Evaluation of AC Microgrid Controllers

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Energy Systems Integration Facility (ESIF)

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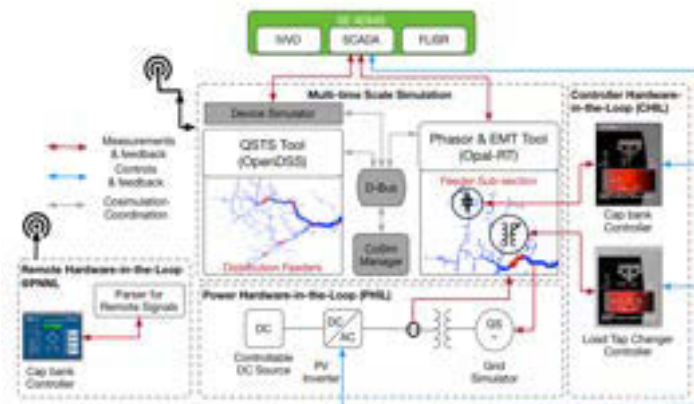

http://www.nrel.gov/esif

Controller and Power Hardware-in-the-Loop (CHIL/PHIL)

NREL's megawatt-scale controller- and power-hardware-in-the-loop (CHIL/PHIL) capabilities allow 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

High-Penetration Microgrid: SDG&E Borrego Springs

Goal: Demonstrate the viability of a microgrid to manage large amounts (up to 100%) of renewable, intermittent energy resources to meet community load that can be replicated by others while leveraging (post-project) off-the-shelf software

Impact: Successful implementation of the largest microgrid in North America will prove that a community-scale, highly renewable microgrid can be implemented with economic benefits.
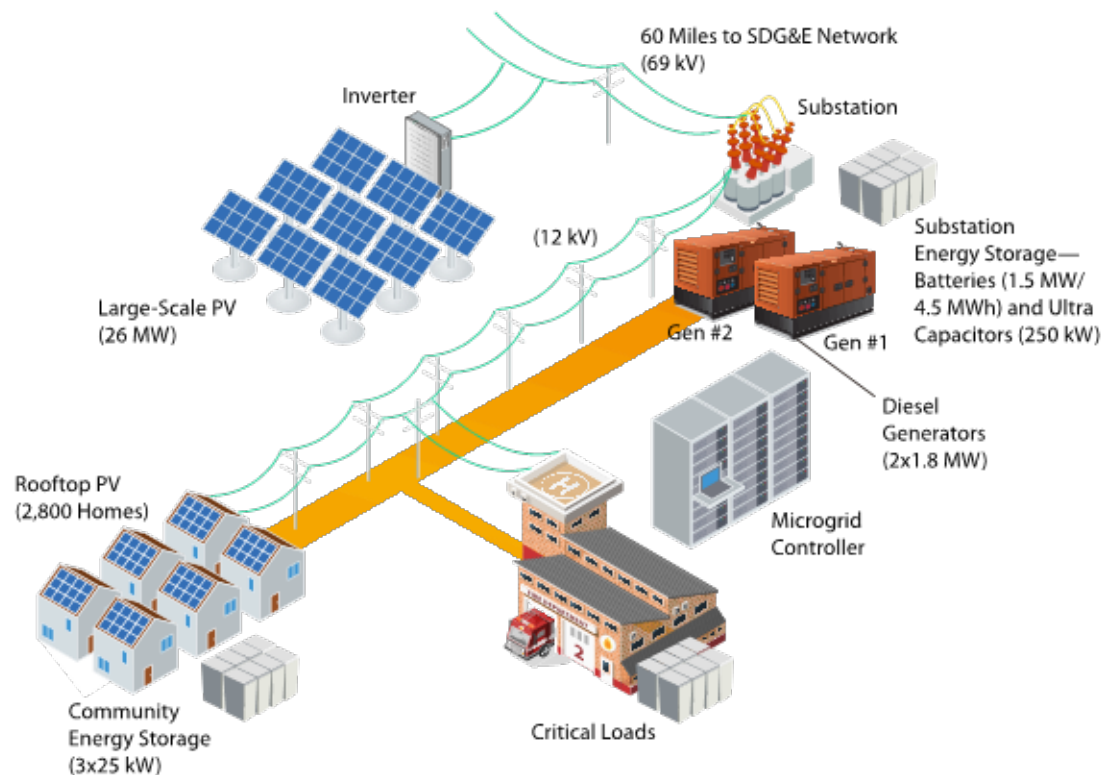
Funded by:
California Energy Commission

Led by:
San Diego Gas & Electric Company (SDG&E)

Partners:
NREL, Spirae, UCSD, OSIsoft, SMA, NRG

60 Miles to SDG&E Network (69 kV)

Inverter

Substation

Large-Scale PV (26 MW)

(12 kV)

Gen #2   Gen #1

Substation Energy Storage— Batteries (1.5 MW/ 4.5 MWh) and Ultra Capacitors (250 kW)

Diesel Generators (2x1.8 MW)

Rooftop PV (2,800 Homes)

Microgrid Controller

Community Energy Storage (3x25 kW)

Critical Loads

Team information

- NREL:
  - Kumaraguru Prabakar
  - Brian Miller
  - Jing Wang
  - John Fossum
  - Annabelle Pratt
  - Martha Symko-Davies
- San Diego Gas & Electric Company:
  - Thomas Bialek
  - Nagadev Shanmukh

- Spirae
- University of California, San Diego

Brief Tour of Borrego Springs

- High concentration of customer-owned solar generation
- Potential for reliability enhancements
- Opportunity to balance supply and demand to be more self-sufficient
- Extendable to service territory
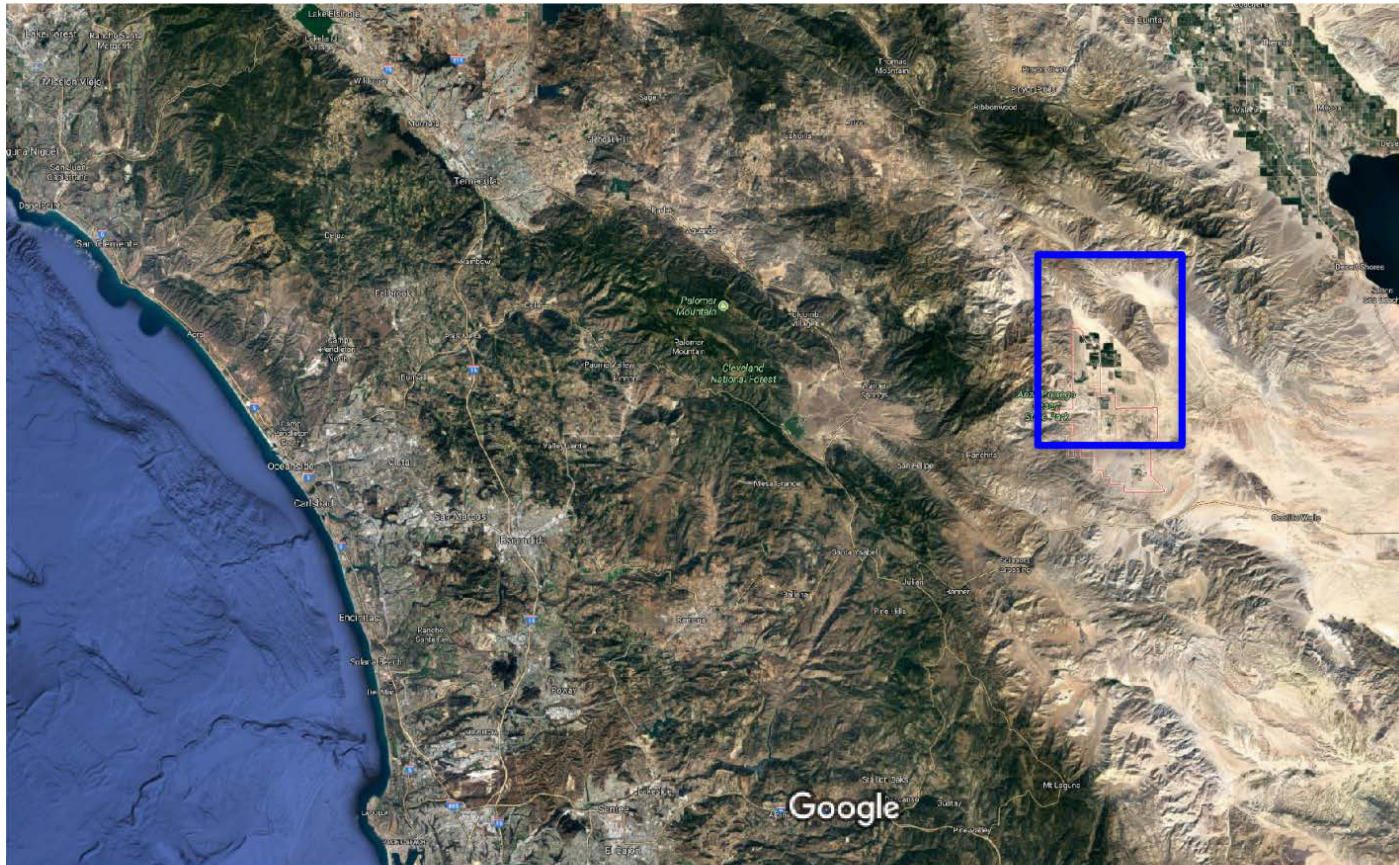
Imagery ©2017 Landsat / Copernicus, Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Data USGS, Data LDEO-Columbia, NSF, NOAA, Map data ©2017 Google, INEGI
United States

Microgrid Setup
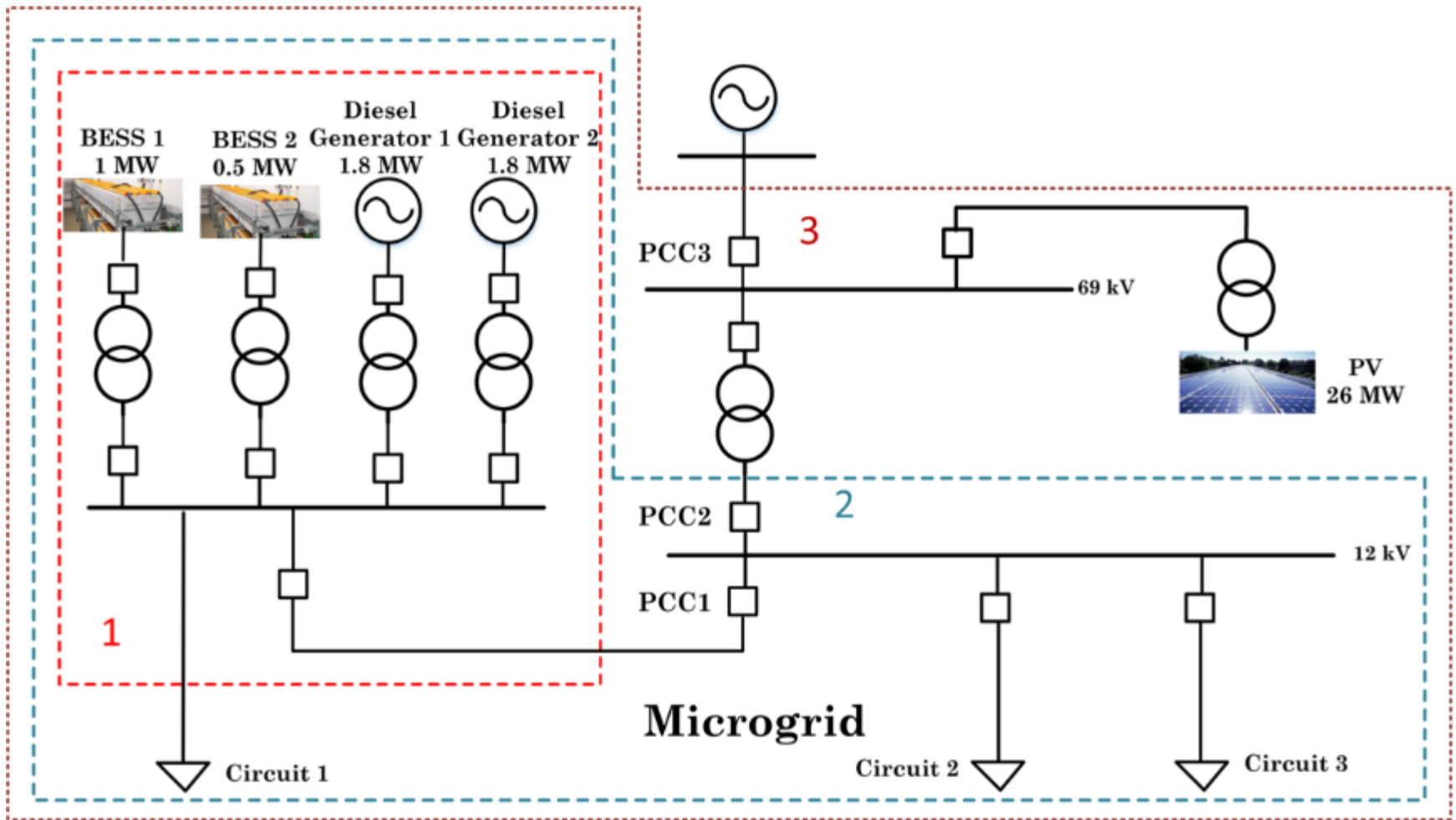
Hardware-in-the-Loop Evaluation of Microgrid Controls

- Evaluation of a microgrid controller
  - Like the one deployed in the field
  - Functional requirements:
    - Dispatch
    - Disconnection and reconnection
    - Steady-state frequency and voltage in islanded mode
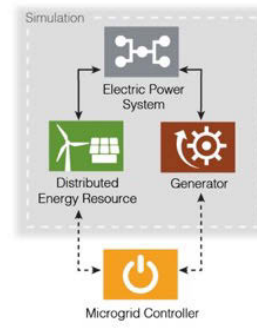   - Protection

A) Pure simulation

Abstract or real-time
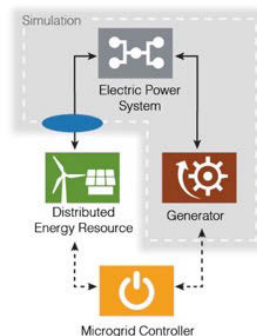
Need to integrate microgrid controller
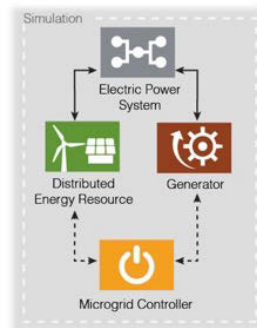
B) CHIL

Interface real controller

Need to add communications interface

C) CHIL and PHIL

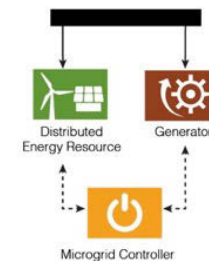Interface real controller and power assets, including internal proprietary controls

Power interface, more complex

D) Hardware only

Real controller and assets

Does not include power system model

A) Pure Simulation

B) CHIL

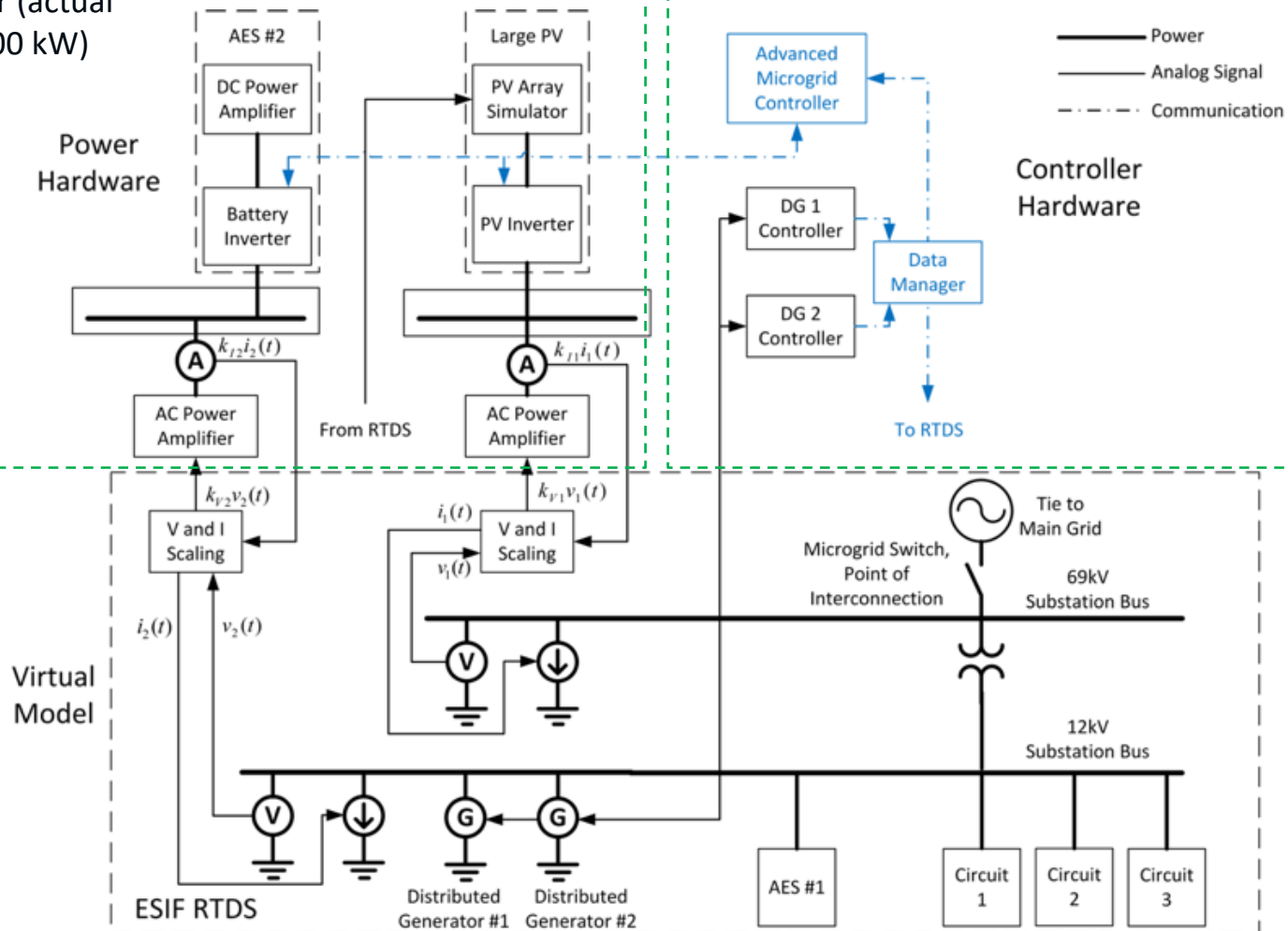C) CHIL & PHIL

D) Hardware only

Controller-/Power-Hardware-in-the-Loop Test Bed
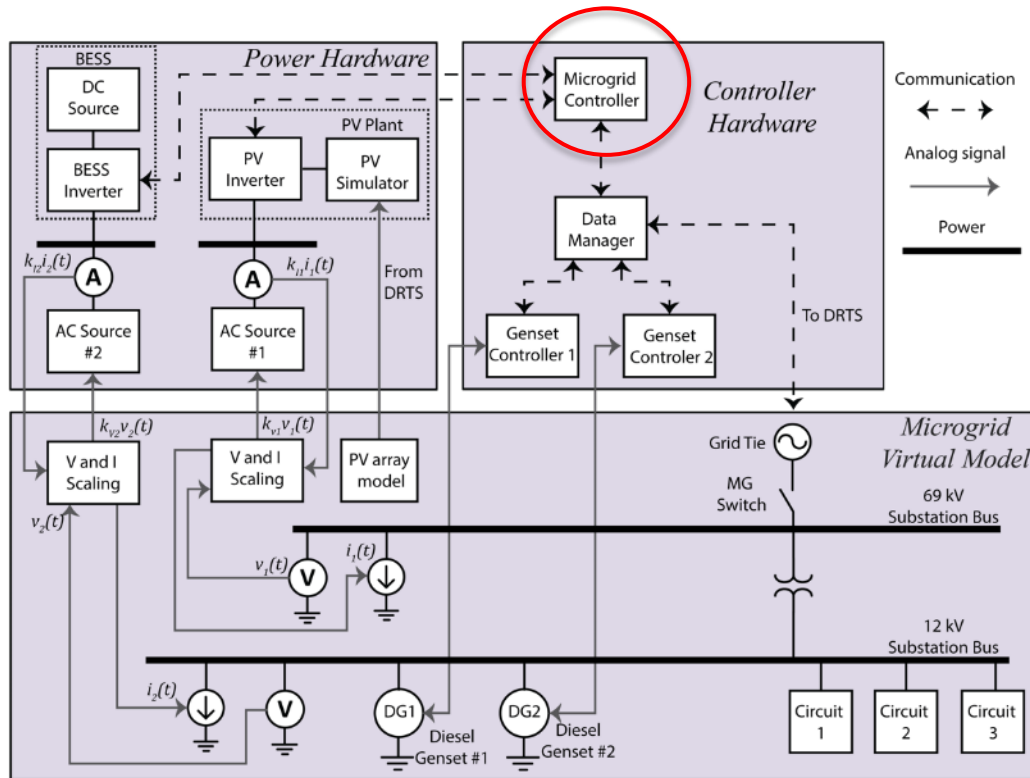
PHIL:

- Energy storage system inverter (representative Schneider 540 kW)

- Photovoltaic (PV) inverter (actual SMA 500 kW)

CHIL:

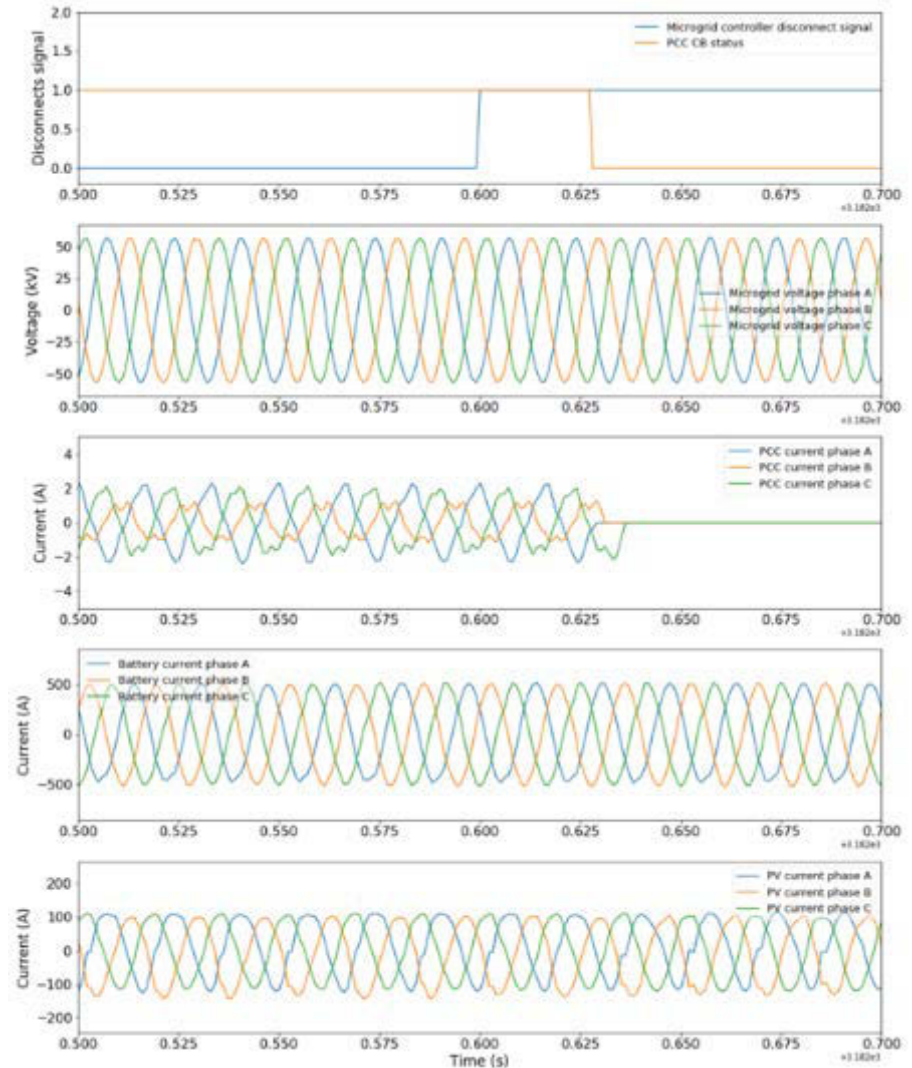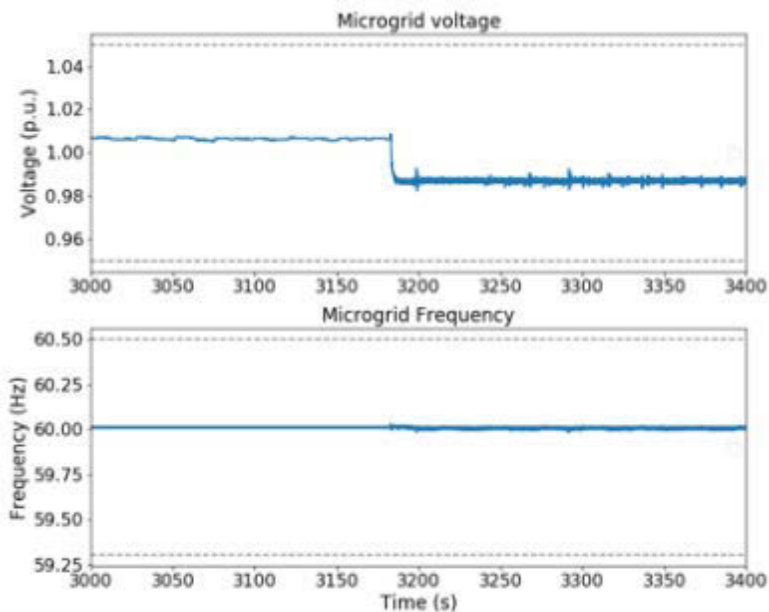- Microgrid controller
- Diesel generator controllers

Photos by NREL

Planned Disconnection

- Heavy-load condition
- MGC regulates power flow across point of common coupling to near zero
- Smooth transition when microgrid switch is opened
- Voltage and frequency meet steady-state requirements.

Unplanned Disconnection

- Simulated (CHIL only) over- and undervoltage and frequency conditions and faults
- MGC does not respond but relies on protection equipment
- MGC redispatches after disconnection if microgrid survives or manages black starts
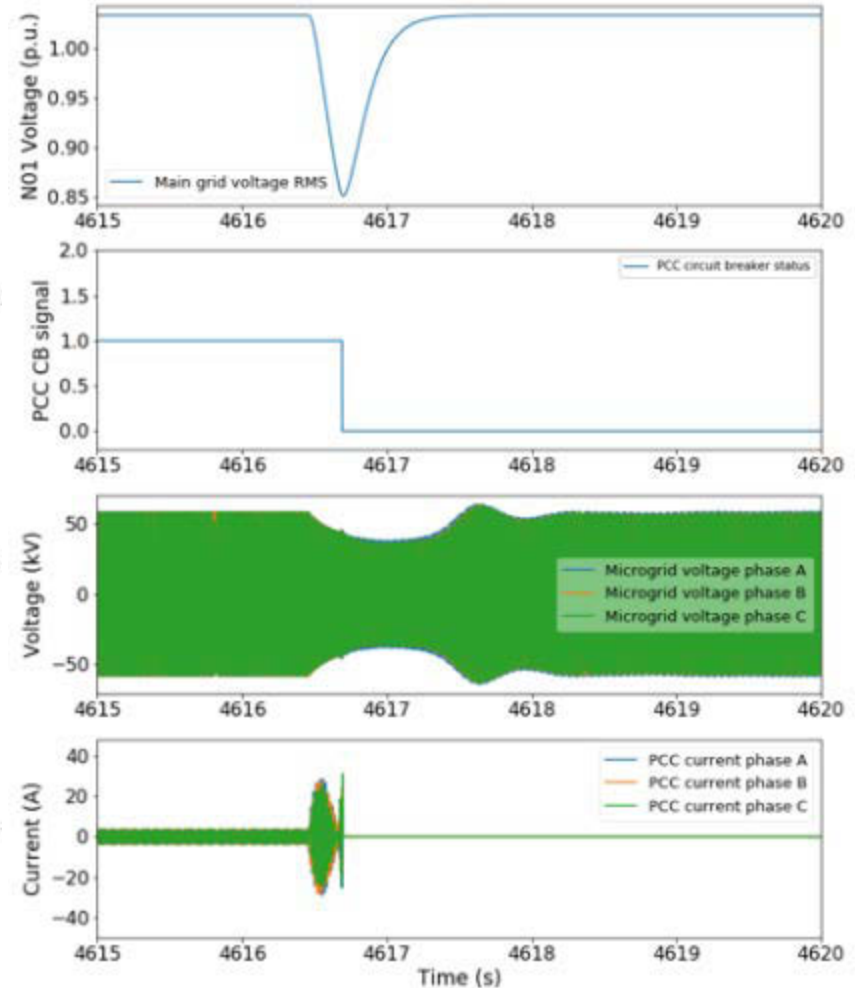
Summary

- An HIL test bed to evaluate the performance of microgrid controllers at the ESIF at NREL prior to field deployment:

  - Uses site-specific models that determine the microgrid performance.

  - Uses either the same or representative hardware as that deployed in the field.

  - Uses the same communications protocols as those used in the field.

- An overall approach to the design of an HIL setup to perform site-specific evaluations of microgrid controller performance with references to previously published works.

- A subset of the test cases evaluated using the test bed and results for these test cases

- The HIL setup could be used by a utility to run scenarios that can provide useful insight prior to field deployment.

References

- K. Prabakar et al., "Site-Specific Evaluation of Microgrid Controller Using Controller and Power-Hardware-in-the-Loop," IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society, Lisbon, Portugal, 2019, pp. 6463-6468, doi: 10.1109/IECON.2019.8927354.

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- A. Maitra et al., "Microgrid Controllers : Expanding Their Role and Evaluating Their Performance," in IEEE Power and Energy Magazine, vol. 15, no. 4, pp. 41-49, July-Aug. 2017, doi: 10.1109/MPE.2017.2690519.

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Thank you

www.nrel.gov

NREL/PR-5D00-78911