CERTS Microgrid Test Bed Renewable Integration Analysis

Smart Grid R&D Program
Peer Review
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Joe Eto
Lawrence Berkeley National Lab

Relevance to OE Mission and Smart Grid Program Goals

Enables Grid Modernization

Enhance the integration of Distributed and Renewable Energy Sources

Meets End User Needs

Supports the Macrogrid

- The CERTS Microgrid Project is recognized both domestically and internationally as one of the leading microgrid R&D activities

Microgrids vs. CERTS Microgrids

"A **microgrid** is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode "

Microgrid Exchange Group. October 2010

Distinguishing features of the **CERTS Microgrid *Concept***

- Seamless islanding and reconnection via single PCC
- Peer-to-peer, autonomous coordination among micro-sources (w/o high bandwidth communications)
- Plug-and-play - no custom engineering
- Energy manager on arbitrary platform

Distinguishing features of the **CERTS Microgrid *Test Bed Demonstration***

- Small sources (<100 kW each)
- No stand-alone storage (yet)
- No power flow onto the grid

CERTS Microgrid R&D Timeline

DOE Transmission Reliability Program – 1999-2002

- Development of original concepts
- Simulation and bench-scale testing
- Assessment of potential test bed sites
- Creation of software tools (DER-CAM, mu-Grid)

CEC PIER Energy Systems Integration Program – 2001-2006

- Construction of AEP CERTS Microgrid test bed
- Completion of proof-of-concept CERTS Microgrid tests

DOE RDSI – Chicago Program Office – 2006-2009

- Value and technology assessment to enhance the business case

DOE Smart Grid – HQ – 2009-present

- Integration of variable renewable generation/storage

Role of Microgrids in Facilitating Integration of Distributed Renewable Electricity Sources

Research Challenges

Maintaining frequency and voltage in response to step changes in load-generation balance (e.g., transition to island; loss of generation when islanded) with sources that are limited in ramping capability (e.g., PV cannot increase output)

Optimizing sizing, technology choice, equipment degradation, charge/discharge management for local energy storage

Establishing requirements for and then developing intelligent (frequency-based) load shedding/demand response strategies within the microgrid

Lowering overall microgrid system costs through less expensive mechanical switches at the point of common coupling and through integration of non-inverter based generation sources within the microgrid

Lowering costs and improve capability of microgrids through more sophisticated energy management controls while relying on legacy EMS systems

Technical Approach

Analysis -> Detailed Simulation -> Bench-Scale Testing at UW -> Prototype Specification -> Factory/Field Acceptance Testing of Prototypes -> Full System Tests at AEP
-> Field Demonstrations led by others -> Commercialization led by private sector

KEY ELEMENTS OF TECHNICAL APPROACH FOR ADDRESSING RESEARCH CHALLENGES

PV – Acquire a PV emulator; implement CERTS control algorithms

Storage – Install a conventional storage system (lead-acid batteries); implement CERTS control algorithms

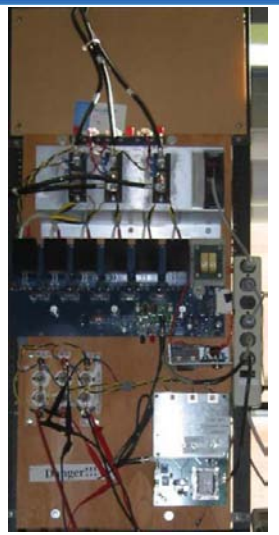
Intelligent load shedding – Install under-frequency relays with adjustable settings for amount of load shed, and frequency trip points

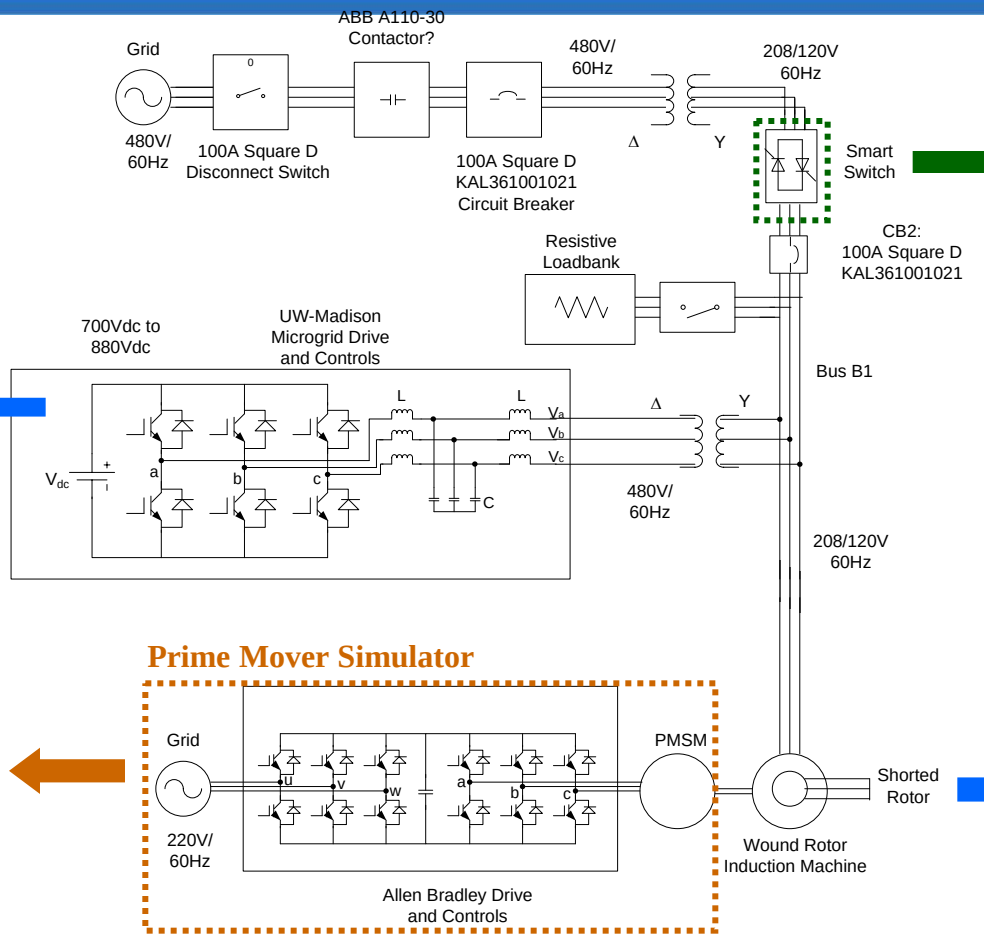
Mechanical switch – Install mechanical switch; repeat tests conducted with semiconductor switch

Synchronous generator – Acquire a synchronous generator; implement CERTS control algorithms in governor and exciter controls

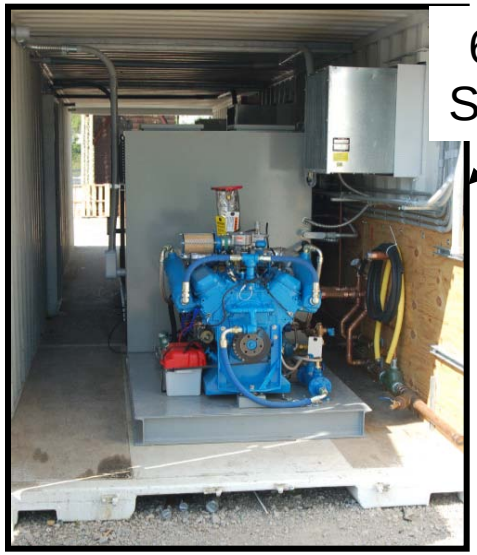
Energy management – Build an interface between AEP test bed and DER-CAM; use information from DER-CAM to support generation dispatch and intelligent load-shedding

Bench-Scale Test Bed at UW

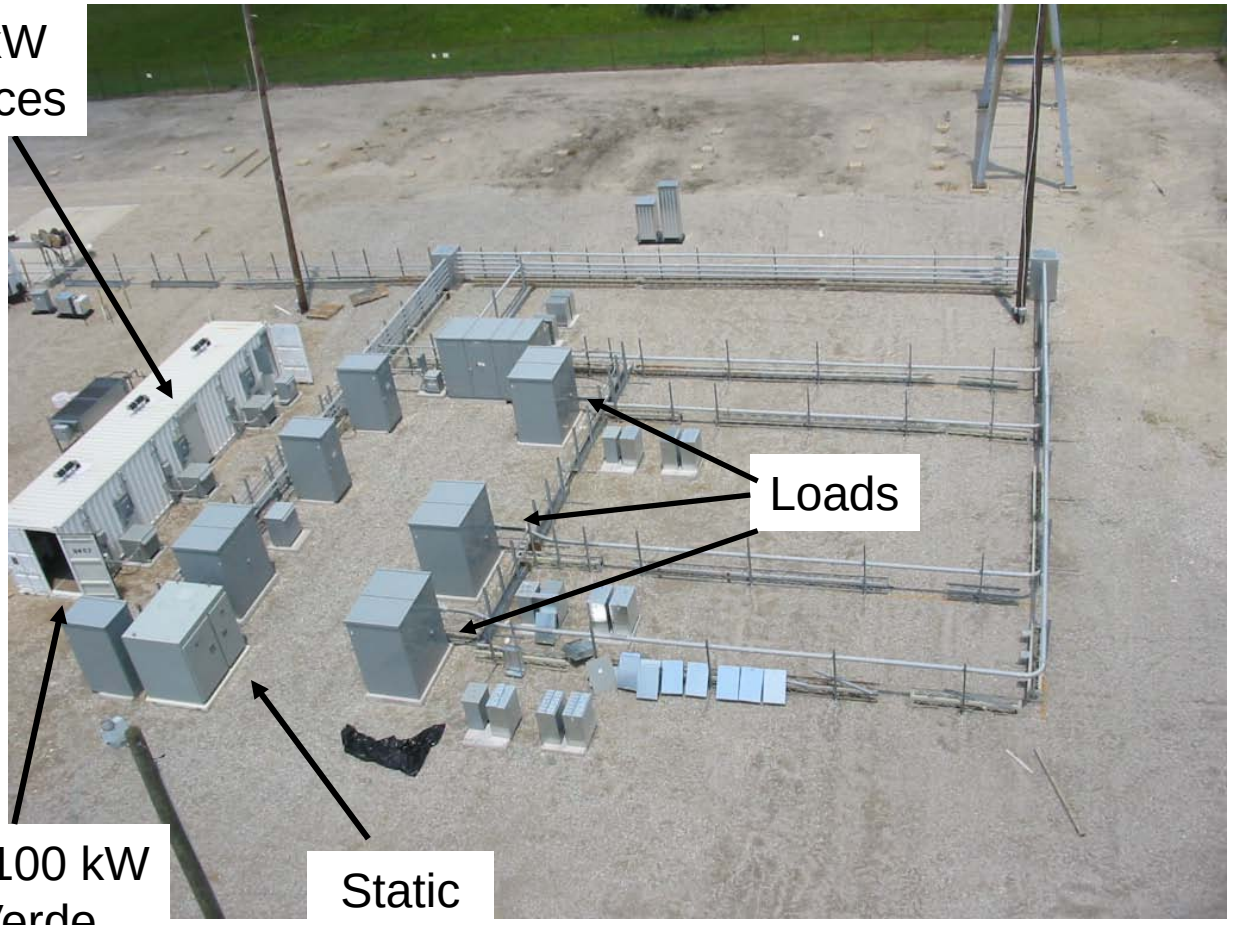




AEP/CERTS Microgrid Test Bed



60 kW Sources



Loads

New 100 kW InVerde

Static Switch

Project Management

The CERTS Microgrid Project Team consists of:

Joe Eto, Lawrence Berkeley National Laboratory – PI
Bob Lasseter, University of Wisconsin
Dave Klapp, Scott Casto, John HowardAmerican Electric Power Company
Ben Schenkman, Sandia National Laboratories
Chris Marnay, Michael Stadler, Lawrence Berkeley National Laboratory

The research partners currently include:

Tecogen
The Switch (inverter manufacturer)
S&C (static switch manufacturer)

In addition the project team is in discussions with several vendors of synchronous generators/controls, energy storage, and PV emulators

FY10 Technical Accomplishments

In FY10, we have or are:

1. Completed bench-scale tests of enhanced concepts for synchronous generator
2. Completed initial modifications to the test bed
3. Replaced prototype TeCogen unit with commercial grade unit employing CERTS controls – repeat system tests with the new unit
4. Established a server to run DER-CAM optimization on a *software-as-a-service* model
5. Installing a mechanical switch and repeating static switch tests
6. Designing, installing relays, and beginning intelligent load shedding tests
7. Implementing an interface between DER-CAM operated as server-based decision support system and the microgrid test bed energy manager at AEP
8. Specifying and purchasing a synchronous generator equipped with CERTS control algorithms
9. Identifying vendors for the PV emulator and energy storage systems, including inverters with CERTS control algorithms

The principal deliverables for FY10 will consist of technical reports on

a) Simulation studies of PV, energy storage, and mixed microgrid systems

b) Bench-scale testing of synchronous generators operated in a CERTS Microgrid environment; and

c) Testing at AEP that is completed on items 3 and 4

Out-year Planned Activities & Milestones

FY 11

1. Complete testing of mechanical switch
2. Complete initial phase of intelligent load shedding tests
3. Establish and demonstrate remote interface between DER-CAM and AEP test bed energy manager
4. Acquire synchronous generator and perform individual and mixed system tests
5. Acquire energy storage and PV emulator, including inverters equipped with CERTS controls

FY 12 – FY 13

1. Complete testing of full system involving all elements: inverter and non-inverter based conventional generation, energy storage, PV, and intelligent load shedding – individually and in conjunction with other hardware elements
2. Reach agreement with AEP on a distribution system field demonstration of CERTS Microgrid concepts
3. Commercialize DER-CAM *Software-as-a-Service*

Technology Transfer, Collaborations, and Partnerships

Visitors to AEP Dolan Test Laboratory since 2009

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
Arts Impact Middle School
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

Technology Transfer, Collaborations, and Partnerships

Project Team members are involved in a number complementary activities

SMUD microgrid field demonstration – 3 Tecogen InVerde units

Chevron microgrid field demonstration at Santa Rita Jail – Energy storage

Maxwell Air Force Base microgrid demonstration – Synchronous generator

Fort Sill microgrid demonstration – Synchronous generator, energy storage, PV

Open-access website at CEC for DER-CAM
http://der.lbl.gov/microgrids-lbnl/current-project-storage-viability-website

International Microgrid Symposium
http://der.lbl.gov/microgrid-symposiums

Technology Transfer, Collaborations, and Partnerships

InVerde® 100

Features & Benefits

- *100 kW Continuous/125 kW Peaking*
- *Standardized Interconnection*
- *Black-Start Grid-Independent Operation*
- *Microgrid compatible with licensed CERTS[1] power balancing control software*
- *Premium Quality Wave Form, Voltage and Power Factor for Special Applications (e.g. computer server farms or precision instrumentation)*
- *Power Boost for Demand-Side Response*
- *Enhanced Efficiency from Variable Speed Operation*
- *Simplified Inter-Unit Controls for either Mode of Operation (parallel or standby)*
- *ETL Listed - Labeled for compliance with UL 1741 - Utility Interactive; Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources*
- ***Renewable Energy Compatible, a Clean Energy Solution for Today and Tomorrow***

[1] *CERTS - Consortium for Electric Reliability Technology Solutions*

UL 1741 Compliant

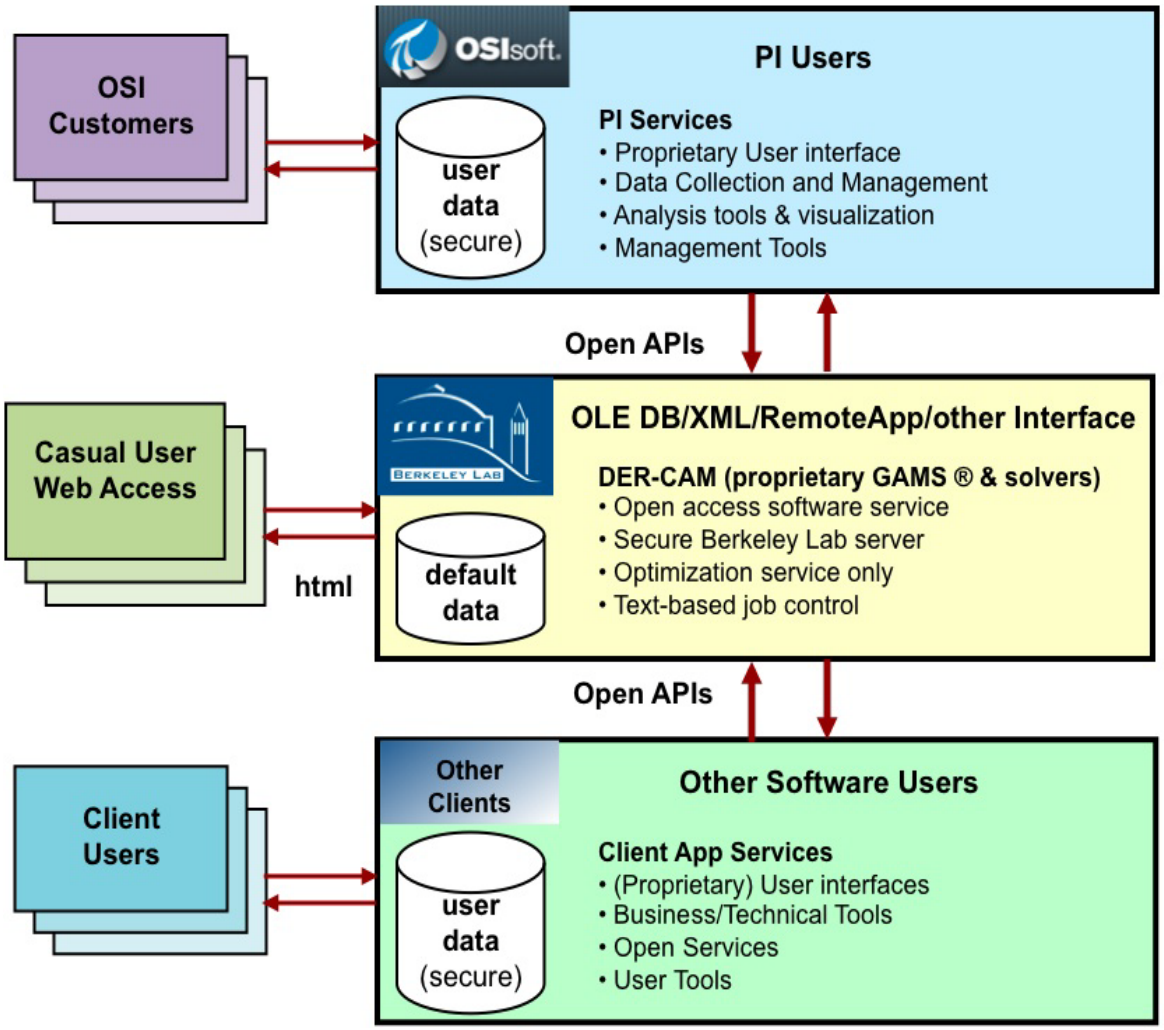
TECOGEN, Inc.

- Over 25 years experience in packaged cogeneration, chillers and refrigeration systems
- More than 1,400 operating units in the field
- Extensive service network with factory-trained technicians exclusively servicing Tecogen products

Technology Transfer, Collaborations, and Partnerships

GAMS® very powerful for optimization but doesn't offer a good path to stand-alone model commercialization: academic, cryptic text interface, expensive, ...

Software as a Service model is one solution.



Next? Coupled Microgrids

Smart Switch:

- Seamless separation
- Automatic re-synchronizing

Two coupled microgrids:

- Distribution level
- Customer level with high *Local Reliability & CHP*