Sector-coupling emulation for PHIL laboratories

Dr. –Ing. Anurag Mohapatra

Center for Combined Smart Energy Systems (CoSES)

MEP, TU Munich

Real-Time Simulation Workshop 2024, KIT

12.12.2024

CoSES Team

Prof.
Thomas Hamacher

Director

Dr. -Ing.
Anurag Mohapatra

Group Lead

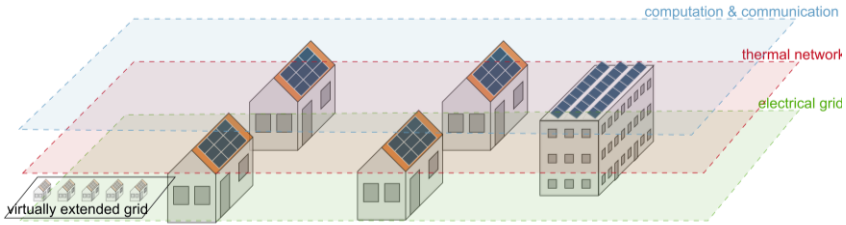
Approx. 10 internal and external doctoral candidates, several guest researchers and student assisstants.

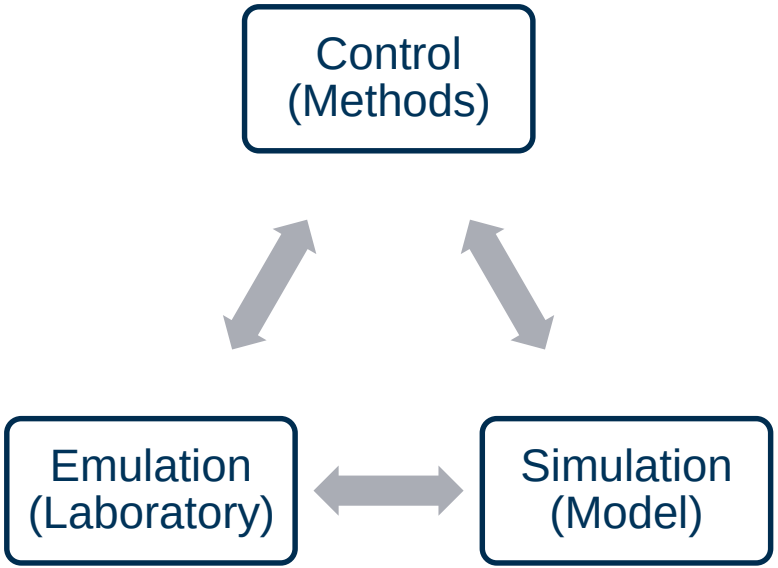
Photo: CoSES Team Retreat, 2024, Berchtesgaaden

Key Areas of Research and Expertise

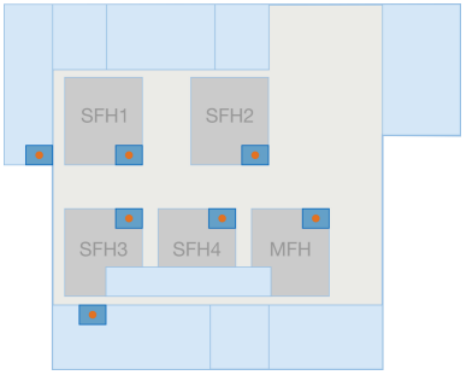
Multi-Energy Systems
on Microgrid / District Level

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





CoSES: Energy technology of five buildings in one lab



Video Presentation:

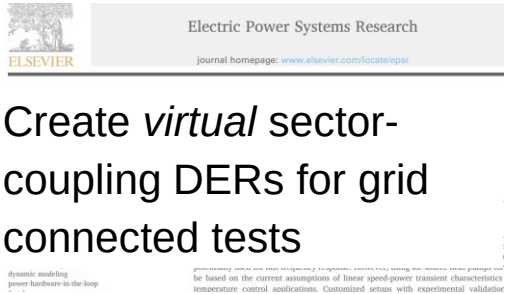
[Lickleder2022]

Detailed info in our publications on the lab:

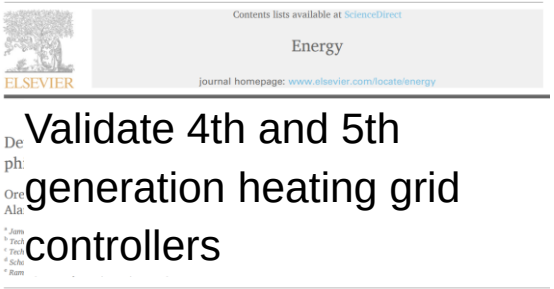
[Zinsmeister2023]

[Mohapatra2022]

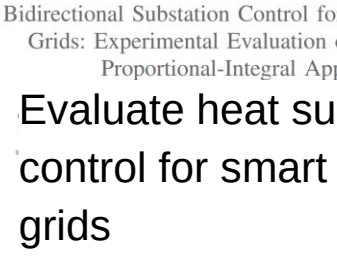
How to use PHIL in Sector-coupling research?



Create *virtual* sector-coupling DERs for grid connected tests



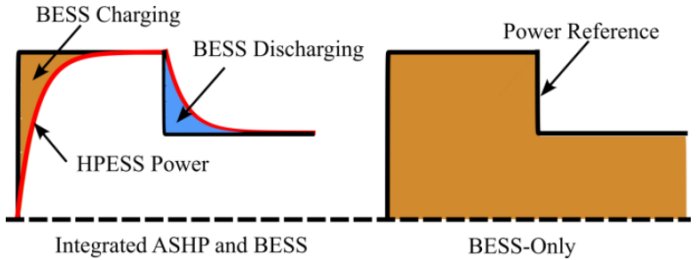
Validate 4th and 5th generation heating grid controllers



Evaluate heat substation control for smart thermal grids

Virtual DERs for sector coupling

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



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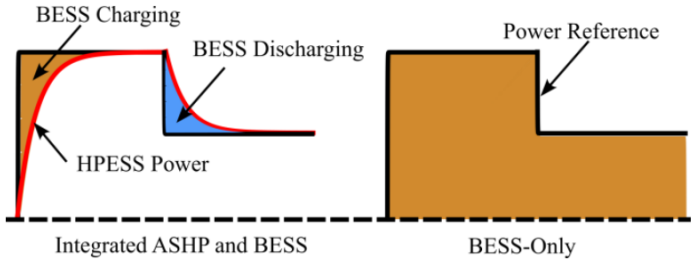


- How exactly should power system laboratories „research“ sector-coupling through heat-pumps?
  - Lack of expertise in heat-pump modelling
  - Lack of access to requisite real hardware
  - Unable to bypass any device safety features for fast control

SPIEGEL Business

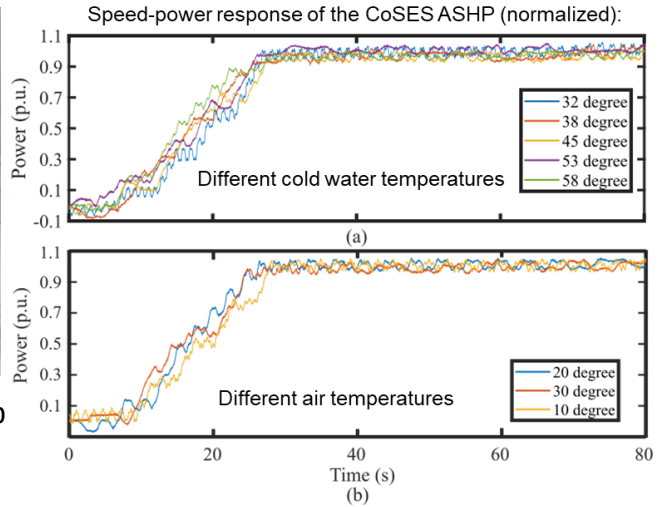
Why heat pumps often consume too much electricity

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**

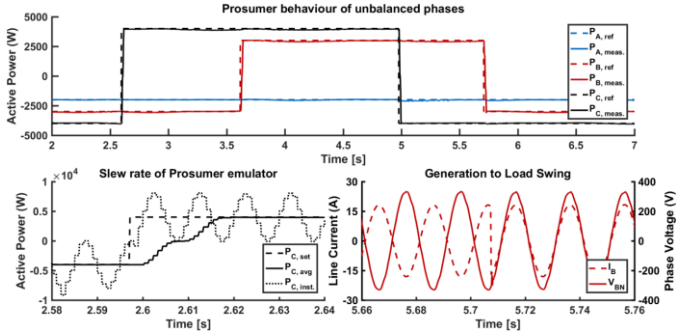
Virtual DERs for sector coupling

Wolf Air Source Heat Pump
(19 kW_{heat}, 9 kW_{cold})
+
HVAC climate generator



Virtual DERs for sector coupling

- High bandwidth PHIL emulation.



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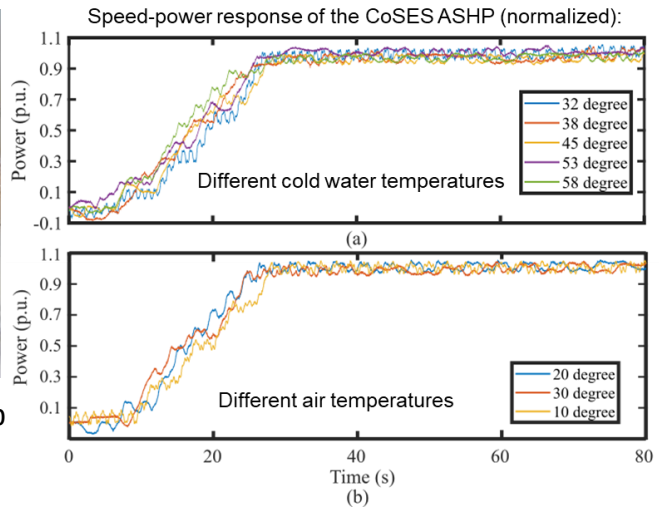

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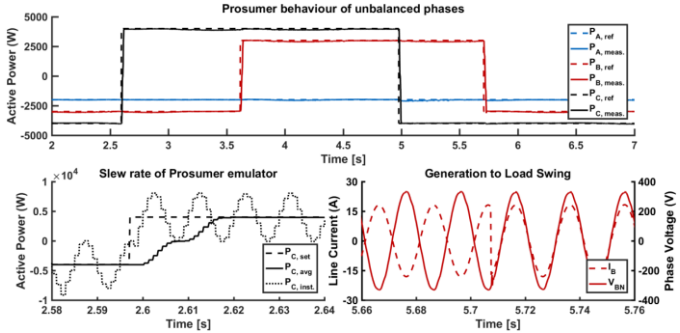

Wolf Air Source Hea
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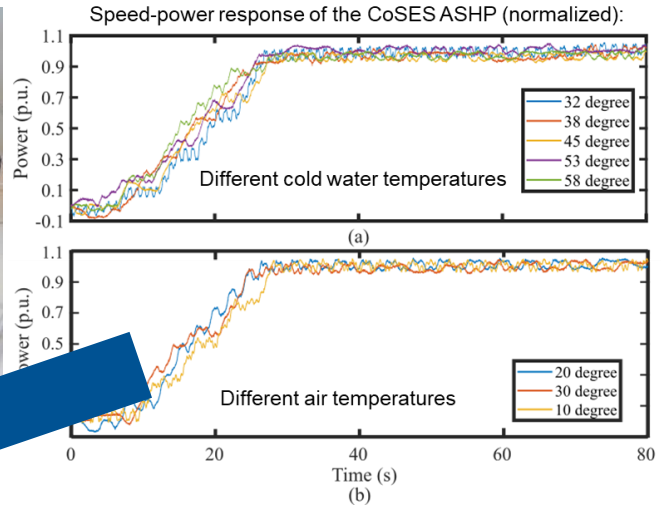
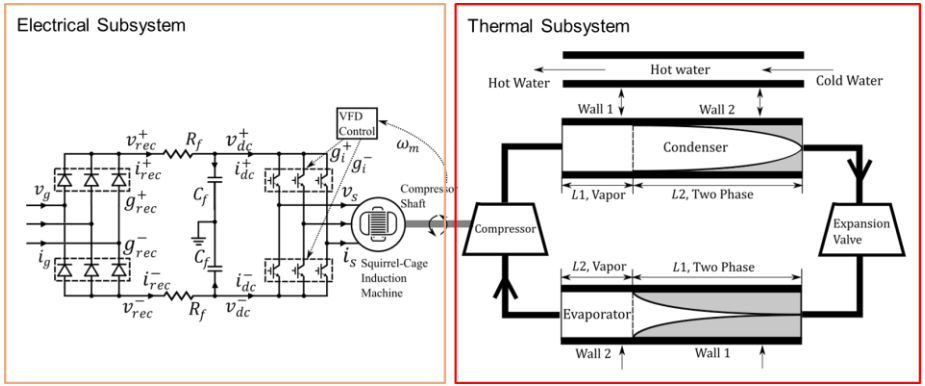


Virtual DERs for sector coupling

- 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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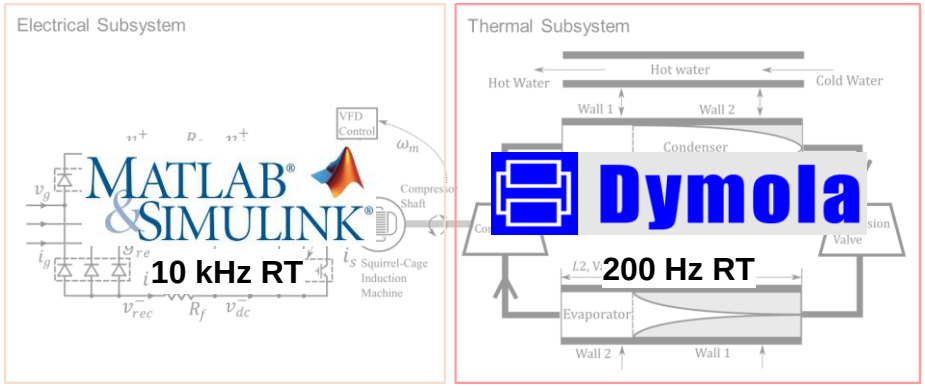

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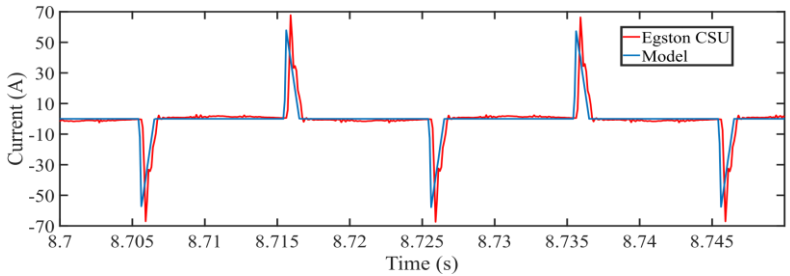

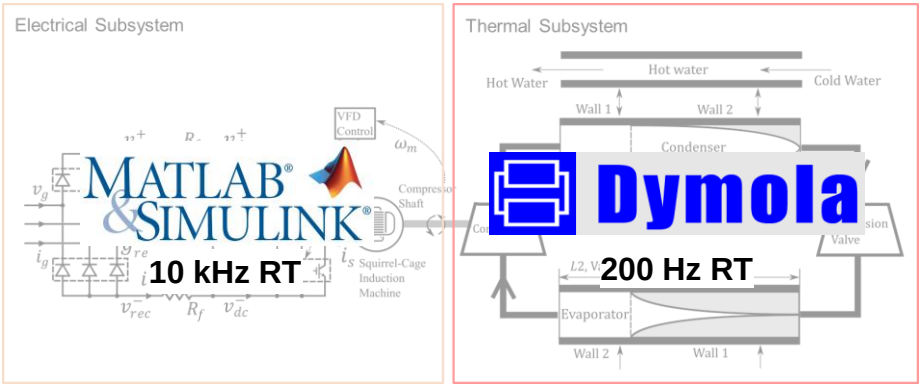

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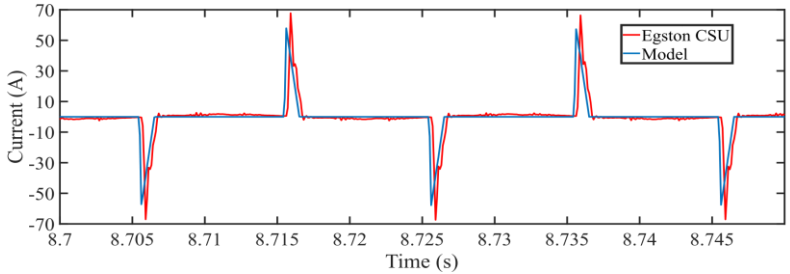

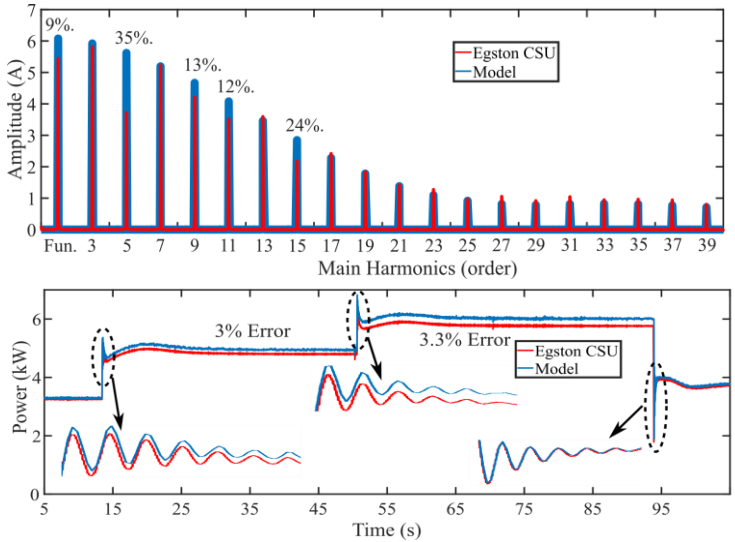

Validate 4th and 5th gen. heating grid control

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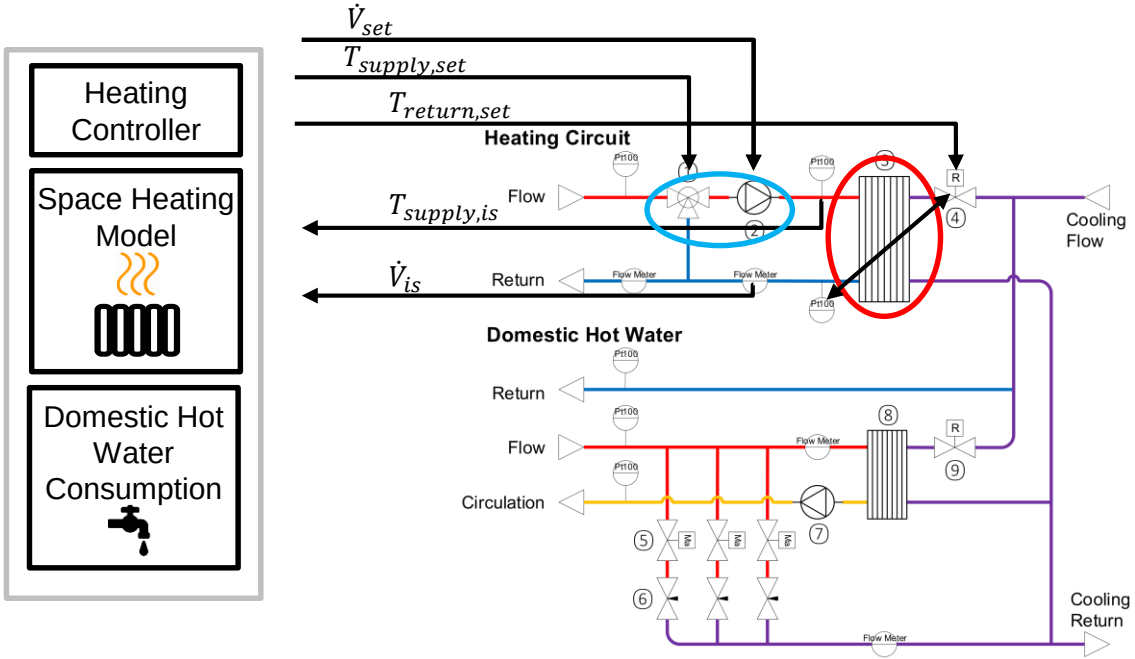
How does PHIL look for a heating grid???

Validate 4th and 5th gen. heating grid control



Validate 4th and 5th gen. heating grid control

Components and functions

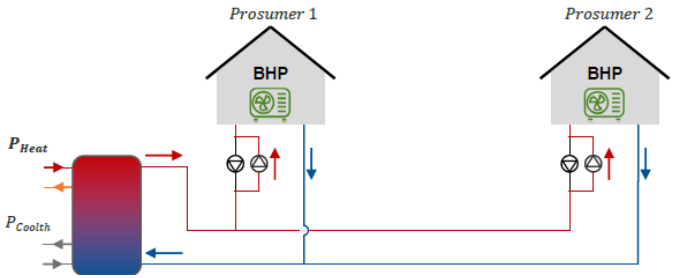
- Passive balancing unit:
  - Hydraulic decoupling
  - Energy balancing
- Booster heat pump transfer station:
  - Temperature boosting
  - Pumping power

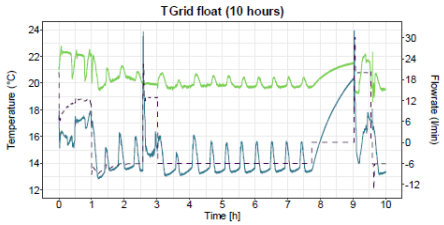
Control philosophies under test:

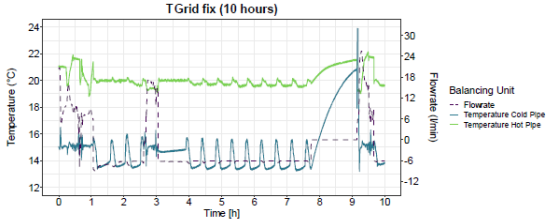
- Controlling the flow rate going through the prosumer
- Controlling the Temperature Difference (ΔT) across the prosumer

Results of concept study:

- Total 20h of experiment; Heating and cooling demand
- Passive balancing unit simplifies prosumer integration
- Control strategy with fixed grid temperature achieves more stable control

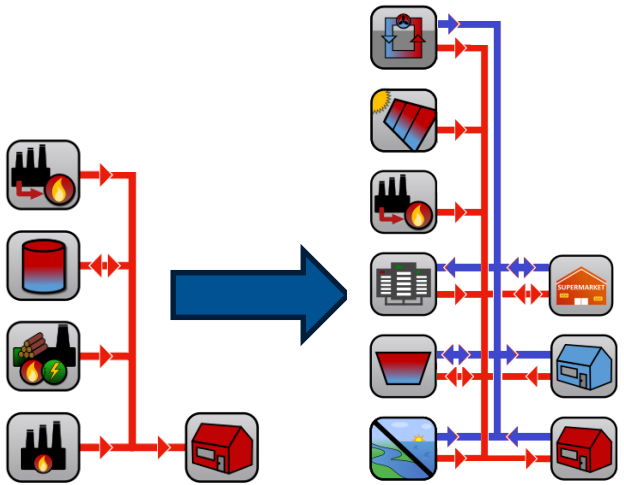






Heat substation control for smart thermal grids

- From centralized, unidirectional networks to decentralized, bidirectional networks
- Need for appropriate control methods:
  - Managing the complex heat exchange between prosumers and the grid



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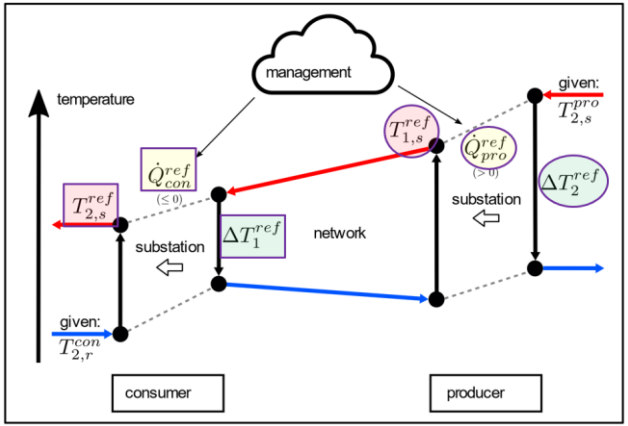

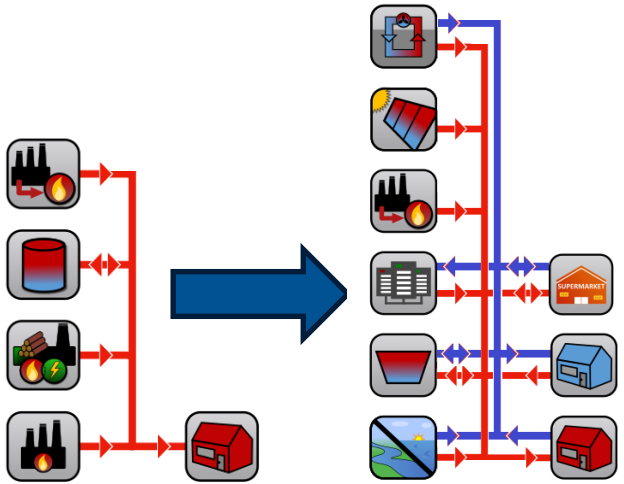

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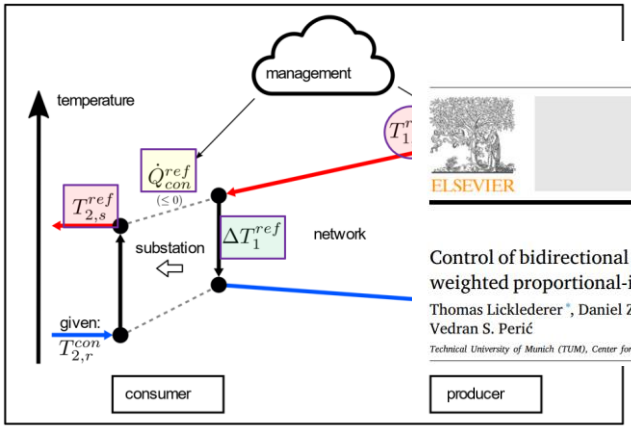

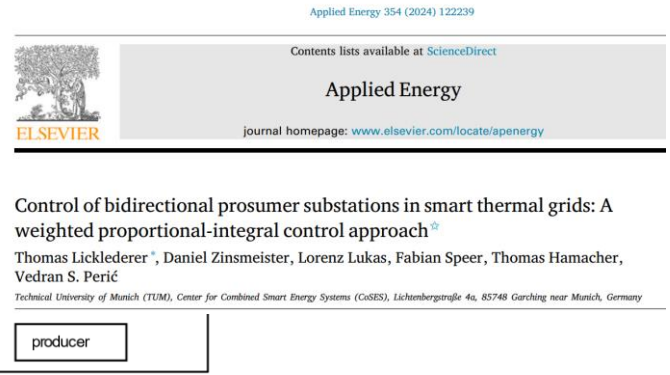
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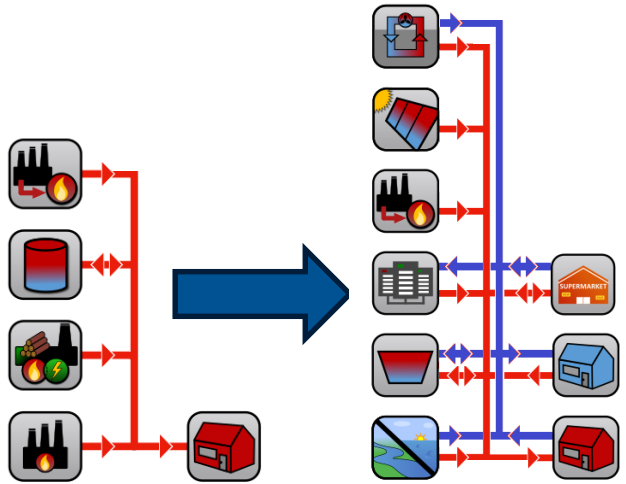
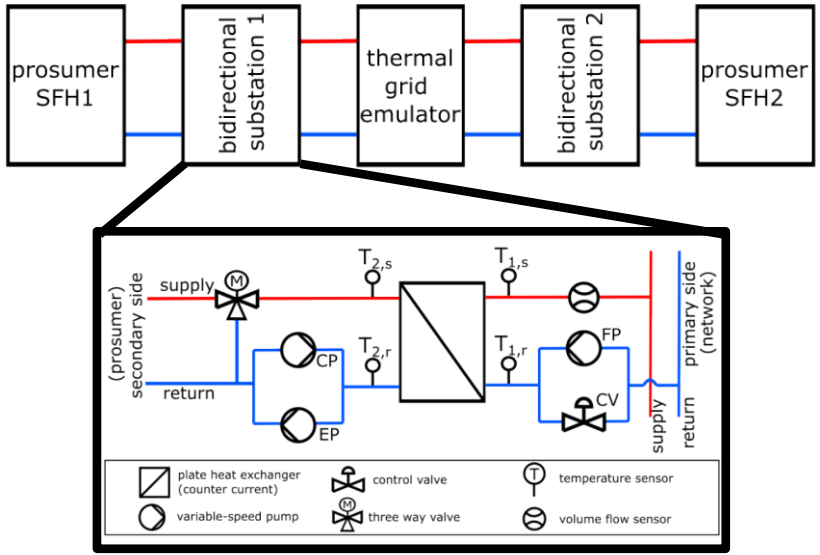
Control of bidirectional prosumer substations in smart thermal grids: A weighted proportional-integral control approach☆

Thomas Lickleder*, Daniel Zinsmeister, Lorenz Lukas, Fabian Speer, Thomas Hamacher, Vedran S. Perić
Technical University of Munich (TUM), Center for Combined Smart Energy Systems (CoSES), Lichtenbergstraße 4a, 85748 Garching near Munich, Germany

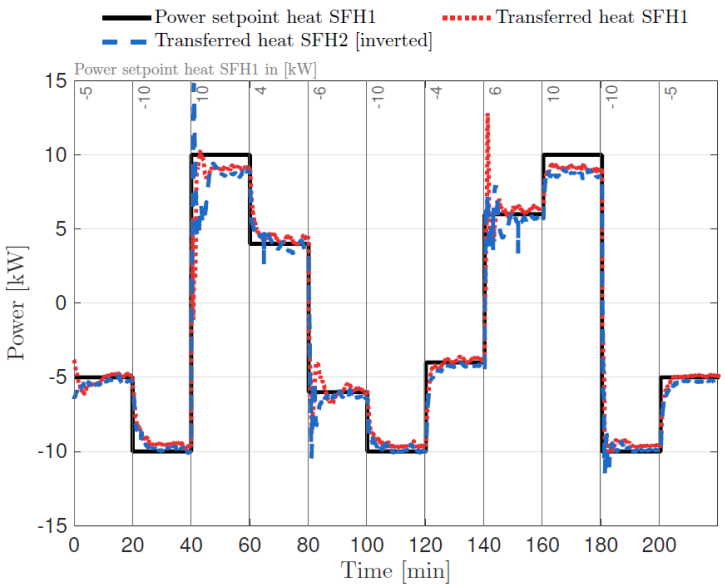


Heat substation control for smart thermal grids

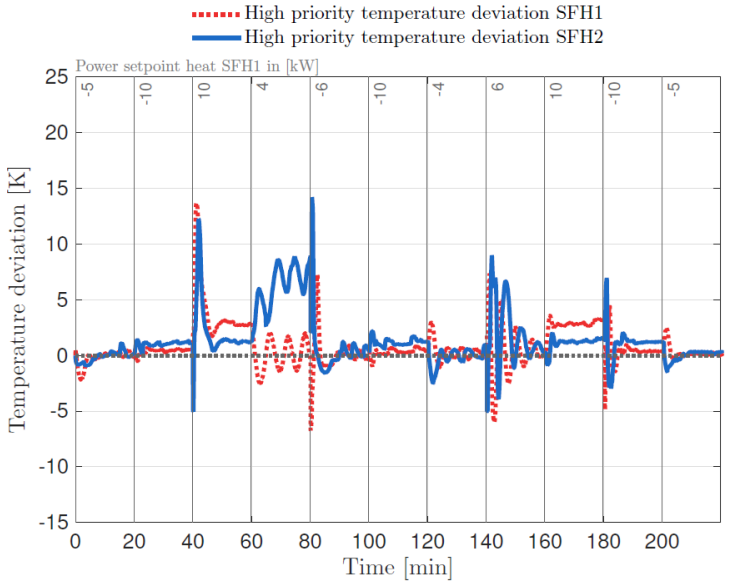


Heat substation control for smart thermal grids

Power Setpoint & Power Actually Transmitted



High Priority Temperature Objective



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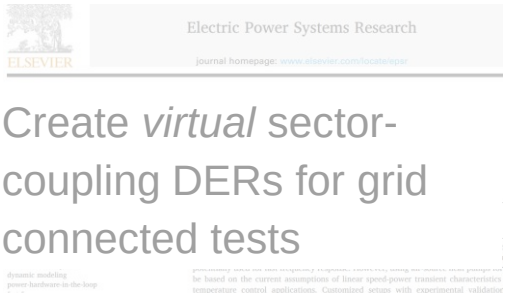

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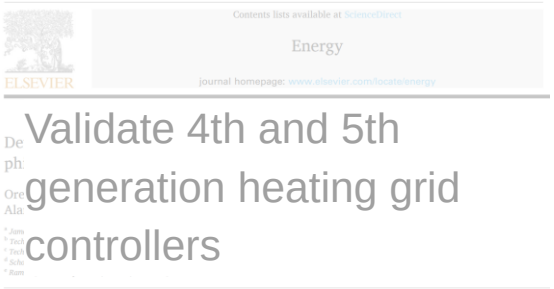

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Choices are many!

References

[1] D. Zinsmeister et al., “A prosumer-based sector-coupled district heating and cooling laboratory architecture,” Smart Energy, vol. 9. Elsevier BV, p. 100095, Feb. 2023. doi: 10.1016/j.segy.2023.100095.

[2] A. Mohapatra, T. Hamacher, and V. S. Peric, “PHIL Infrastructure in CoSES Microgrid Laboratory,” 2022 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe). IEEE, pp. 1–6, Oct. 10, 2022. doi: 10.1109/isgt-europe54678.2022.9960295.

[3] R. Song, A. Mohapatra, T. Hamacher, and V. S. Perić, “Power-hardware-in-the-loop validation of air-source heat pump for fast frequency response applications,” Electric Power Systems Research, vol. 235. Elsevier BV, p. 110754, Oct. 2024. doi: 10.1016/j.epsr.2024.110754.

[4] O. Angelidis et al., “Development and experimental validation of a hydraulic design and control philosophies for 5th generation district heating and cooling networks,” Energy, vol. 308. Elsevier BV, p. 132835, Nov. 2024. doi: 10.1016/j.energy.2024.132835.

[5] T. Lickleder, D. Zinsmeister, L. Lukas, F. Speer, T. Hamacher, and V. S. Perić, “Control of bidirectional prosumer substations in smart thermal grids: A weighted proportional-integral control approach,” Applied Energy, vol. 354. Elsevier BV, p. 122239, Jan. 2024. doi: 10.1016/j.apenergy.2023.122239.

[6] U. Ganslmeier, L. Lukas, T. Hamacher, and T. Lickleder, “Bidirectional Substation Control for Smart Thermal Grids: Experimental Evaluation of a Weighted Proportional-Integral Approach,” 2024 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe), IEEE, 2024