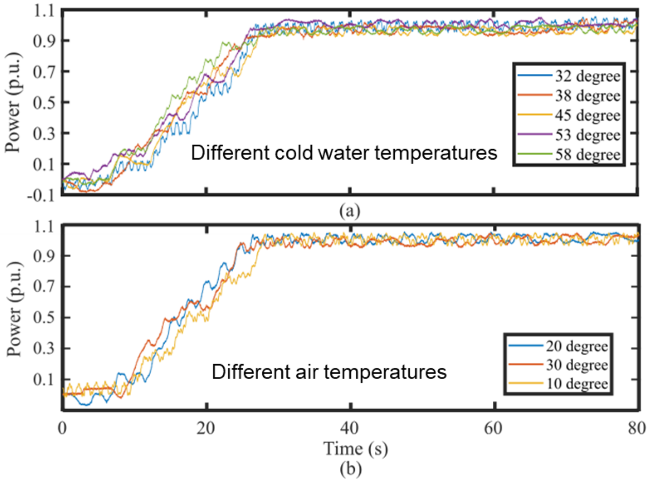

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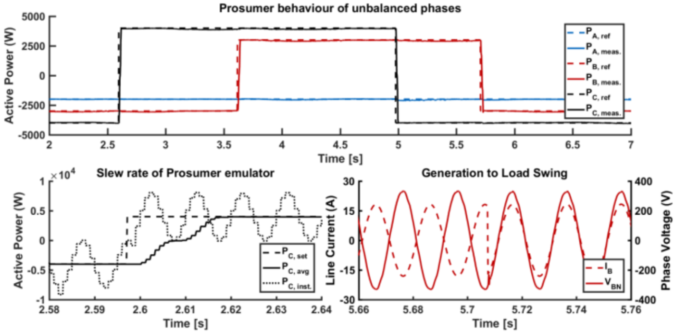
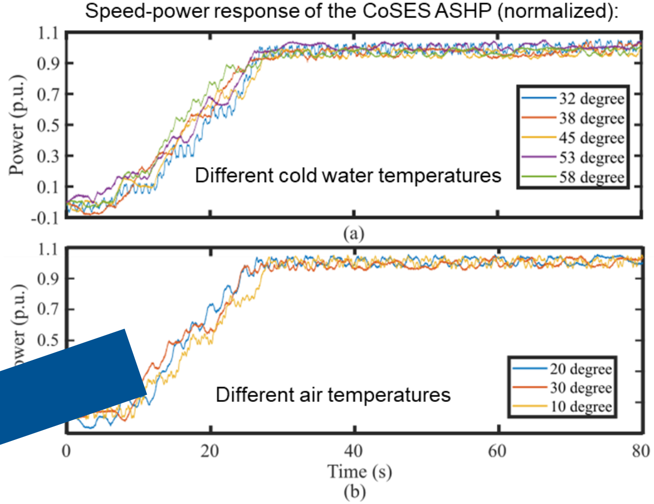


Wolf Air Source He

(19 kW

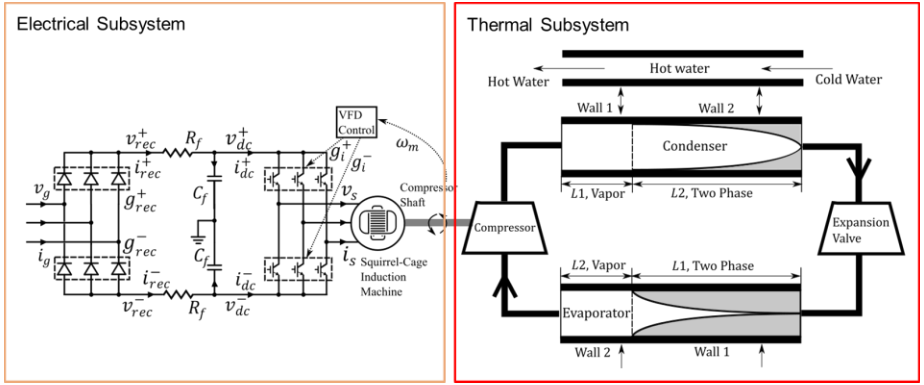
+

AC climate generator



Virtual DERs for sector coupling

- Remove all the internal safety control gains and delays.
- Reflect important non-linear dynamics based on physics principles (for rapid control validation).
- Establish our “virtual PHIL Heat Pump” in a real grid environment.



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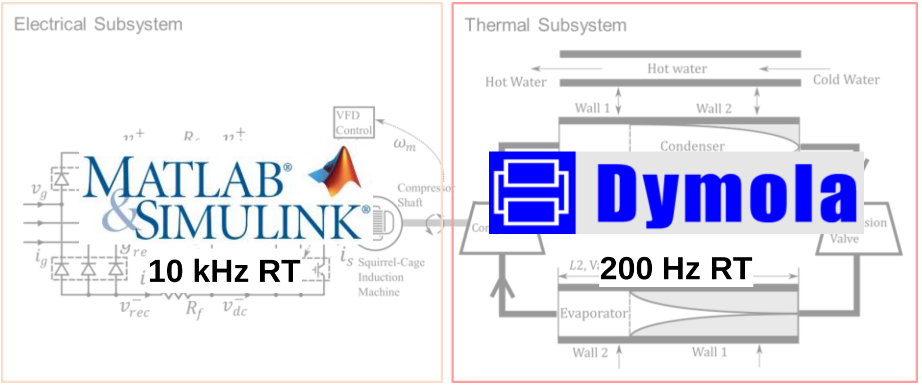

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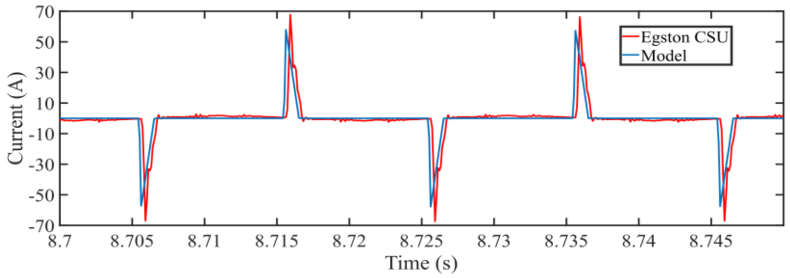

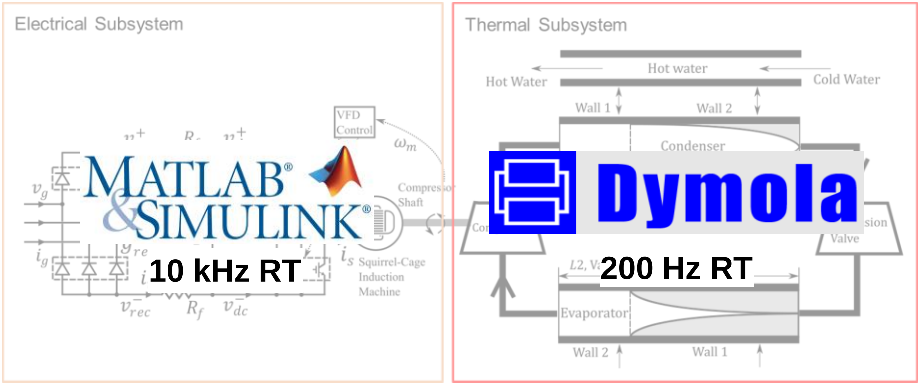

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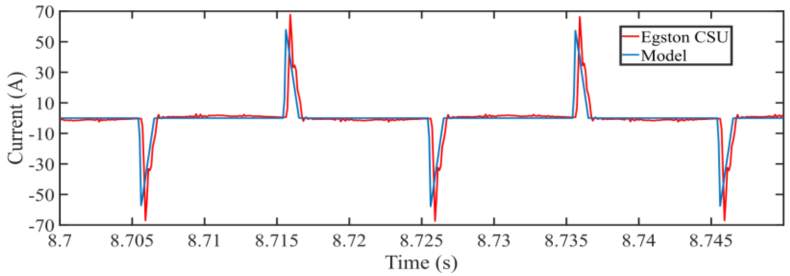
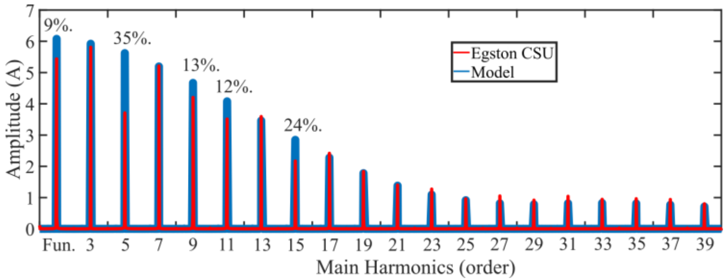
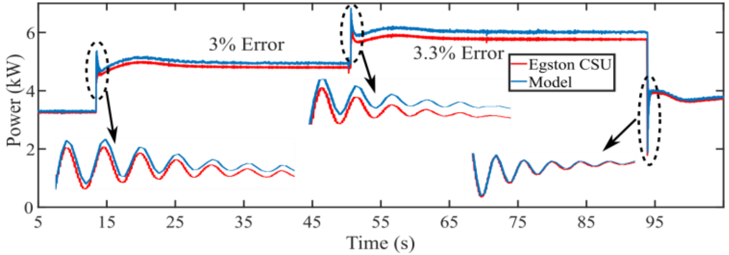
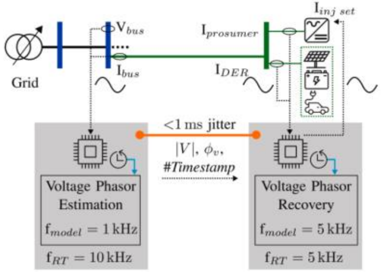


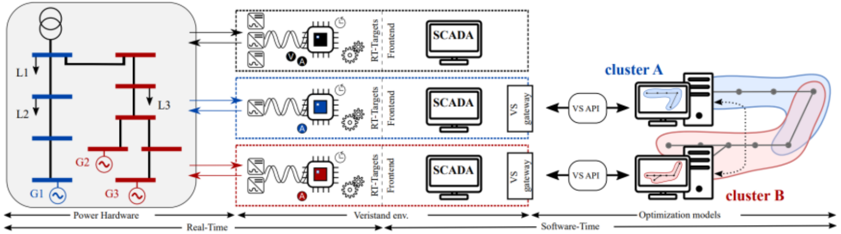


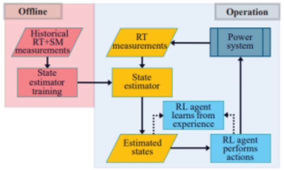


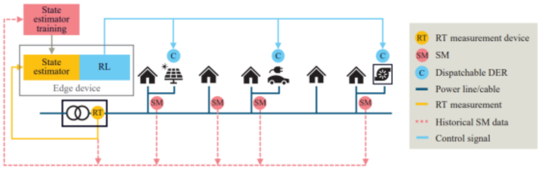
Relevant Publications

- Designing experiments in an ADG lab
  - CoSES research infrastructure [Peric2020, *PES GM*]
  - IoT integration for CoSES [Mayer2021, *WF-IoT Conf.*]
  - PHIL infrastructure in CoSES [Mohapatra2022, *ISGT Europe*]
- PHIL implementation
  - Online decentral OPF in PHIL [Cornejo2022, *PES GM*]
  - PHIL emulated M-Class PMU [Mohapatra2023, *PowerTech*]
  - PHIL emulated Heat pumps for frequency response [Song2024, *PSCC*]
- ML applications in Power Systems
  - RL for Demand Response Problems [Ludolfinger2023a, *PowerTech*]
  - Adaptive Control of Practical Heat Pump Systems based on RL [Song2023, *PowerCon*]
  - Data-driven modelling of heat pump dynamic model [Song2022, *PES GM*]
  - Transformer Model Based Soft Actor-Critic Learning for HEMS [Ludolfinger2023b, *PowerCon*]
  - LV grid control based on data driven SE and RL [Özlemis2024, *PES GM*]









Appendix – Electrical Equipment

Transformers	2 x MV/LV OLTC, 250 KVA; 1 x MV/LV 630KVA for feedback loop
LV Grid	12 x Power cables, 10 Lv Busbars, 2 x LV circuit breaker (to change the network topology)
Prosumers	Egston Compiso, 7 x bidirectional 4 leg inverters, SFP interface for control, 250KVA (total), 100KVA (single cabinet)
DERs	18KWp PV divided into 3 inverters, 2 x 13KWh battery storage, 2 x 22KW car chargers.



Appendix – Thermal Equipment

	Haus 1	Haus 2	Haus 3	Haus 4	Haus 5
Thermal generators	CHP (2 kW_{el}, 5,2 kW_{th}) Boiler (20 kW_{th}) Solar thermal (9 kW_{th})	Boiler (20 kW_{th}) Heat pump (19 kW_{heat}, 9 kW_{cold}) Solar thermal (9 kW_{th})	Ground source heat pump (19 kW_{heat}) Solar thermal (9 kW_{th})	Stirling Engine (1 kW_{el}, 6 kW_{th}) Boiler (20 kW_{th})	CHP (5 kW_{el}, 11,9 kW_{th}) CHP (18 kW_{el}, 34 kW_{th}) Boiler (50 kW_{th})
Thermal storage	800 l	785 l	1000 l	1000 l	2000 l
Domestic hot water	Fresh water storage (500 l)	Fresh water storage	Fresh water storage	Internal heat exchanger	Fresh water storage
Transfer stations	Bidirectional transfer station (30 kW_{th}) Booster heat pump (19 kW_{heat}, 14 kW_{cold})	Bidirectional transfer station (30 kW_{th})	Bidirectional transfer station (30 kW_{th})	Bidirectional transfer station (30 kW_{th})	Bidirectional transfer station (60 kW_{th})
Thermal loads	30 kW_{heat}, 9 kW_{cold}	30 kW_{heat}, 9 kW_{cold}	30 kW_{heat}, 9 kW_{cold}	30 kW_{heat}	60 kW_{heat}