NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Power Systems
Engineering Center

NREL Microgrid Controller Innovation Challenge Event

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Overview

- Background: NREL capabilities and testbeds
  - Computer models; HIL; smart inverters (PV & ESS); cyber lab
  - Enable hardware testing/debugging prior to field deployment
- Microgrid Controller Innovation Challenge event hosted at NREL
- Strategic Goals for Future Research

Energy Systems Integration Facility (ESIF)

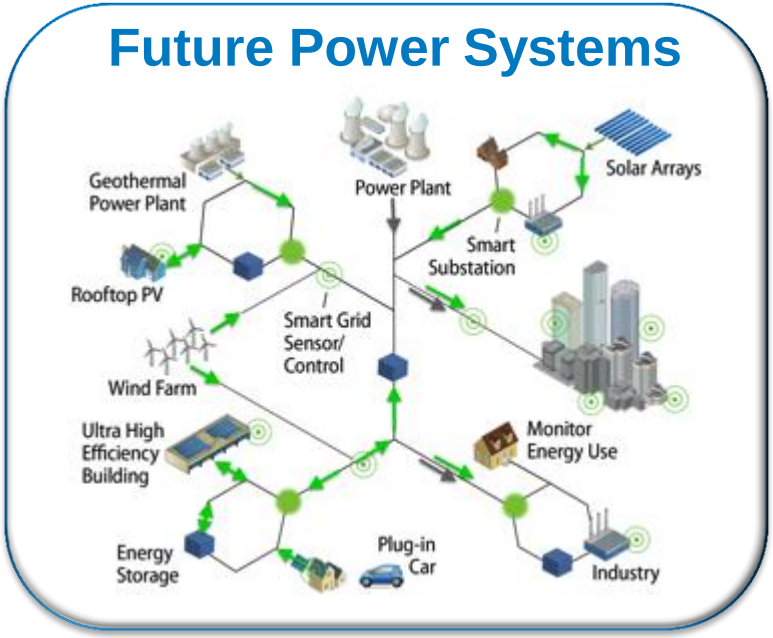
- NREL's largest R&D facility (182,500 ft^2 /20,000 m^2)
- Space for 200 NREL staff and research partners
- 15 state-of-the-art hardware laboratories
- Integrated megawatt-scale electrical, thermal and fuel infrastructure
- Peta-scale supercomputer and data analysis
- Interactive 3D advanced visualization

www.NREL.gov/esif

Collaborations

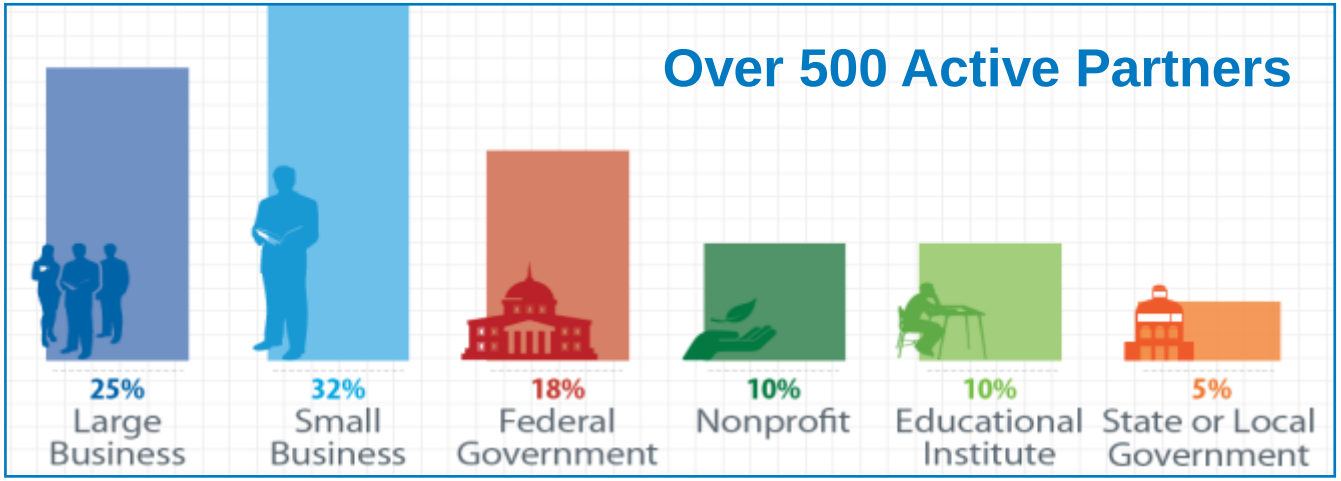
Strategic Partnership Project Agreements:

- **Technical services**
- **Partner performs research**



Cooperative Research and Development Agreements:

- **Shared resources**
- **Intellectual property**



NREL + CSIRO

Energy Systems Integration

TECHNOLOGY ADDRESSED

Advanced microgrid technology components and optimized their use for remote applications in Australia, primarily PV.

R&D STRATEGY

Performed prototype testing of the microgrid controller in the ESIF to test the hardware's ability to manage the output power of a diesel generator in the presence of loads and solar PV. Demonstrated co-simulation between CSIRO and ESIF that allows remote (geographically distant) connection of test equipment.

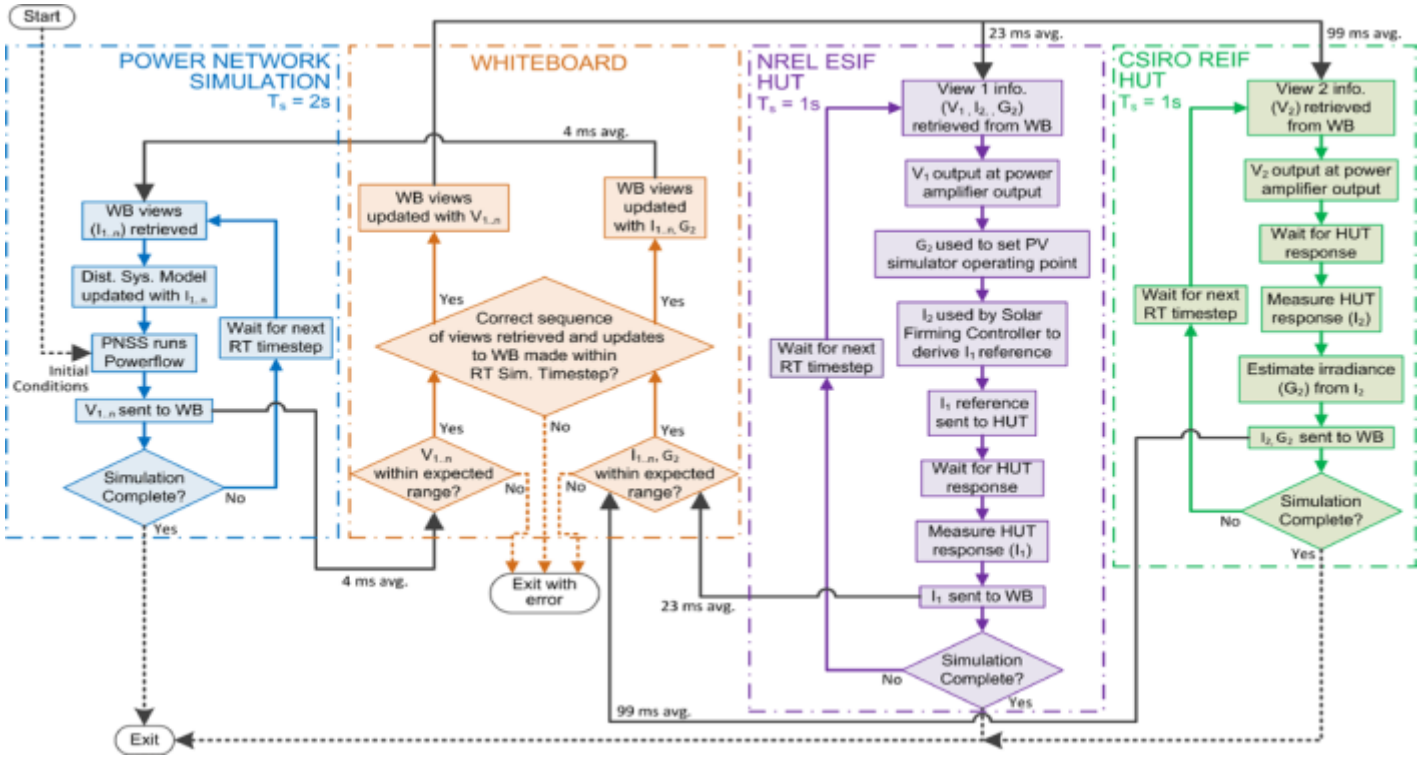
IMPACT

Simplified the integration, accelerated the deployment, and lowered the cost of hybrid distributed generation systems by 20% by creating 'plug and play' solar technology for these applications. First demonstration of co-simulation with power hardware and control signals across Pacific.

Novel Trans-Pacific Closed-Loop HIL System

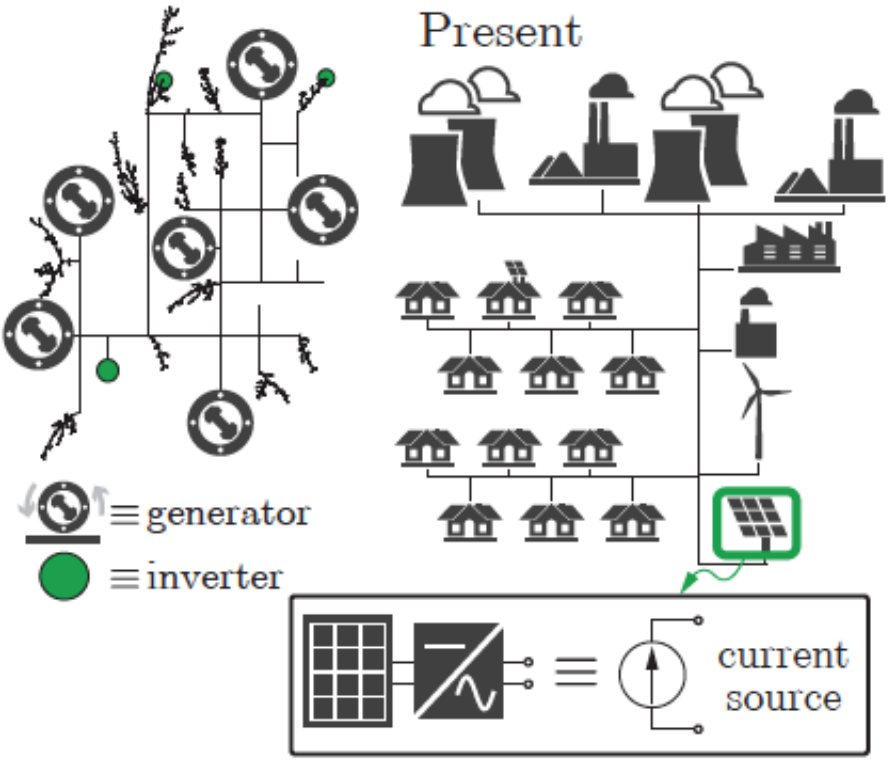
- Real-time simulator and inverter at NREL in Golden, CO, USA
- PV inverter at CSIRO Energy Centre in Newcastle, NSW, Australia

This capability enables researchers worldwide to leverage multi-site collaborations and validate emerging microgrid technologies.

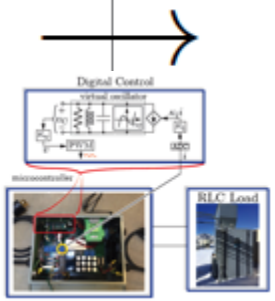


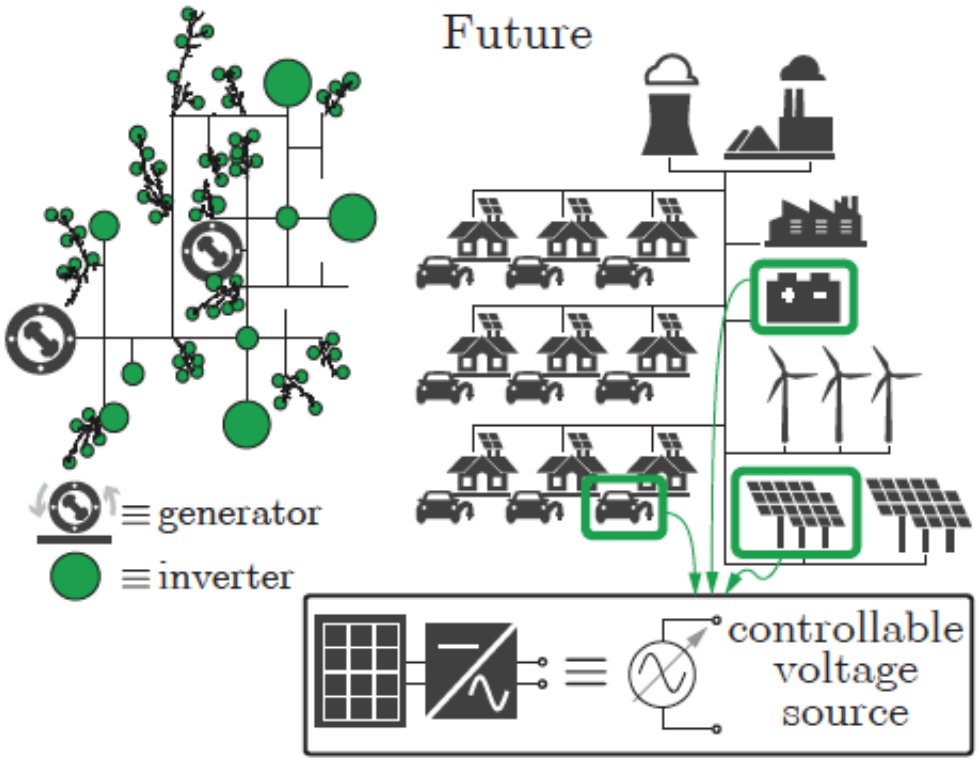
Developing Decentralized Controls

Energy Systems Integration



From grid-following controls



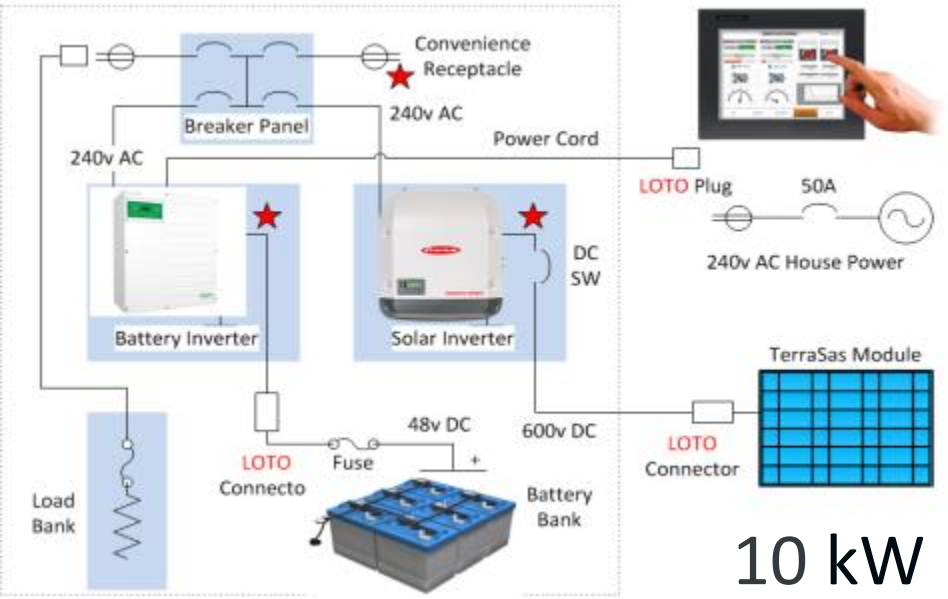


To next-generation grid-forming controls

Four Reconfigurable Microgrid Hardware Testbeds

- Each testbed has:
  - Real-time simulation platform to model actual locations
  - Fully controllable AC sources
  - Smart PV inverter(s)
  - Load banks(s)
- 10 kW- grid-forming inverter, battery, home, master PLC
- 100 kW- commercial grid-forming battery inverter, genset, genset control, micro-turbines, electric vehicle, POI switch
- 1,000 kW- utility battery inverter, DC source, gensets, hydrogen facilities, 13 kV yard, POI switch, master control
- 10,000 kW- wind turbines, dyno, solar array, PMU system, 115 kV t-line, substation, container pads, energy storage

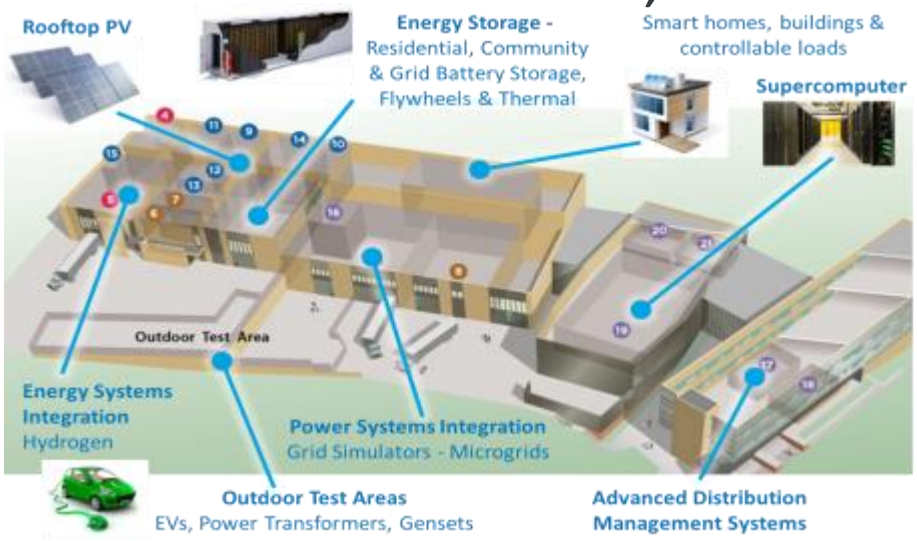
NREL Microgrid Hardware Testbeds



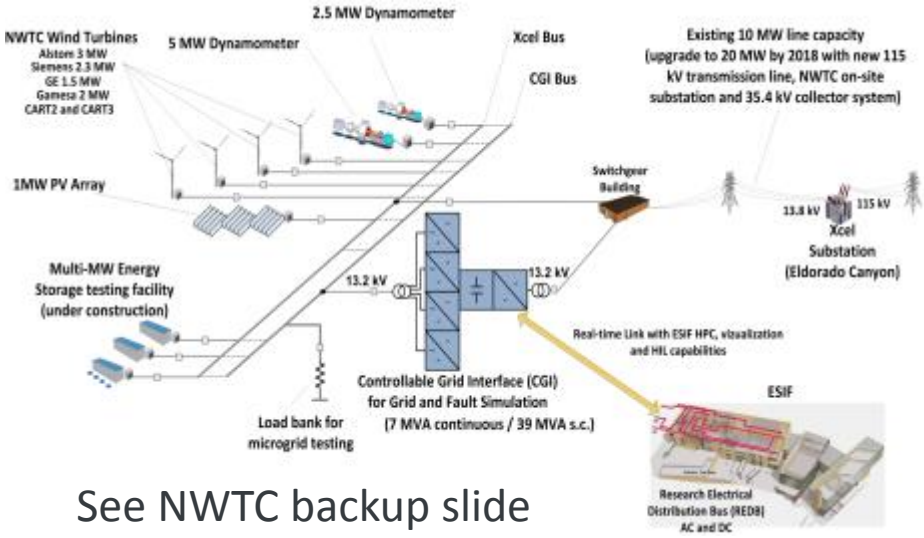
10 kW

100 kW

1,000 kW



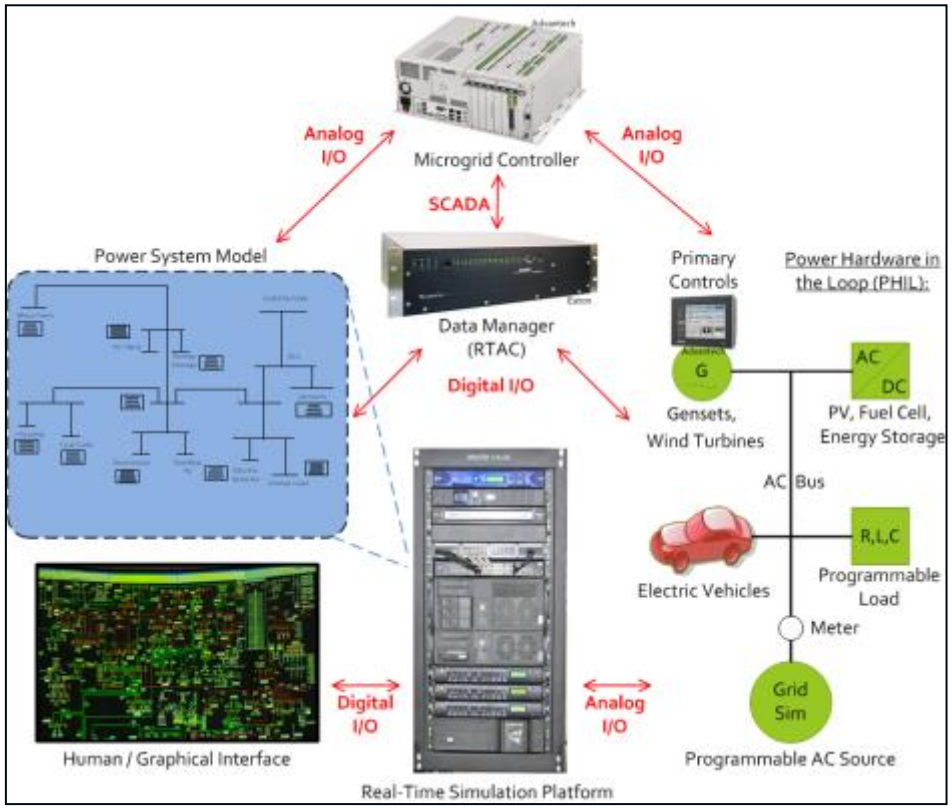
10,000 kW



See NWTC backup slide

NREL Microgrid Controller Innovation Challenge

NREL is hosting a dual-stage (CHIL, then PHIL) competitive event for microgrid control technology wherein contestants will compete on state-of-the-art test beds at NREL between June and December 2017.



Stage 1: CHIL Evaluation + Cyber Review

Stage 2: PHIL Evaluation + Cyber Testing

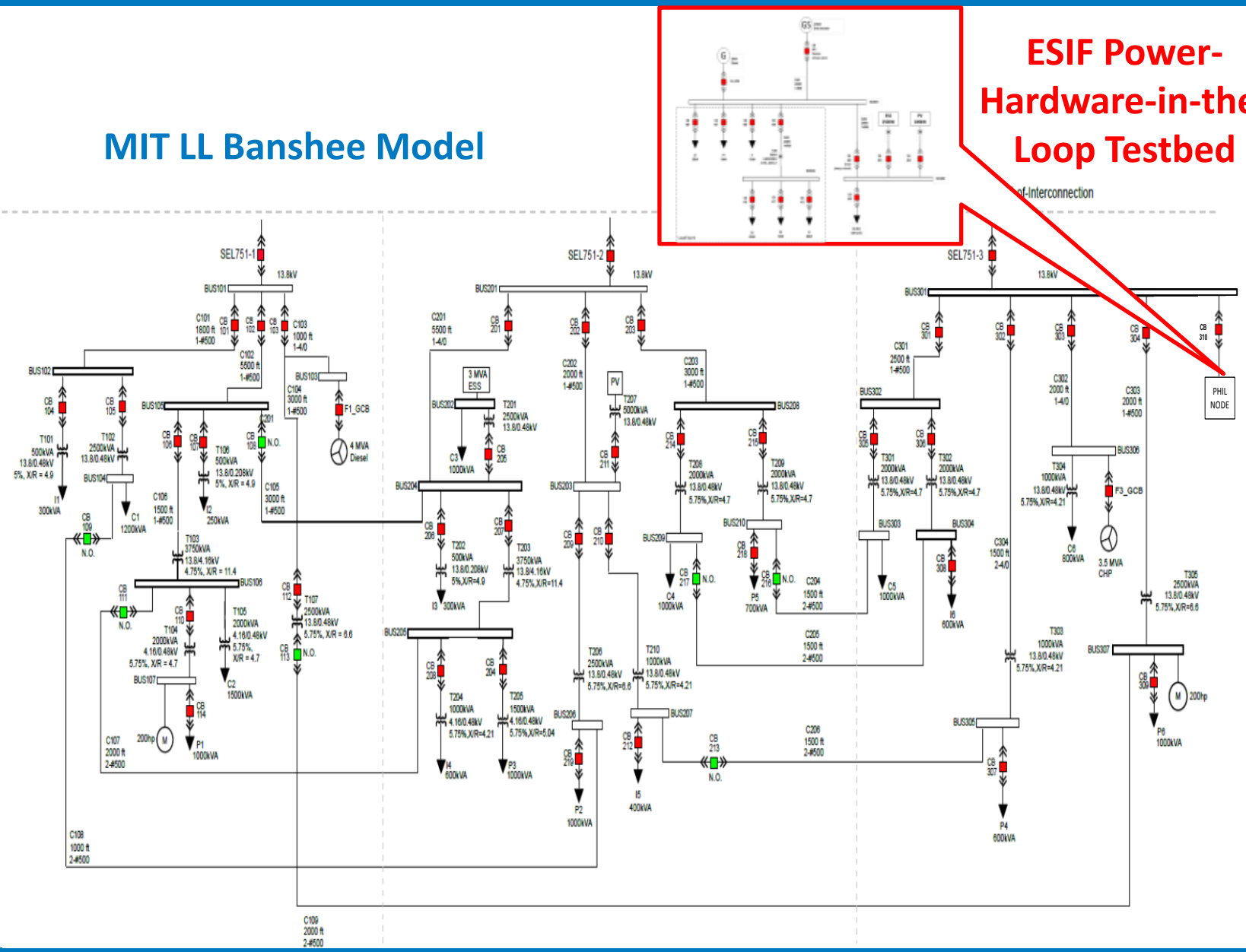
Scoring of Key Performance Metrics*

- Resiliency and Reliability
- Microgrid Survivability
- Power Quality
- Fuel- Free Asset Utilization
- Interconnection Contract
- Utility Commands
- Operation and Maintenance

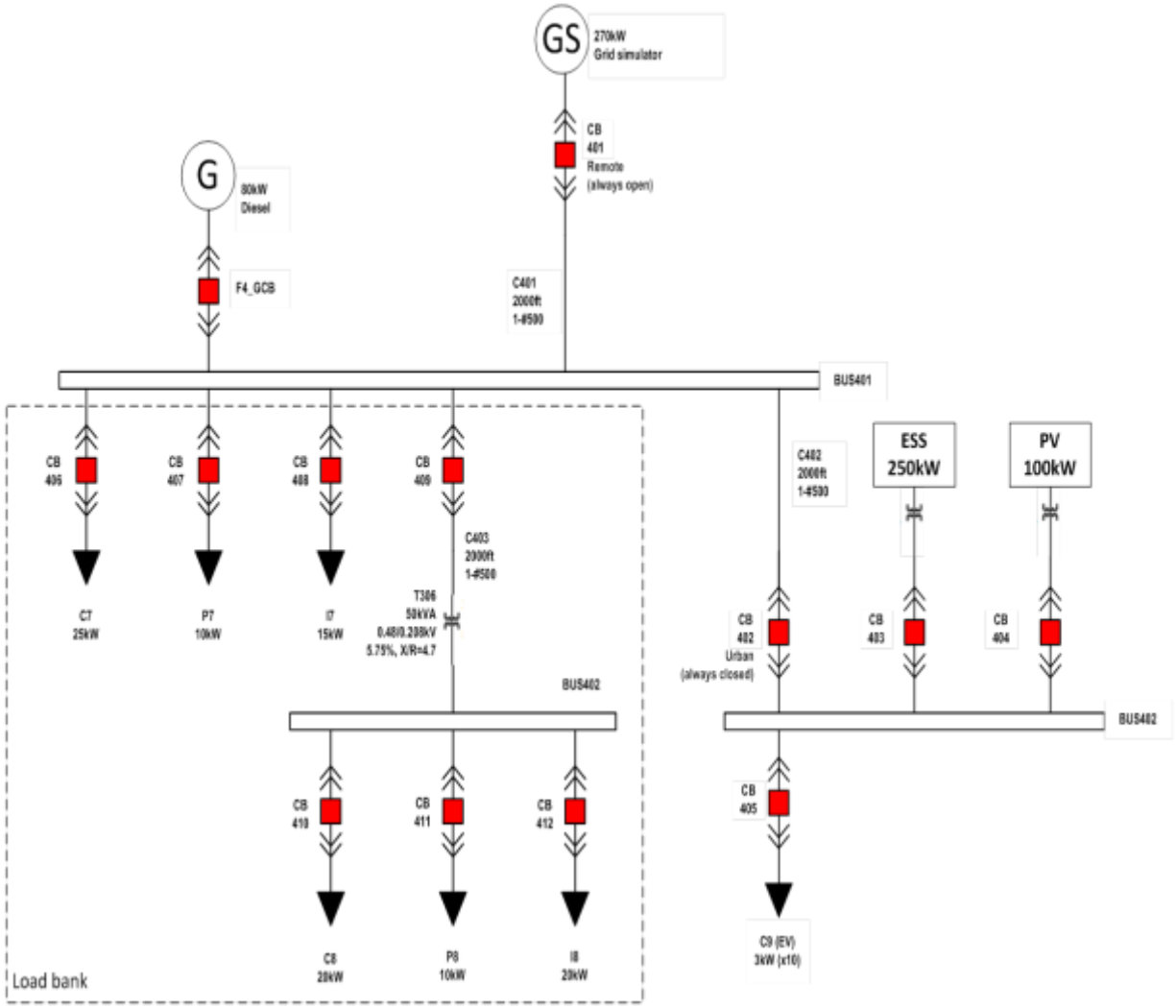
**** NREL built upon KPPs developed at MIT Lincoln Laboratory. Relative weighting of KPPs derived from two focus groups held by NREL.***

Banshee Model + PHIL Testbed

MIT LL Banshee Model



Power Systems Testbed Schematic



Power-Hardware in-the-Loop (PHIL) Testbed at ESIF

Testbed Components:

- Microgrid controller – provided by participant
- Real time power simulation – (RTS) Opal RT and Mathworks - Matlab & Simulink
- Operator interface (HMI) and data manager- SEL RTAC
- Ametek 270kW bidirectional programmable AC source/sink,
- Research electrical distribution bus (REDB),
- ABB 100kW solar inverter w/ MagnaPower programmable DC source (solar array emulator),
- Loadtec 250kW RLC load bank,
- Caterpillar 250kW battery inverter w/ AV900 bidirectional programmable DC source/sink (battery emulator),
- Onan Cummins 80kW diesel genset w/ Woodward paralleling controller
- Nissan Leaf w/ electric vehicle service equipment (EVSE) and Sparkmeter

Power Systems Evaluation – 70% of Final Score

All Key Performance Parameters (KPP)s will be converted to USD and the sum of KPPs will be presented as a microgrid operator's bill.

Resiliency and Reliability

Measured by calculating the energy delivered to predetermined categories of load. A penalty will be added for any outage on critical loads.

Microgrid Survivability

Keeping battery State of Charge (SoC) below the predetermined level during grid connected conditions will result in a penalty.

Power Quality

Voltage and frequency violating IEEE 1547a-2014 clearing times (Tables 1 and 2 of the standard) will be counted. of the standard will be counted.

Fuel- Free Asset Utilization

The amount of energy generated from PV to supply 1MWh of loads in the microgrid and PV energy generation will be measured.

Interconnection Contract

The price of energy during the test sequence will vary to allow the controller to benefit from various choices (e.g. dispatching energy from battery).

Distribution Service Operator (DSO) Commands

The microgrid controller can allow additional revenue by providing services to DSO on request. Failing to provide required services will result in a penalty.

Operation and Maintenance

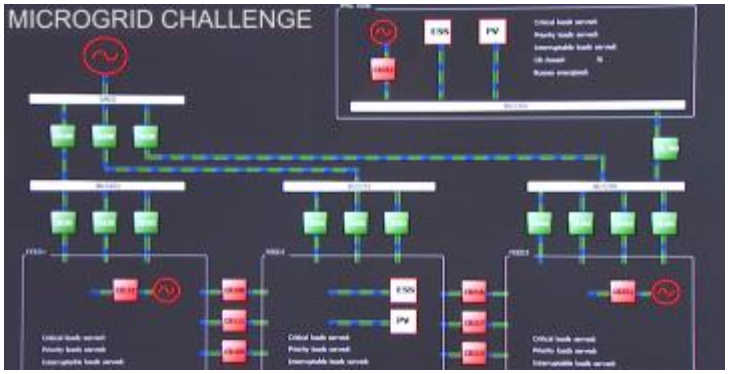
The cost places a value on device degradation from use (e.g. causing faster failure, circuit breakers use).

NREL built upon existing KPPs developed by MIT Lincoln Laboratories. Relative weighting of KPPs derived from two focus groups held in Nov.

Results- Microgrid Controller Innovation Challenge

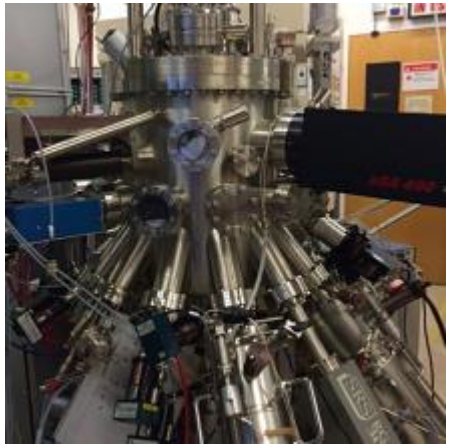
- Preliminary Findings
  - High external interest- potential customers need better information
  - General controls- significant effort required to program “microgrid” controls
  - Capabilities/functionalities tend to be overstated/understated
  - Vendor participation resulted in new features being developed

- Final report and presentations to be completed in December



Strategic Goals for Future Microgrid R&D

- Strategic Goals
  - More focus on thermal cogen (trigen) and water/energy nexus
  - Materials & manufacturing of advanced solar cells/panels
    - National Center for Photovoltaics
      - Thin film research
      - Low-cost perovskite production



  - Military expeditionary power
    - Variable speed diesel gensets with integrated storage
  - Autonomous power systems
    - Self-configuring (plug-and-play) to form microgrid by nature

Thank you!

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