2014 Smart Grid R&D Program
Peer Review Meeting

CERTS Microgrid Test Bed

Joe Eto, Lawrence Berkeley National Lab
Bob Lasseter, University of Wisconsin

10 June 2014

CERTS Microgrid Test Bed

Objective

To lower the cost and improve the performance of clusters of smaller distributed energy resources and loads when operated in an integrated manner, i.e., as a microgrid

Life-cycle Funding Summary ($K)

FY09-FY13	FY14, authorized	FY15, requested	Out-year(s)
3020K	380K	350K	200K

Note: Does not include funding for LBNL DER-CAM activities

Technical Scope

The CERTS Microgrid Test Bed has been expanded through the addition of new hardware elements: 1) a CERTS-compatible conventional synchronous generator; and 2) a commercially available, stand-alone electricity storage device with CERTS controls. In addition, a smart load functionality has been implemented using existing equipment.

The 2013 International Microgrid Symposium was held in Santiago Chile; the 2014 Symposium will be held in Tianjin China

LBNL DER-CAM modeling activities are discussed in a separate presentation at this peer review

Problems & needs addressed by the project

With exponential increase in the variety of different DER technologies available for microgrids it is necessary to simplify the control and design problems with the objective to reduce outages, complexity, costs, and emissions.

Work completed for inverter based sources:

- ✓ Autonomous operation that ensures stable operation following the loss of centralized command and control systems.
- ✓ Lower construction/engineering costs through a plug-and-play functionality.
- ✓ Automatic load transfer from overloaded sources to other system sources using only local information.
- ✓ Seamless islanding and re-connection using only information available at the interface switch.
- ✓ Fast load tracking, stable voltage and frequency control, and minimum reactive power flow without reliance on communication.

Problems & needs addressed by the project

Needs currently being addressed:

- Understanding mixed system design issues in order to allow for customized microgrids using different DER technologies (e.g., inverter-based internal combustion engines, direct connected synchronous generators, storage, and renewables).
- Enabling graceful degradation (rather than complete system shut-down) following the unplanned loss of equipment including generation.

Current practices and their challenges addressed by the project

Current practices depend on fast command and control systems, which introduces unnecessary complexity, costs, and risks to survivability.

- Fast controls are required to track load, insure stability, control reactive power, regulate voltage/frequency and prevent microgrid shut down.
- It is difficult to scale/expand such microgrids due to the complexity of the control software.
- High construction (excess capacity)/engineering (more complicated controls) costs are required to enable the microgrid to keep operating following unplanned events.

Current inverter practices rely on control mode switching when moving between grid connect and island operation (usually between current sourced and voltage sourced operation) – not a seamless transition

Significance and Impact

- CERTS microgrids have broad applicability in systems that require higher reliability (outage reduction for critical loads by >98%) at lower cost than the standard utility grid can provide.
- For smaller microgrid projects involving multiple distributed energy resources (< 10 MW total installed capacity) the costs associated with traditional approaches for equipment selection, dispatch/operation, and field or custom engineering/project commissioning can easily represent 30-50% of total project costs. This project seeks to reduce these costs by up to 90%.
- Can continue to operate with loss of the central control system.
- The inclusion of direct connected synchronous generators reduces costs.
- Survivability is enhanced through graceful degradation

Significance and Impact

Santa Rita Jail
CERTS Microgrid

No critical load outages since dedication 3/22/2012

"The CERTS Protocol is a powerful tool for integrating distributed generation resources."

Brevoort Co-op, Manhattan

"*CERTS microgrid-cogen system from Tecogen comes through for Greenwich Village Co-op building during supperstorm Sandy."*

"The CERTS microgrid control technology is the most radical of all options-as well as the lowest cost-as it is embedded into a 100-kW CHP system offered by Tecogen"

Peter Asmus, Navigant.

Technical approach for solutions to accomplish the project's objectives/outcomes

Reduce load outages by ~ 98% (UPS like system)

- Fast islanding (~1 cycle)
- Provides for a stiff voltage during all events (SVC)

Reduces complexity, provides greater modularity & lower cost

- Minimize engineering errors/cost/and maximizes flexibility using plug-and-play concepts (plug-and-play allows for design & expansion with minimum engineering cost)
- Autonomous local control (independent of loss of central controller)
- Simplifies the design and construction of mixed DER microgrid
- Graceful degradation

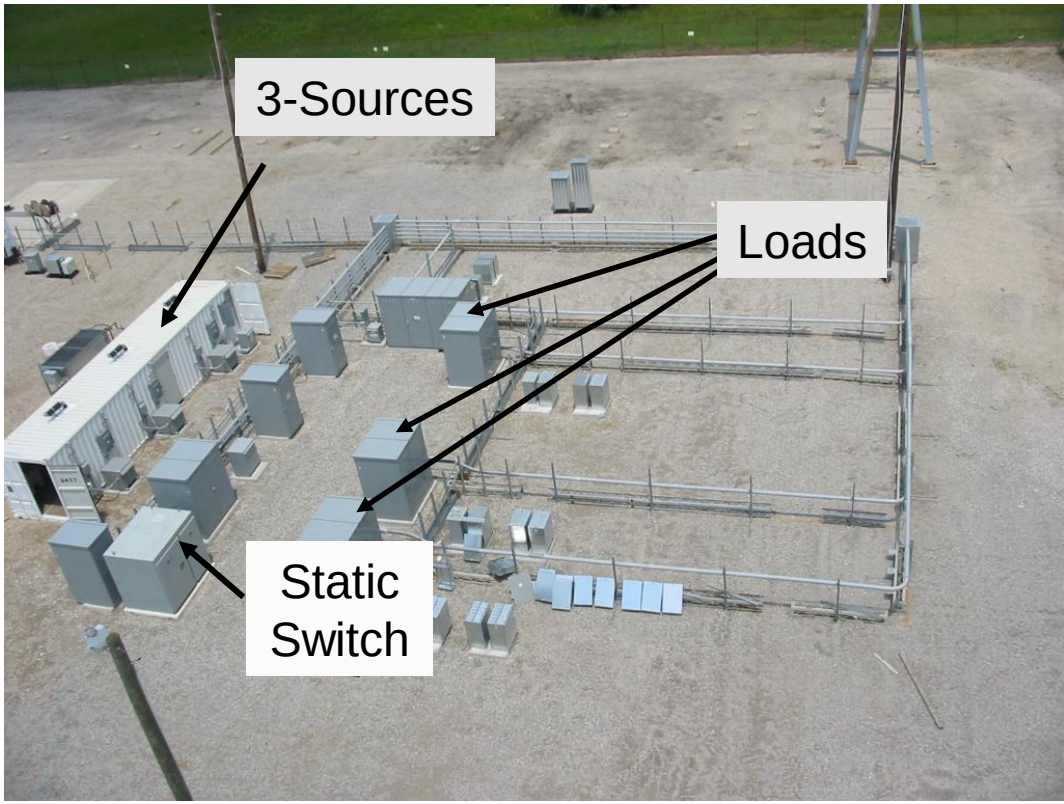
Reduced emissions and improve energy efficiencies

- Effective use of Combined Heat & Power (CHP)
- Enables easier integration of local renewables (e.g., PV)
- No transmission and distribution losses
- Facilitates demand side management
- Supports provision of ancillary services

Prior-years progress and results: AEP Test site

Concepts Demonstrated at Site
(without communications)

- ✓ No mode switching for DER
- ✓ Autonomous load following
- ✓ Seamless separation & automatic re-synchronizing with the grid.
- ✓ Autonomous load transfer from overloaded source to other sources
- ✓ Voltage and frequency control
- ✓ UPS level power quality
- ✓ Stable operation for multi-sourced systems.
- ✓ Plug & play
- ✓ Commissioned direct connected NG synchronous generator



DOE TR	2000-2001
CEC PIER	2001-2006
DOE RDSI solicitation	2006-2009
DOE Microgrid program	2009-present

http://certs.lbl.gov/certs-der-pubs.html

FY 2014 performance and results

Direct connected synchronous generators.

- Install CERTS governor and exciter (UW lab and Santa Rita Jail)
- Use an external control (Woodward) on a standard NG gen-set to achieve CERTS performance. Stand alone test completed. (AEP and OSU including simulation)

Energy storage.

- CERTS controls effective (UW lab and Santa Rita Jail)
- Non-CERTS controls which meet functional specifications (Factory test completed, AEP test started).

Graceful degradation (autonomous load shedding with loss of energy source)

- Completed smart load shedding without loss of a source.(AEP & OSU including simulation)

CERTS PV

- Wei Du, Qirong Jiang, M. Erickson, R.Lasseter, *"Voltage Source Control of PV Inverter in a CERTS Microgrid,"* Accepted for publication IEEE Transaction on Power Delivery, 2014
- Wei Du, R.Lasster, "*Voltage Source Control of PV Inverters in CERTS Microgrids Report,"* 6/20/2013

CERTS Electrical Vehicle Charging Station

- Phil Hart, R.Lasseter, Investigation of Hybrid CERTS Microgrids with Droop-Controlled AC and DC Buses for Use in Electric Vehicle Charging Stations report, Jan 2014
- P.J. Hart, P.J. Kollmeyer, L.W. Juang, R.H. Lasseter, T.M. Jahns, *"Modeling of Second-Life Batteries for Use in a CERTS Microgrid"* ECCE 2014

FY 2015-2016: Key Tasks

- Complete the storage unit stand alone testing.
- Perform mix-source transient tests

  Tecogen to NG gen-set, Tecogen to storage, storage to NG gen-set following AEP's reduced system test procedures. Expected outcome will be provided through simulation before the AEP tests. This will provide understanding of the effects of different response times.
- Start Loss of source survivable tests

  Three sources: Tecogen, NG gen-set and storage with loss of single source for a range of total generation loss between 25% to 30 %)
- Create guidelines for design of mixed source microgrids (2016).

Project Team Capabilities & Funding Leverage

The CERTS Microgrid Project Team consists of:

- Lawrence Berkeley National Laboratory
- University of Wisconsin
- American Electric Power Company
- Sandia National Laboratories
- Ohio State University

Research partners currently include:

- TeCogen
- Woodward
- Princeton Power

Project Team members are involved in a number complementary activities

- SMUD microgrid field demonstration
- Chevron microgrid field demonstration at San Ramon
- Maxwell Air Force Base microgrid demonstration
- International Microgrid Symposium

In addition the project team is in discussions with a wide variety of potential field demonstration partners and microgrid equipment manufacturers

Project Team Capabilities & Funding Leverage

Visitors to AEP Dolan Test Laboratory since 2011

Hawaiian Electric + Texas A&M
Raytheon Microgrid
Ohio House Committee on Alternate Energy
KEMA + CPFL (Brazil)
Tokyo Electric
UCAIug OpenSG - 80 utility members
International Microgrid Consortium tour group
State Grid of China
Ohio Green Energy Open House
Tokyo Electric
Eisenhower Fellows
Consert EMS Tour
HD Supply Tour
Battelle RTP Team
Energy Conversion Devices
Kyushu Electric and Hitachi
GE Energy
Cooper Power Systems
Energy Conversion Devices + Ovonics
Rexorce Waste Heat Recovery
Panasonic Home Energy Manager Team
Chevron
EPRI Intelligrid meeting - 50 members from various utilities
Ohio State Student Group
AEP Coop Students
University of Michigan Group
Columbus State University
Chung Yuan Christian University
Ohio Secretary of State