Remote Hardware-in-the-Loop Approach for Microgrid Controller Evaluation

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Contents

Energy Systems Integration Facility (ESIF)

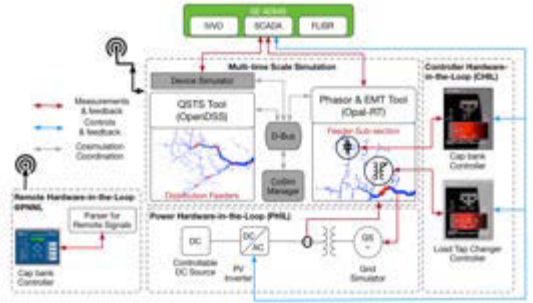
The ESIF is a national User Facility located in Golden, Colorado on the campus of the National Renewable Energy Laboratory (NREL).

http://www.nrel.gov/esif

Controller and Power Hardware In The Loop (CHIL/PHIL)

NREL's megawatt-scale controller and power hardware-in-the-loop (CHIL/PHIL) capability allows researchers and manufacturers to test energy technologies at full power in real-time grid simulations to safely evaluate performance and reliability

Microgrids



Cosimulation

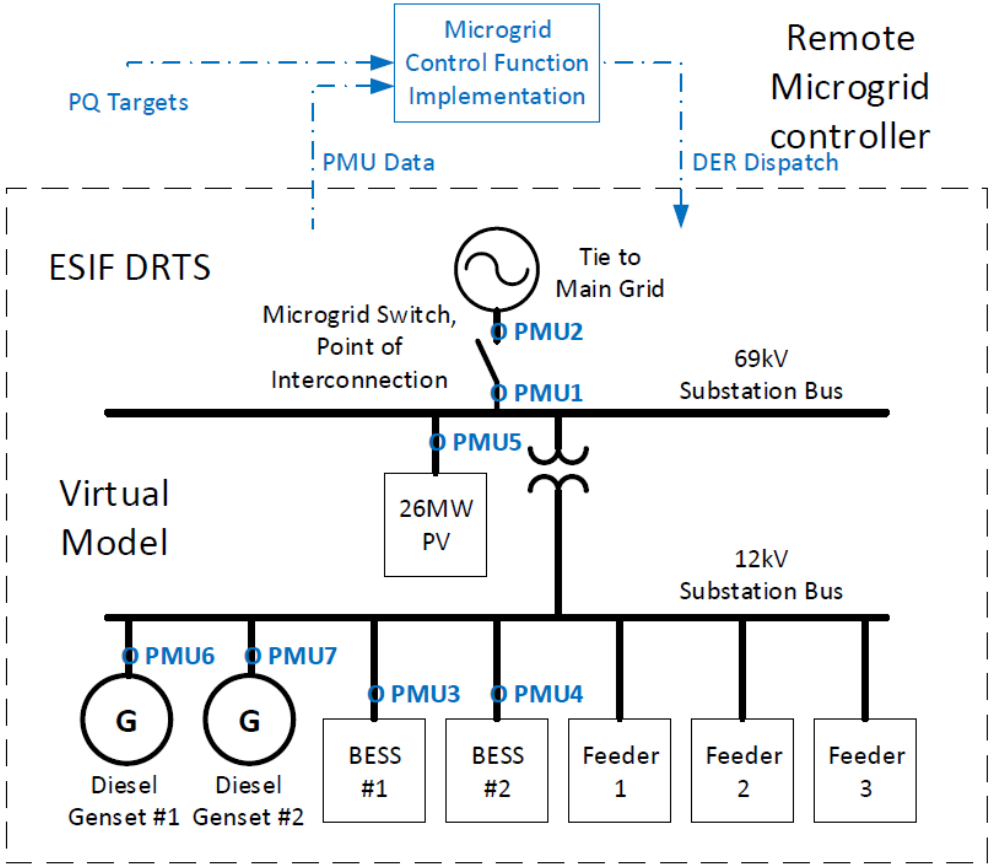
Power System Studies

Team information

- NREL
  - Kumaraguru Prabakar
  - Brian Miller
  - Annabelle Pratt
  - Martha Symko-Davies
- San Diego Gas & Electric Company
  - Thomas Bialek
- University of California, San Diego
  - Amir Valibeygi, Sai Akhil R. Konakalla Courtney Pailing
  - Raymond A. de Callafon

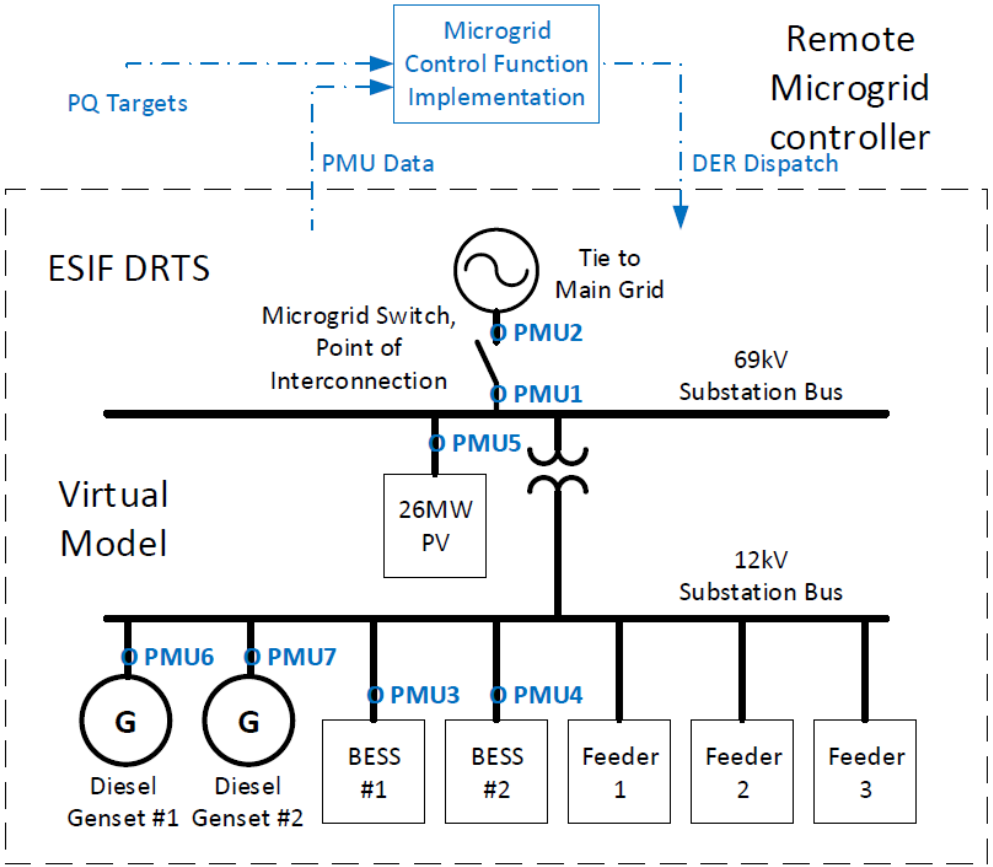
Hardware-in-the-loop setup

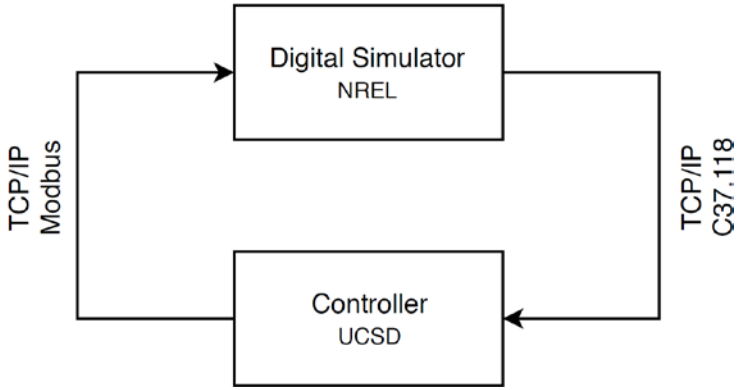
Remote controller hardware-in-the-loop setup

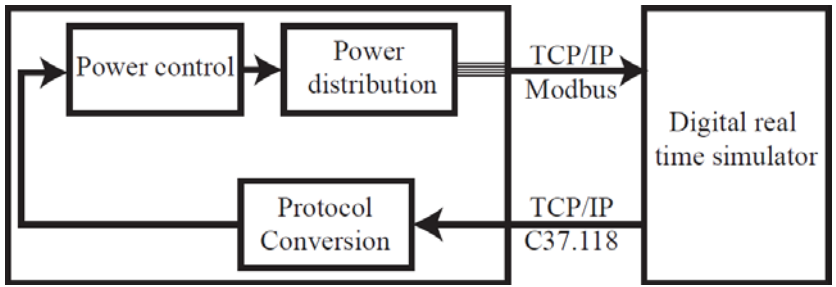


- Five assets
  - Two BESS
  - Two diesel generators
  - One 26 MW PV plant
- One POI circuit breaker
- Seven PMUs

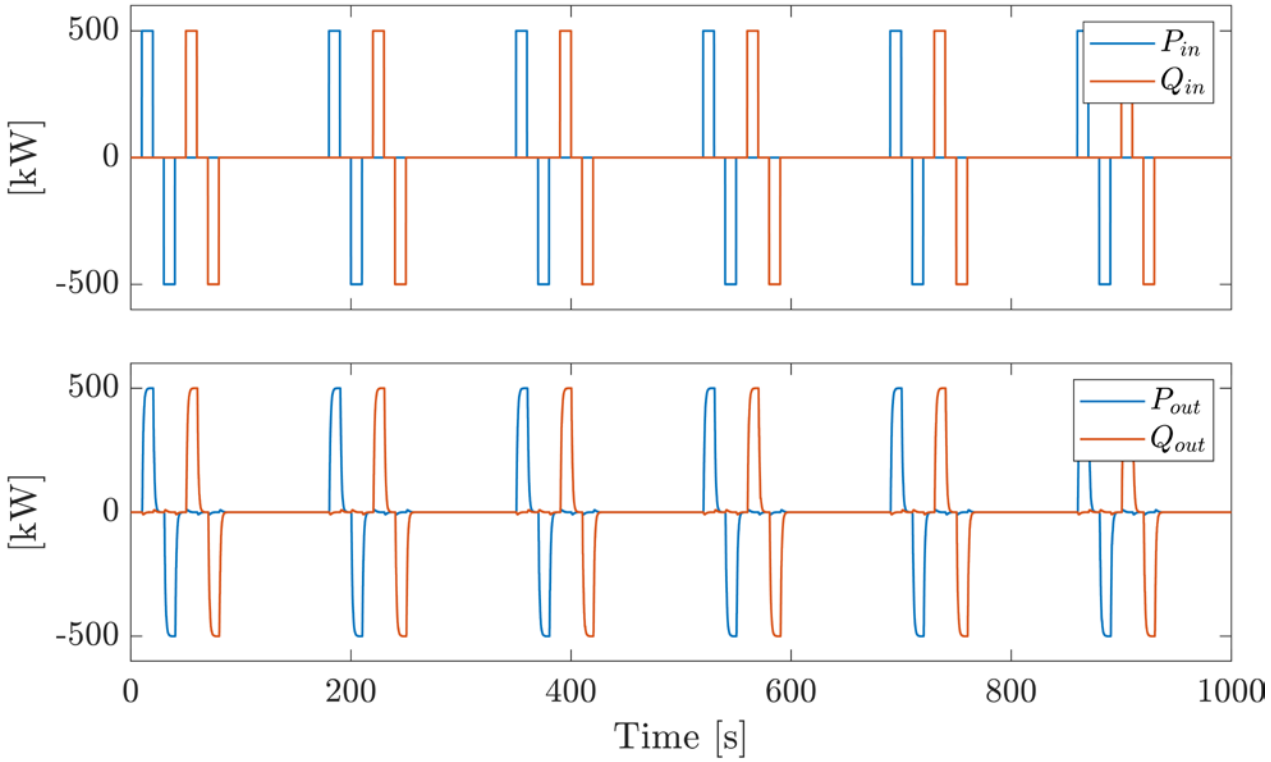
Remote controller hardware-in-the-loop setup



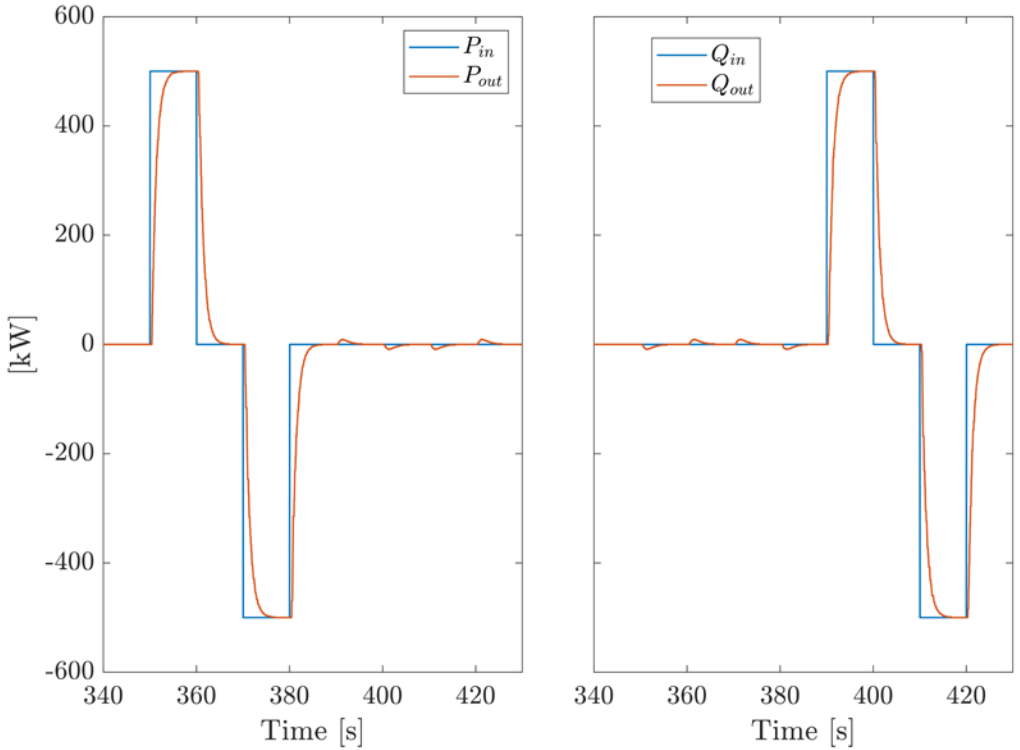




Remote setpoint experiments



Remote setpoint experiments



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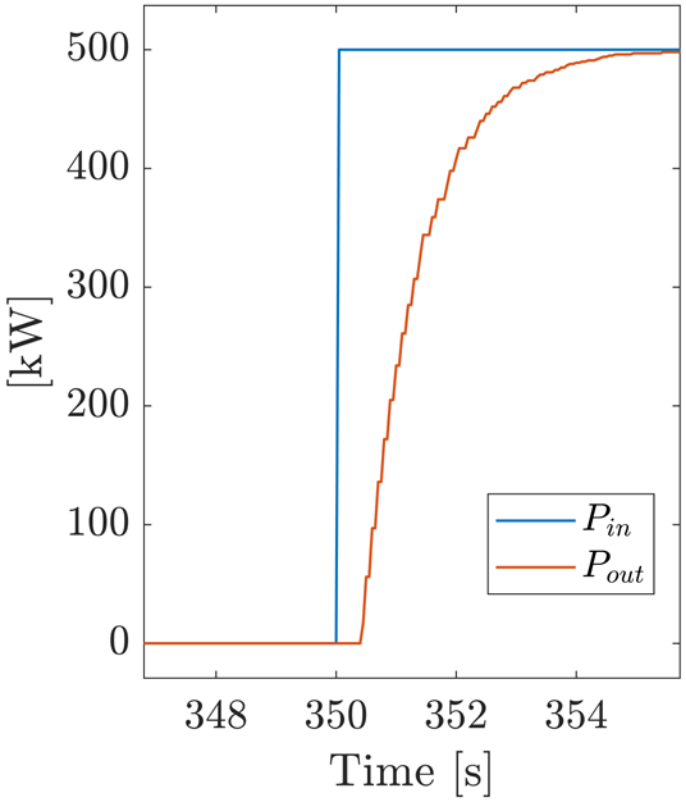
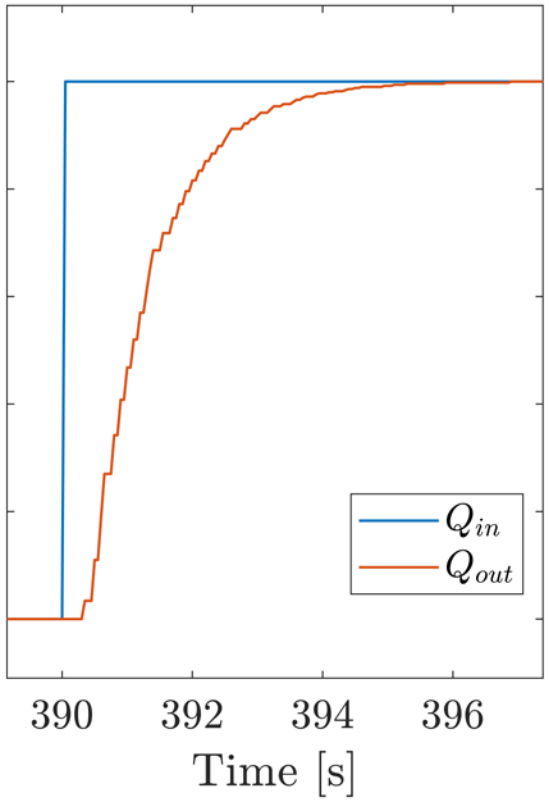
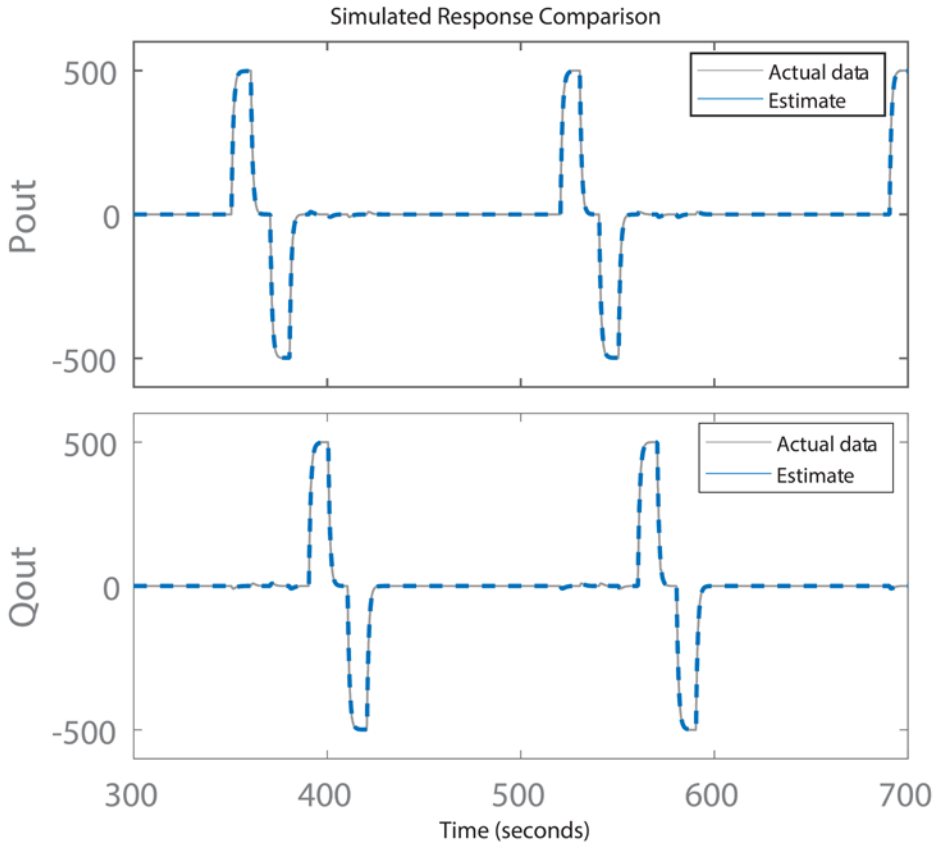




Remote setpoint experiments

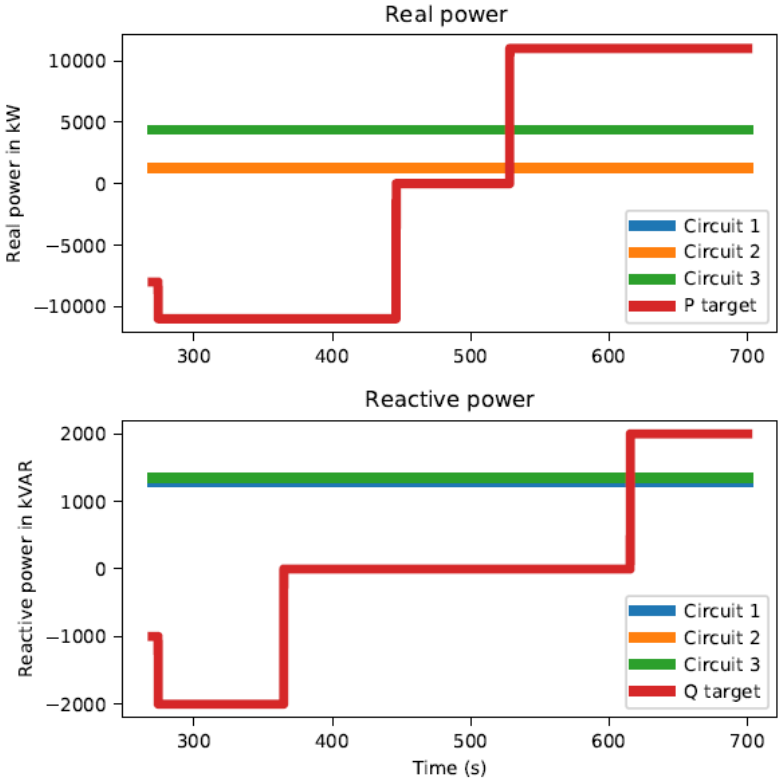
$$P_{out} = z^{-8}\left[\frac{0.05z^{-1} - 0.047z^{-2}}{1 - 1.9z^{-1} + 0.9z^{-2}} P_{in} + \frac{0.002z^{-1} - 0.002z^{-2}}{1 - 1.9z^{-1} + 0.9z^{-2}} Q_{in}\right]$$

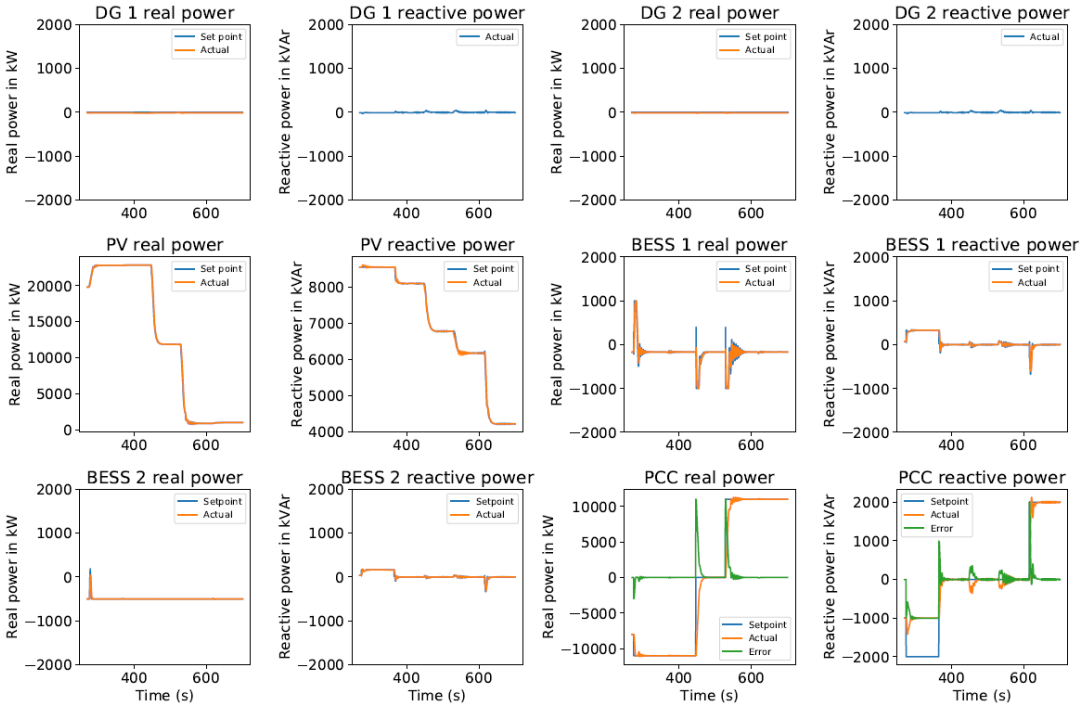
$$Q_{out} = z^{-8}\left[\frac{-0.002z^{-1} + 0.002z^{-2}}{1 - 1.9z^{-1} + 0.9z^{-2}} P_{in} + \frac{0.05z^{-1} - 0.047z^{-2}}{1 - 1.9z^{-1} + 0.9z^{-2}} Q_{in}\right]$$



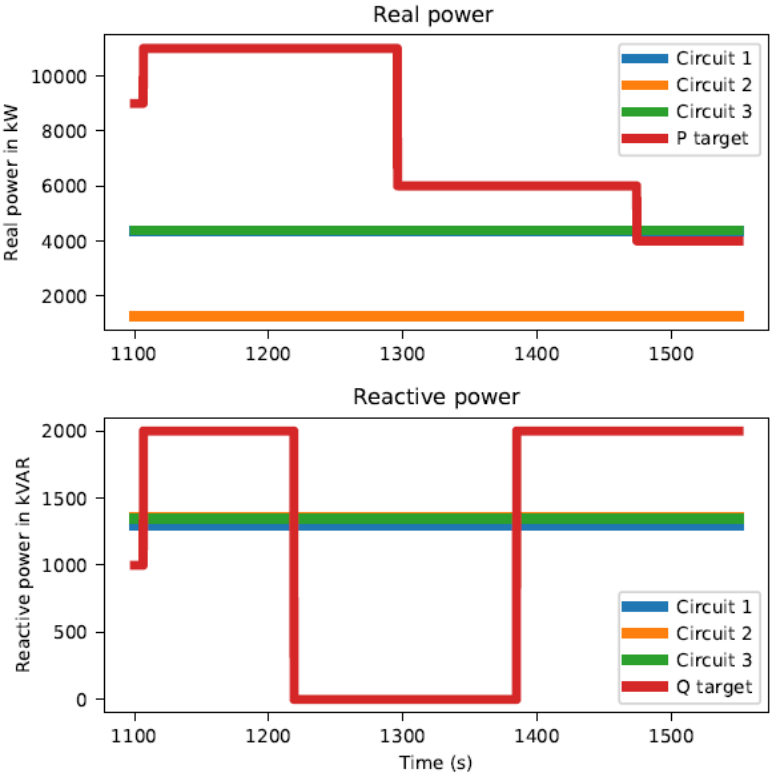
Microgrid controller experiments

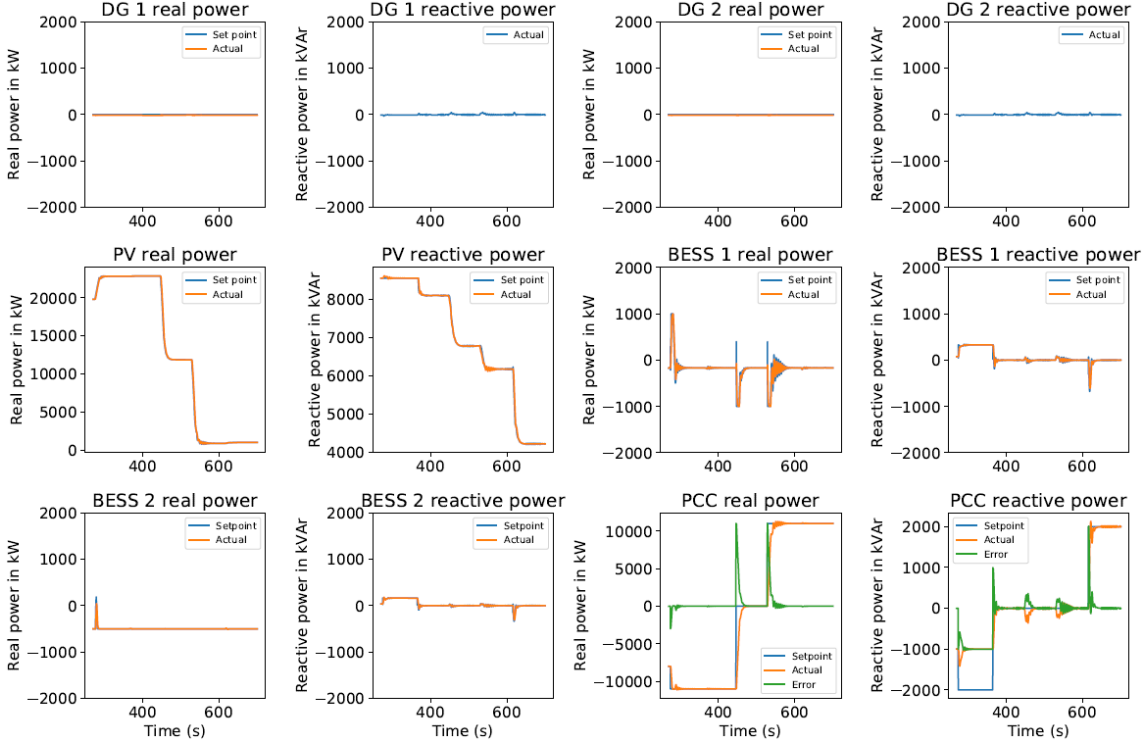
Remote microgrid controller experiments



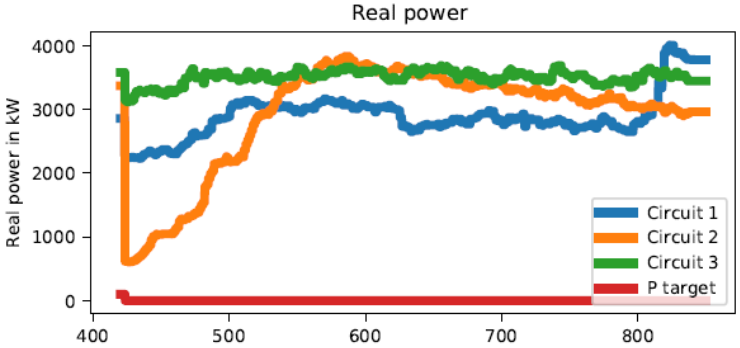


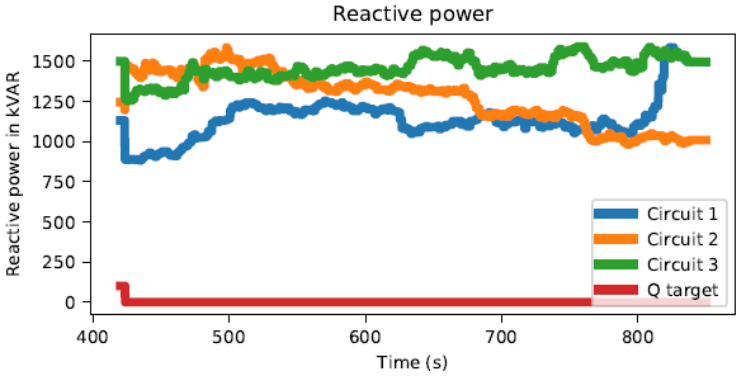
Remote microgrid controller experiments

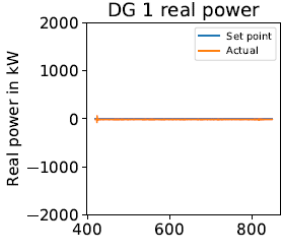


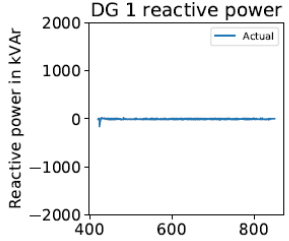


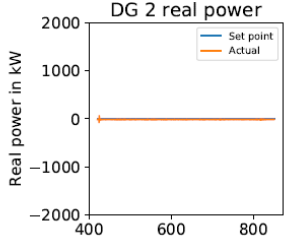
Remote microgrid controller experiments

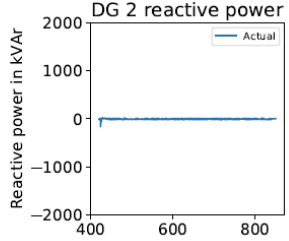


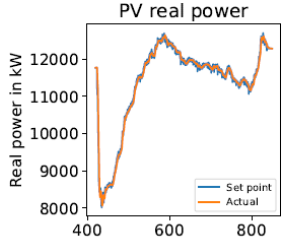


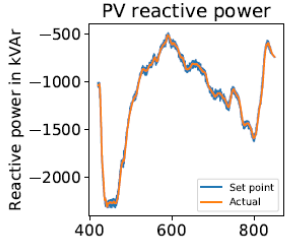


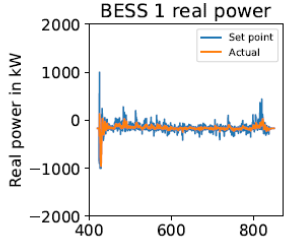


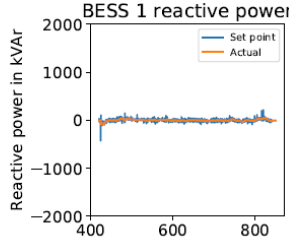


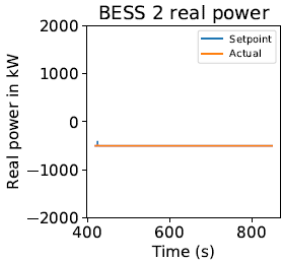


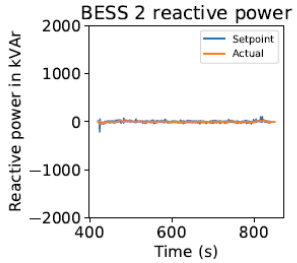


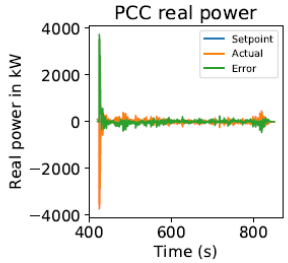


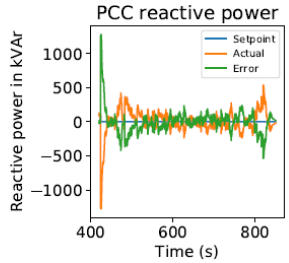










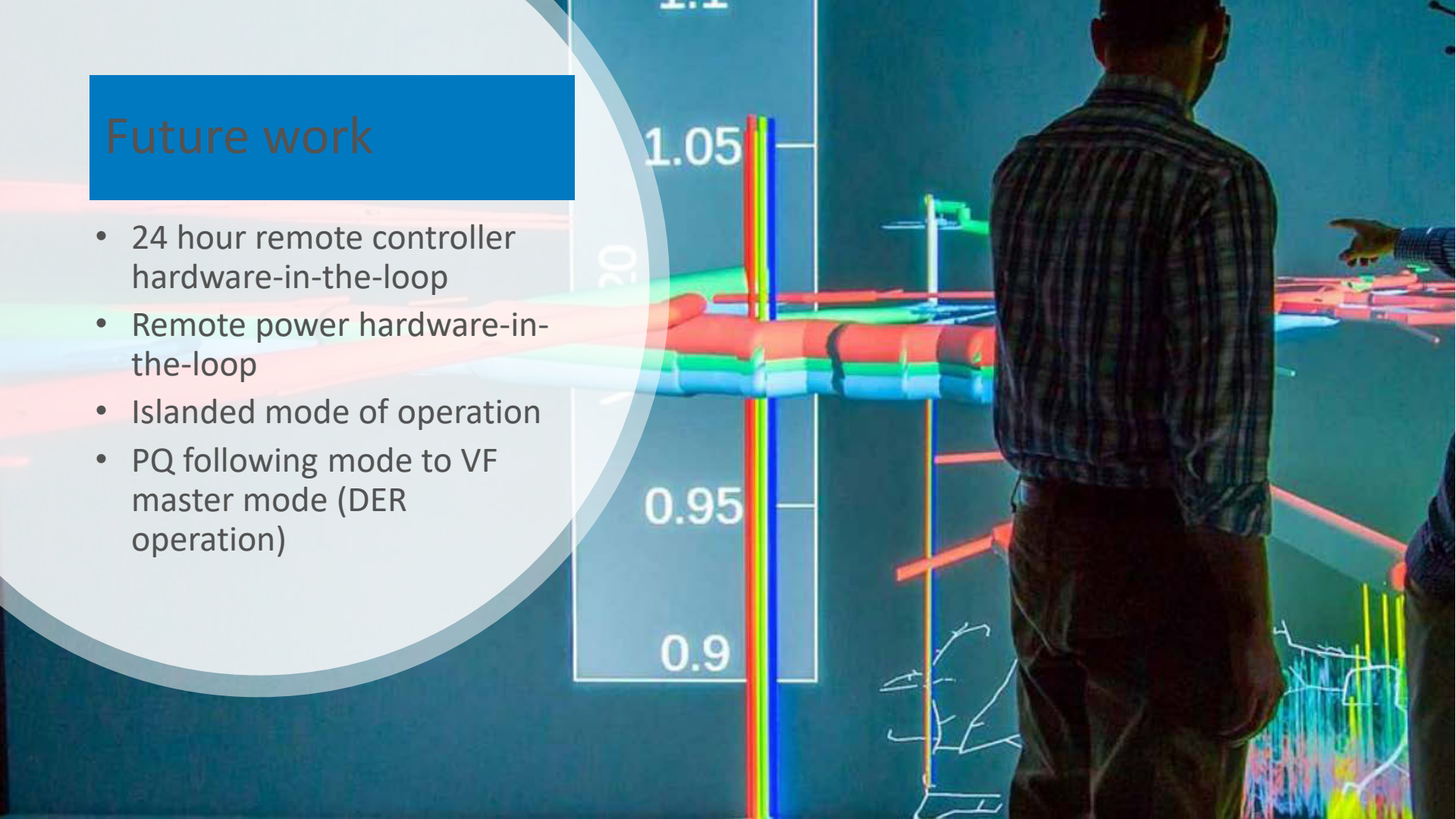


Summary

- A remote HIL setup was implemented to evaluate a microgrid control function developed by the SyGMA laboratory at UCSD.
- The remote HIL setup consists of a DRTS running a simulation of the microgrid at NREL in Colorado, an implementation of the microgrid control function at UCSD in California, and an internet-based connection between these two location.
- The novelty of the approach is the use of power system communications protocols (C37.118) to exchange information between two different locations.
- By characterizing the effects of networked communications on the closed-loop feedback controller, a control system is designed that sends DER power commands to each simulated DER over the Internet and successfully achieves the objective of following the power set points.
- The remote controller-simulator setup is tested with three test cases, demonstrating successful power control at the POI of the microgrid.

Future work

- 24 hour remote controller hardware-in-the-loop
- Remote power hardware-in-the-loop
- Islanded mode of operation
- PQ following mode to VF master mode (DER operation)



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NREL/PR-5D00-76279

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