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PHIL Infrastructure in CoSES Microgrid Laboratory

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Motivation

What to expect from a smart/microgrid lab designed for universities?

Hardware

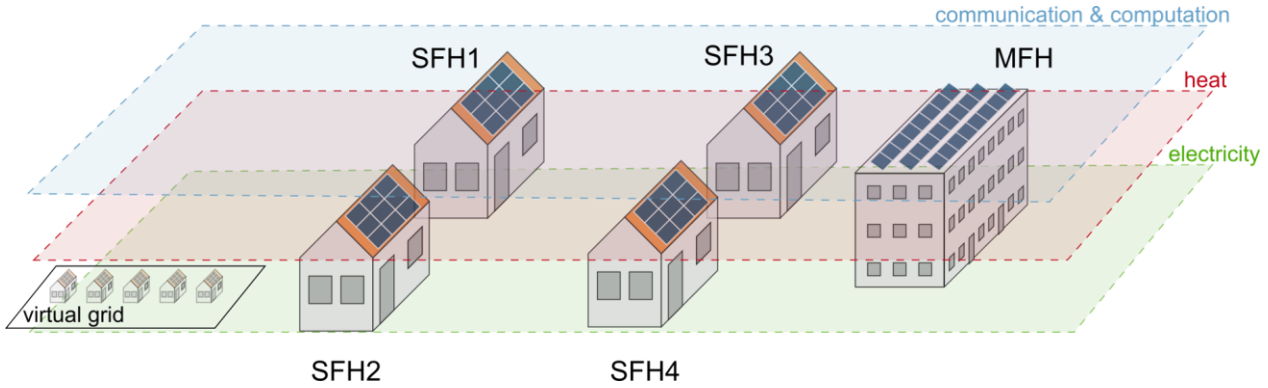
- If possible, emulate
- Easily reconfigurable grid
- Minimize power losses

Software

- Toolchain freedom
- Distributed instrumentation
- Open to commercial protocols

CoSES lab at TU Munich*

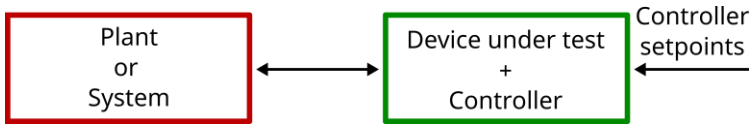
Center for Combined Smart Energy Systems (CoSES)



- Reconfigurable LV grid (~1.5km)
- Heat and electrical Power Hardware-in-the-loop (PHIL)
- No simulated grid model
- Fully controlled prosumer emulators
- Distributed Energy Resources (DER)

*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: 10.1109/PESGM41954.2020.9281442.

Definitions



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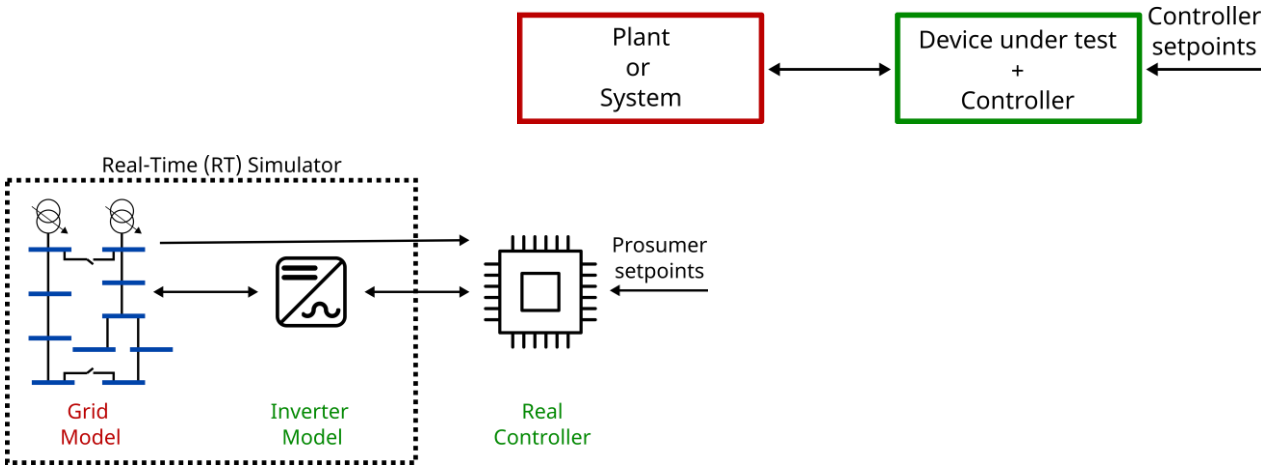

Hardware-**I**n-the-**L**oop

(**HIL**)

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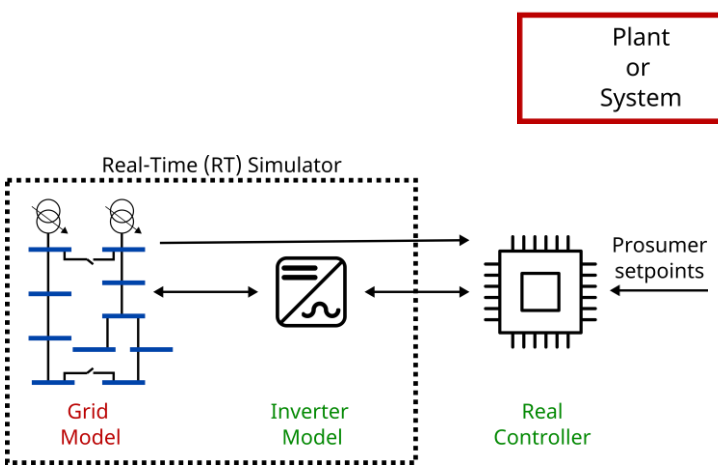

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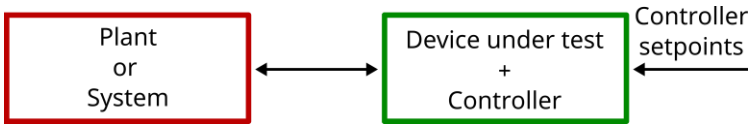
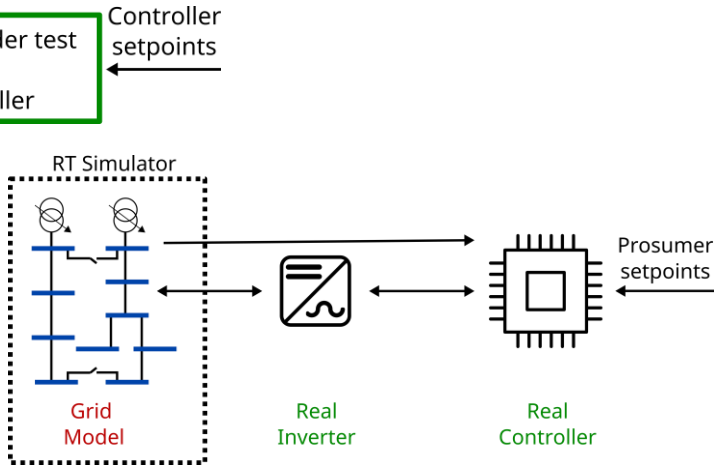
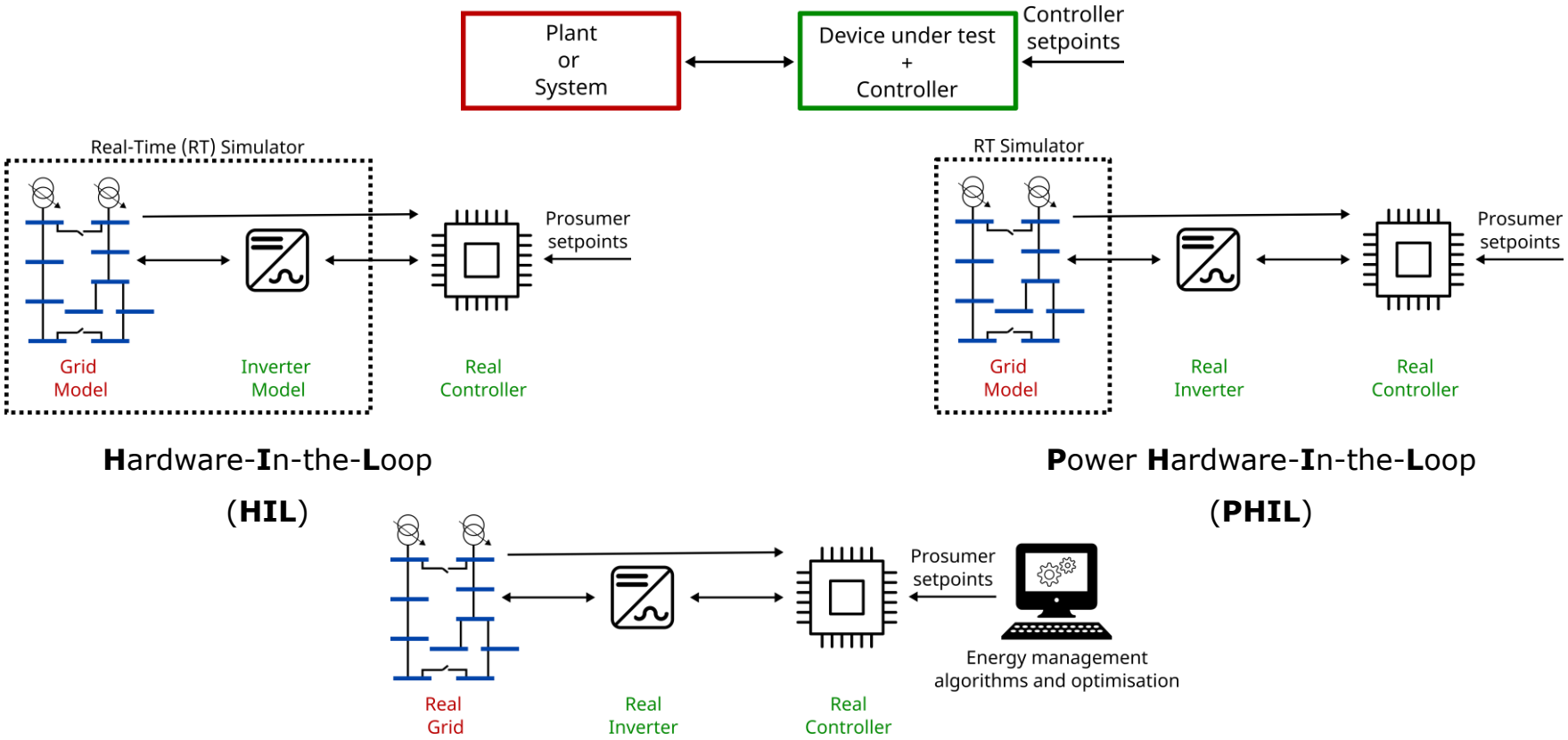




Power **H**ardware-**I**n-the-**L**oop

(**PHIL**)

Definitions



Hardware-**I**n-the-**L**oop

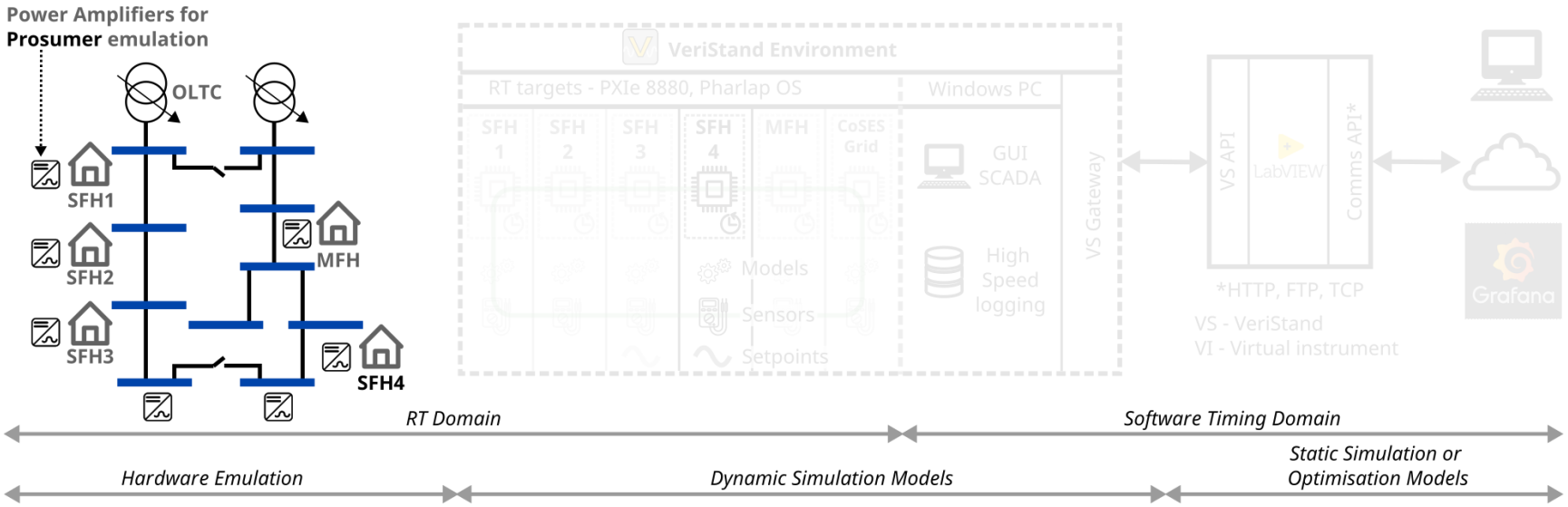
(**HIL**)

Power **H**ardware-**I**n-the-**L**oop

(**PHIL**)

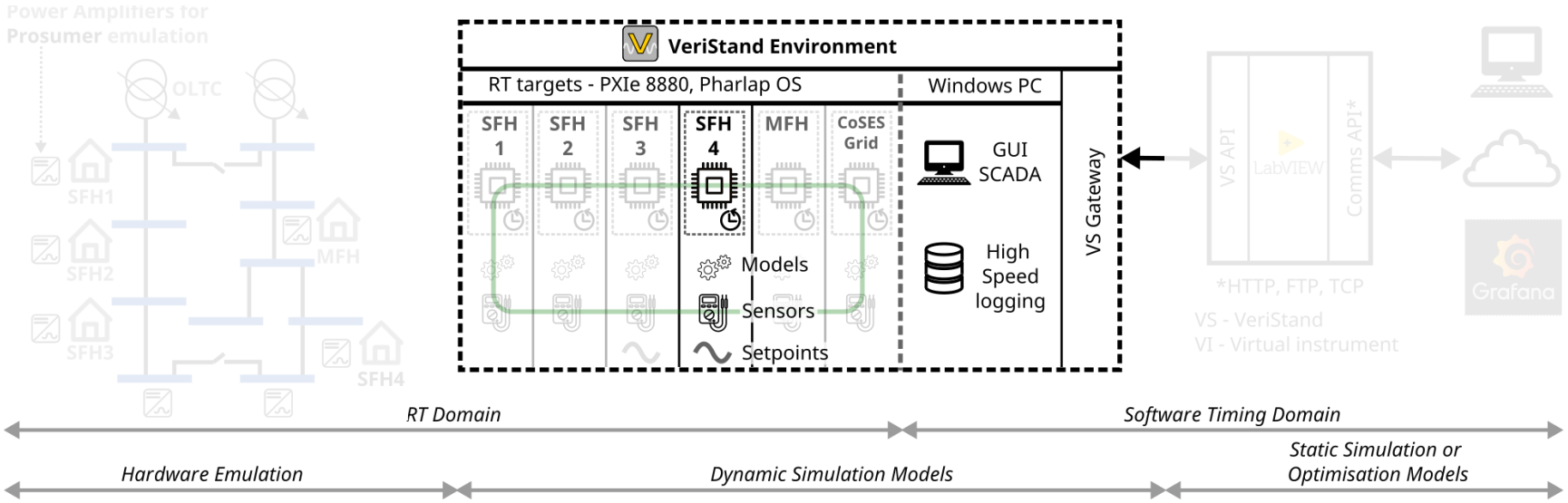
CoSES *PHIL* at TU Munich

CoSES PHIL Framework



PHIL testbeds (left), RT hardware and software (center), LabVIEW API access to external software (right)

CoSES PHIL Framework



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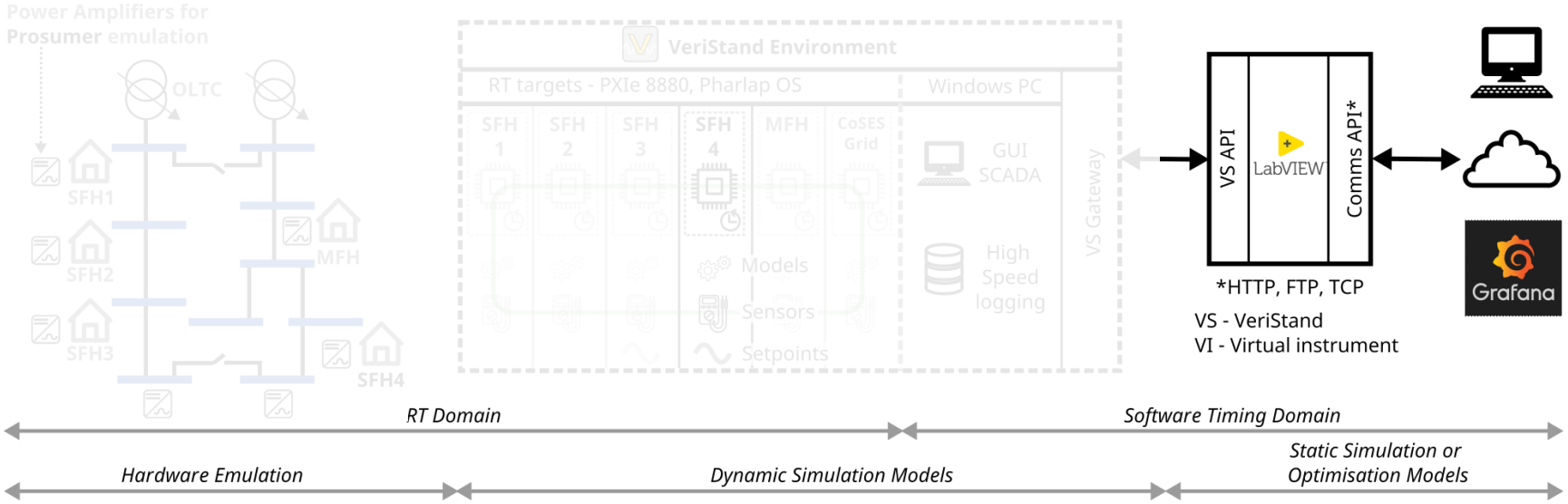

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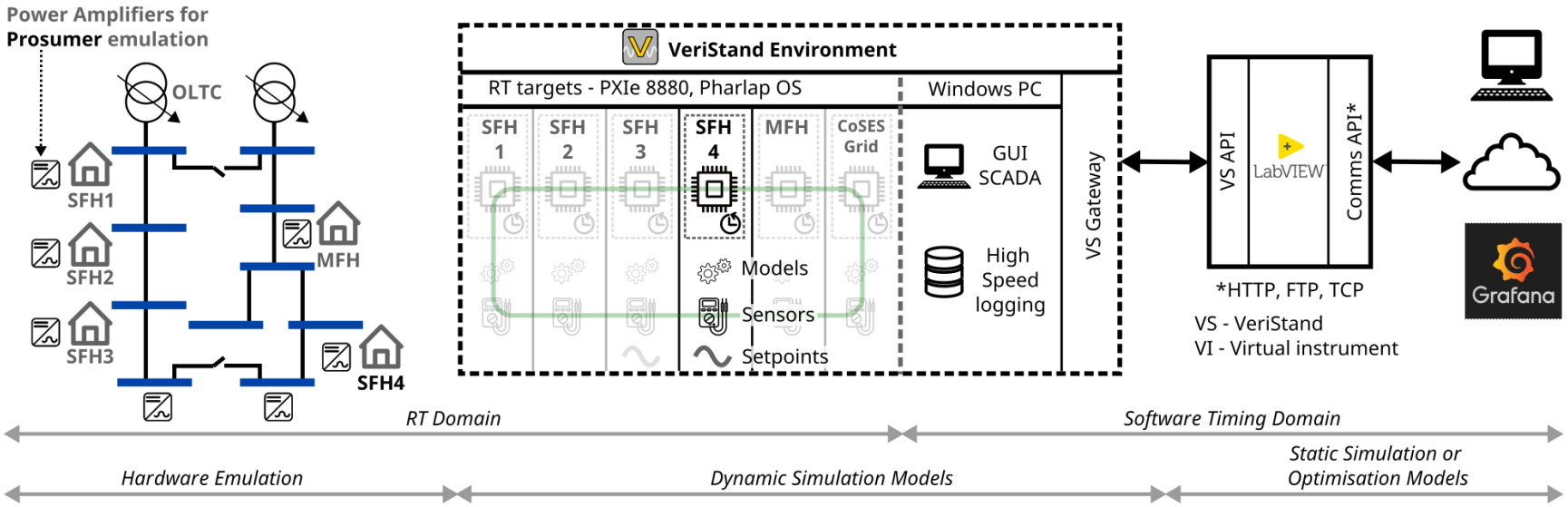
CoSES PHIL Framework



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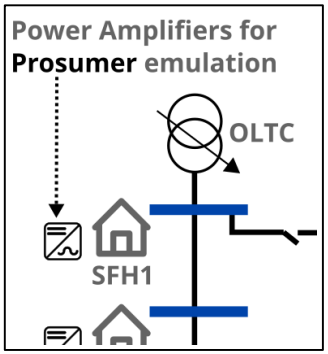
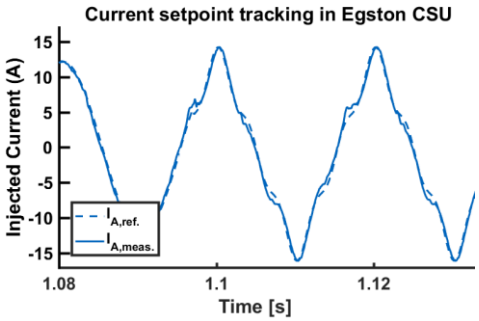
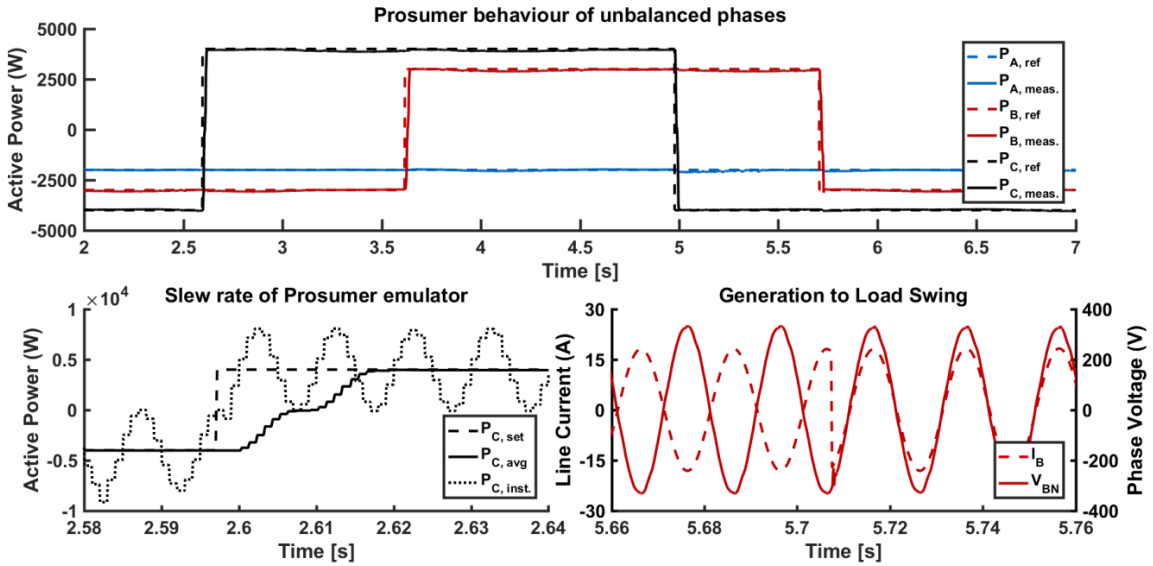
Prosumer demonstration





Power ampilifier

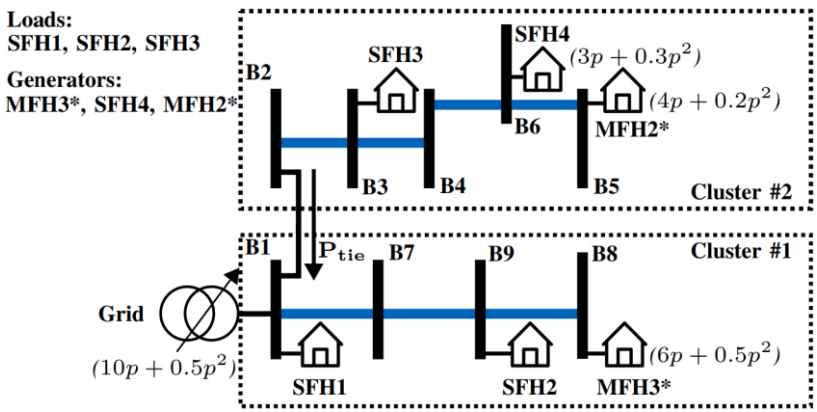
@ 5kHz RT control loop.

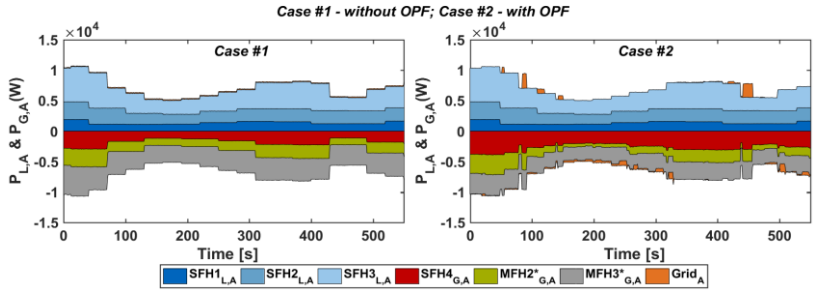


Unbalanced 3-Ph prosumer operation

@ 5kHz RT control loop and 1kHz measurement loop.

Exemplary experiment design





Distributed Online OPF using CoSES PHIL Framework.*

Features:

- Grid connection – Munich LV grid
- LV network – 70 & 95mm² 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

*M. Cornejo, A. Mohapatra, S. Candas and V. S. Peric, “PHIL implementation of a decentralized online OPF for active distribution grids”, IEEE PES General Meeting 2022, doi: 10.36227/techrxiv.17065193.v1.

Conclusion

- CoSES Microgrid lab with fully controllable PHIL prosumers in real LV grid with DERs.

What to expect from a smart/microgrid lab designed for universities?

Hardware

- If possible, emulate ✓
- Easily reconfigurable grid ✓
- Minimize power losses ✓

Software

- Toolchain freedom ✓
- Distributed instrumentation ✓
- Open to commercial protocols ✓