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

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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
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.
Team information

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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

![Graph showing input (P_in, Q_in) and output (P_out, Q_out) power over time.](image-url)
Remote setpoint experiments
Remote setpoint experiments
Remote setpoint experiments

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

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