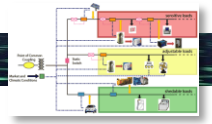


CERTS Microgrid Research and Lessons Learned

Advanced Grid Technologies Workshop
Microgrid Controls and Management Systems
July 9, 2015

Bob Lasseter
University of Wisconsin – Madison

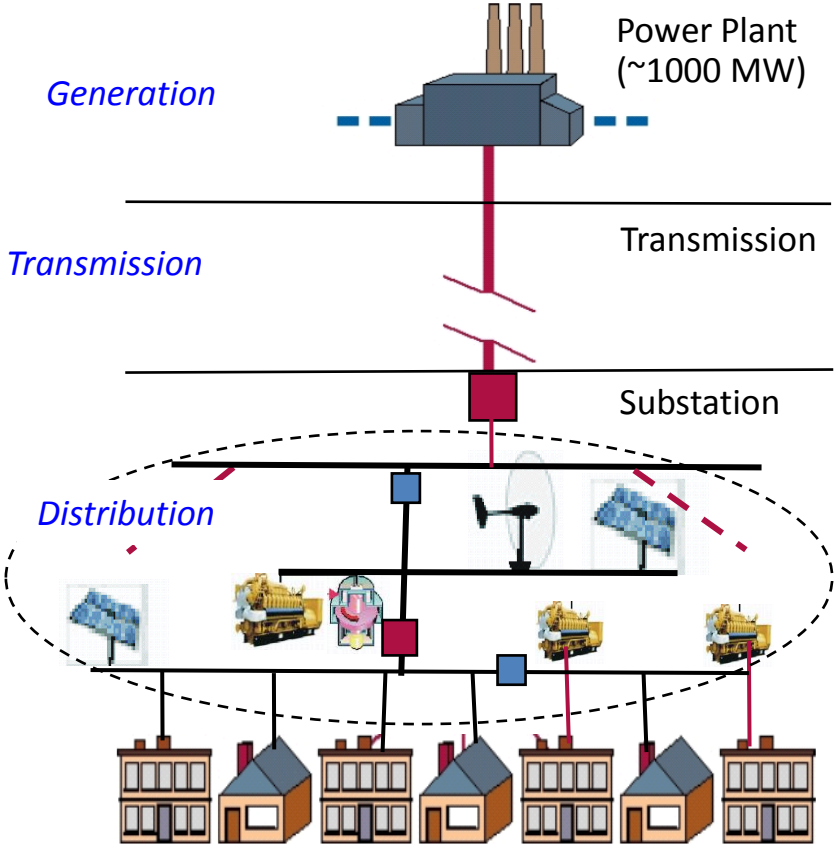
Power System of the Future

Central Generation with Low CO_2
Economy of Scale, 100s MW
Scalable, Reliable

Distributed Energy Resources
Economy of numbers, 10,000s units
Small, Efficient and Robust

Problem with 10,000s of DERs

The challenge is how to manage this wide, dynamic set of distributed energy resources and their control points.

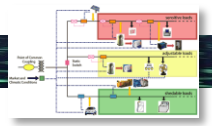


Central Control by ISO/RSO

- ***Complexity is huge***
- ***It is structurally problematic***
- ***Extra cyber-security problems***

Highly Decentralized: Many clusters of DER and loads (i.e. microgrids) with hierarchical control

- ***Structurally sound***
- ***Scalable***
- ***Easier to secure***



Clusters of DER & Loads

A system approach to high penetration issues

Enhance Robustness (UPS like system)

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

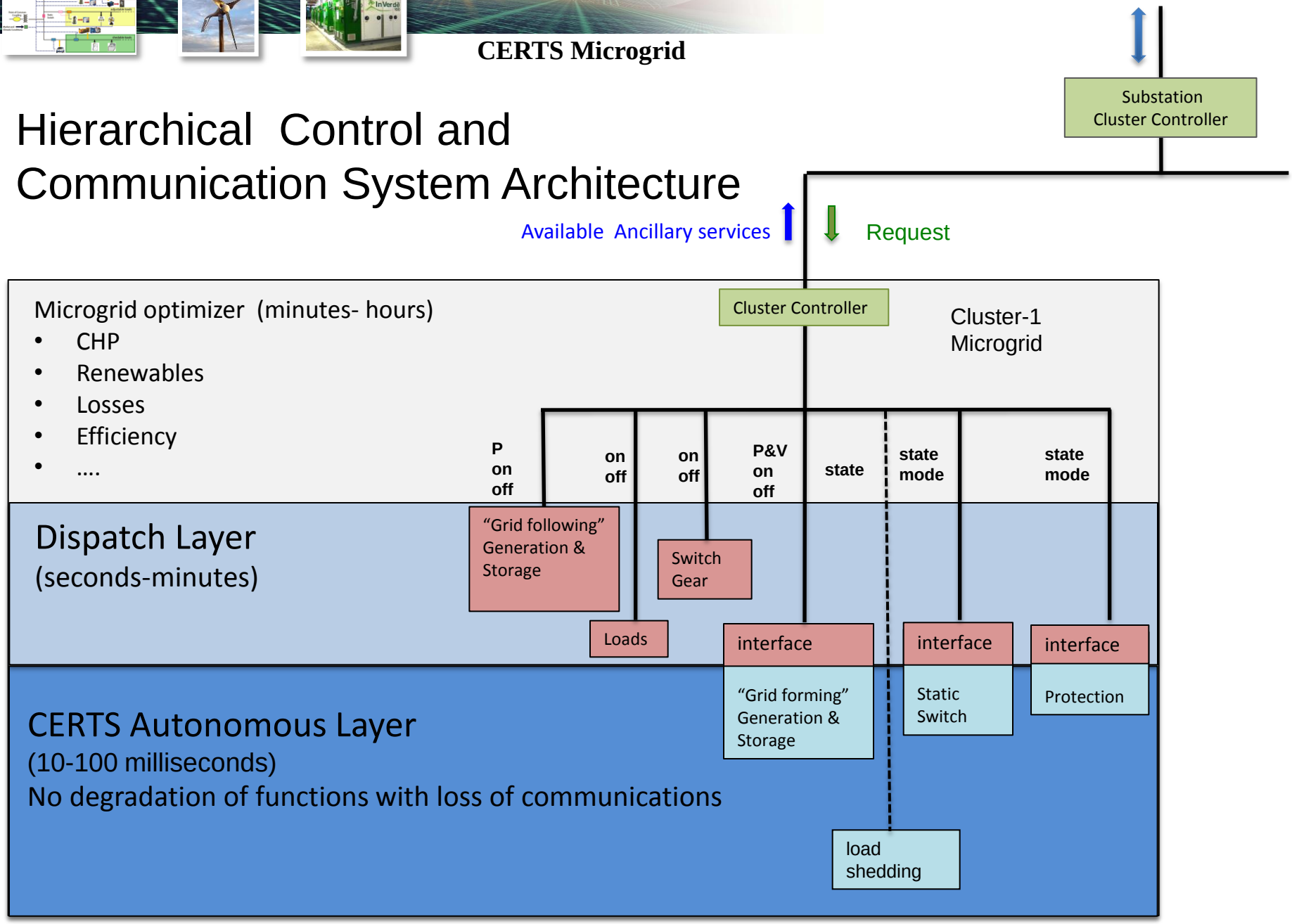
Reduces complexity, provides greater modularity & lower cost

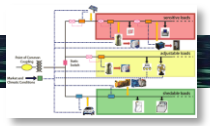
- Minimize engineering errors/cost/and maximizes flexibility using plug-and-play concepts
- (plug-and-play allows for design & expansion with minimum engineering cost)
- Autonomous local control (independent of loss of central controller)
- Graceful degradation

Reduced emissions and improve energy efficiencies

- Effective use of Combined Heat & Power (CHP)
- Facilitates renewables
- Facilitates demand side management
- Support ancillary services
- Reduces transmission losses

Hierarchical Control and Communication System Architecture



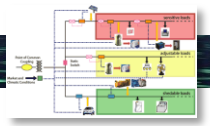


Autonomous Layer Functional Needs

Each DER unit is a grid-forming component (controls ac voltage and frequency).

- No degradation of functions with loss of communications
- Autonomous load following
- Insures multi-unit stability (local voltage control)
- Autonomous load transfer from overloaded source to other sources
- Graceful degradation
- Plug-and-play

The interface switch provides for autonomous islanding and re-synchronizing to the network (opens on IEEE-1547 & power quality events)



Autonomous Layer Functional Needs

Each DER unit is a grid-forming component (controls ac voltage and frequency).

- No degradation of functions with loss of communications
- Autonomous load following
- Insures multi-unit stability (local voltage control)
- Autonomous load transfer from overloaded source to other sources
- Graceful degradation
- Plug-and-play

The interface switch provides for autonomous islanding and re-synchronizing to the network (opens on IEEE1547 & power quality events)

Autonomous Load Transfer

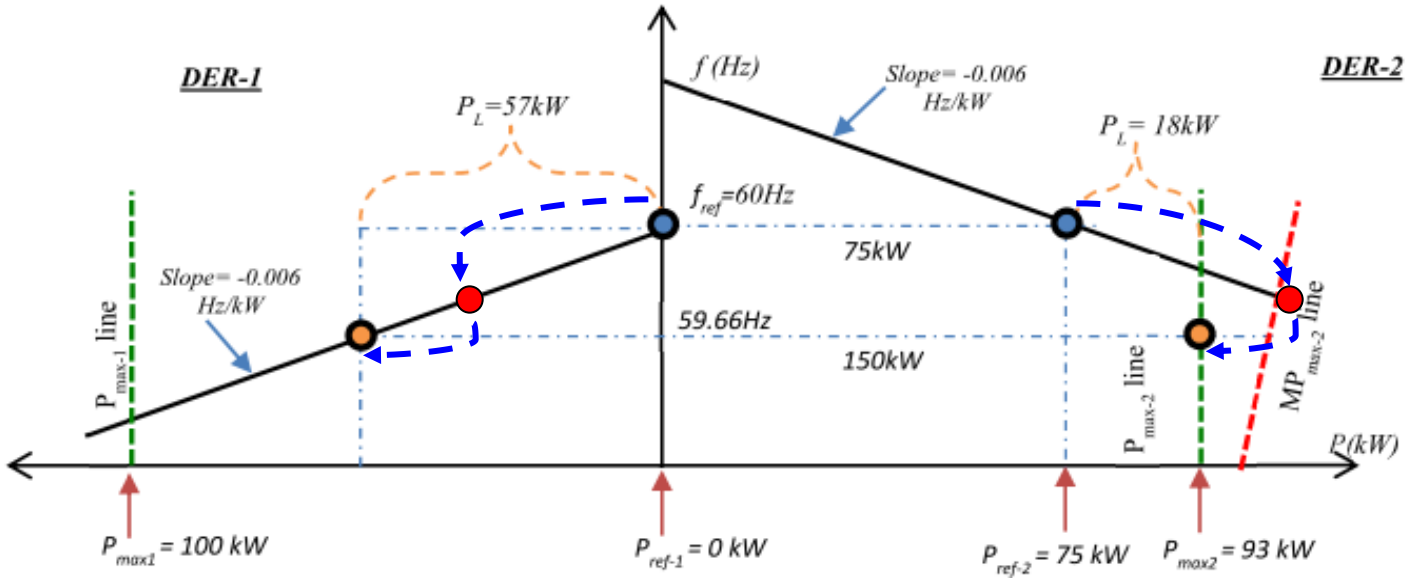
75-150kW step load change at t=0sec

DER-k	DER-1 (Inverter)	DER-2 (Synchronous generator)
P_{ref}	*0kW*	*75kW*
Q_{ref}	*0*	*0*
P_{max}	*100kW*	*93kW*

$\Delta P_{DER\text{-}1} = \Delta P_{DER\text{-}2} = 75/2 = 37.5kW$

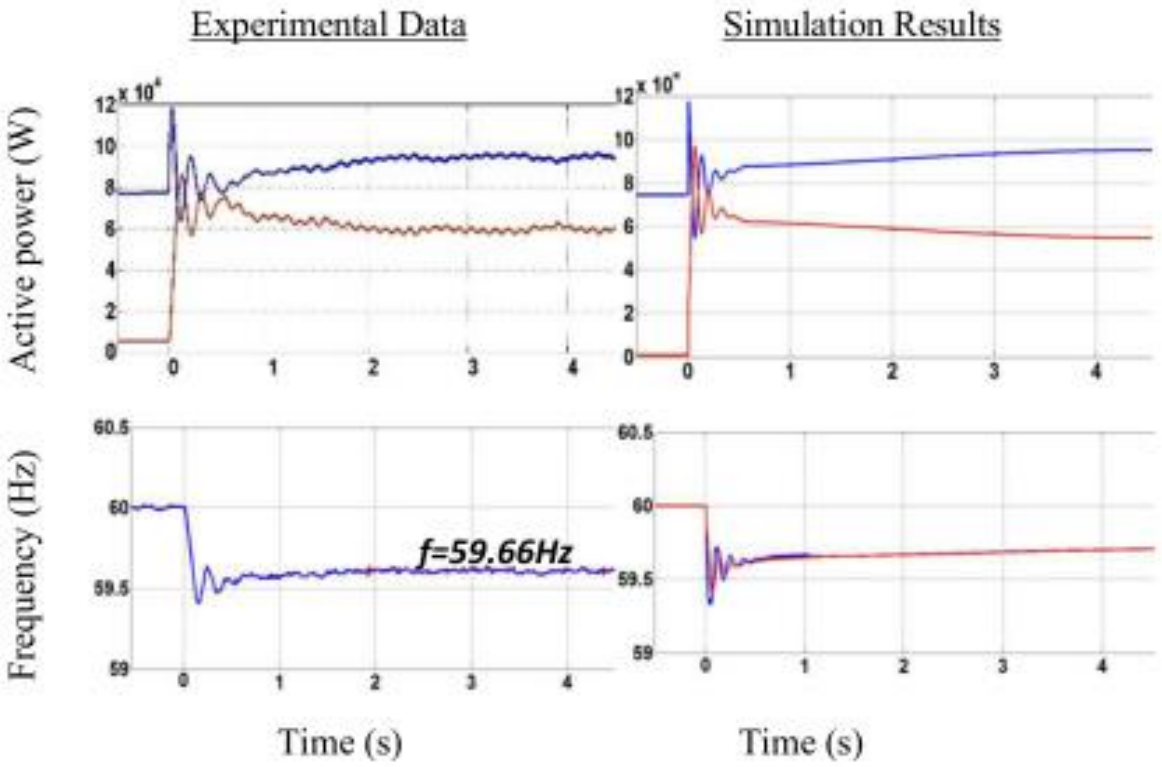
$P_{DER\text{-}1}$ 0 → 37.5kW → 57kW

$P_{DER\text{-}2}$ 75kW → 112.5kW → 93kW



Traces
AEP Test Site

DER-k	DER-1 (Inverter)	DER-2 (Synchronous generator)
P_{ref}	*0kW*	*75kW*
Q_{ref}	*0*	*0*
P_{max}	*100kW*	*93kW*



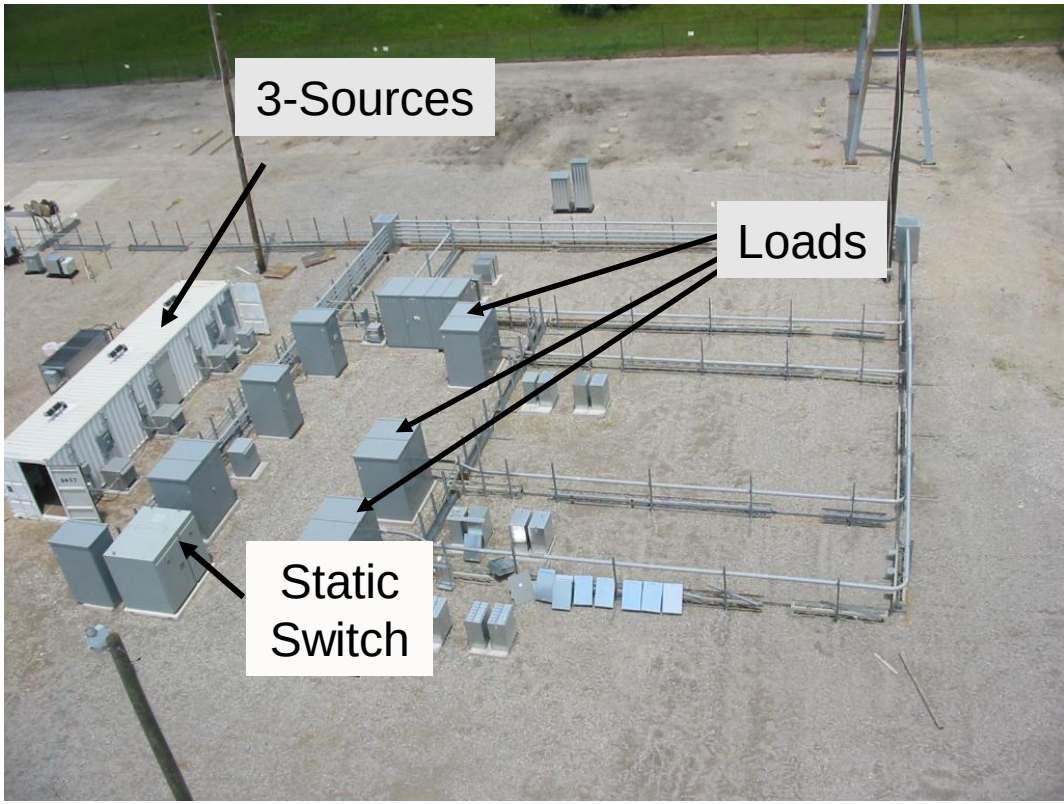
Synchronous generator

Inverter

AEP/CERTS Microgrid Test Bed

Demonstrated at Site
(no communications & no storage)

- ✓ 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

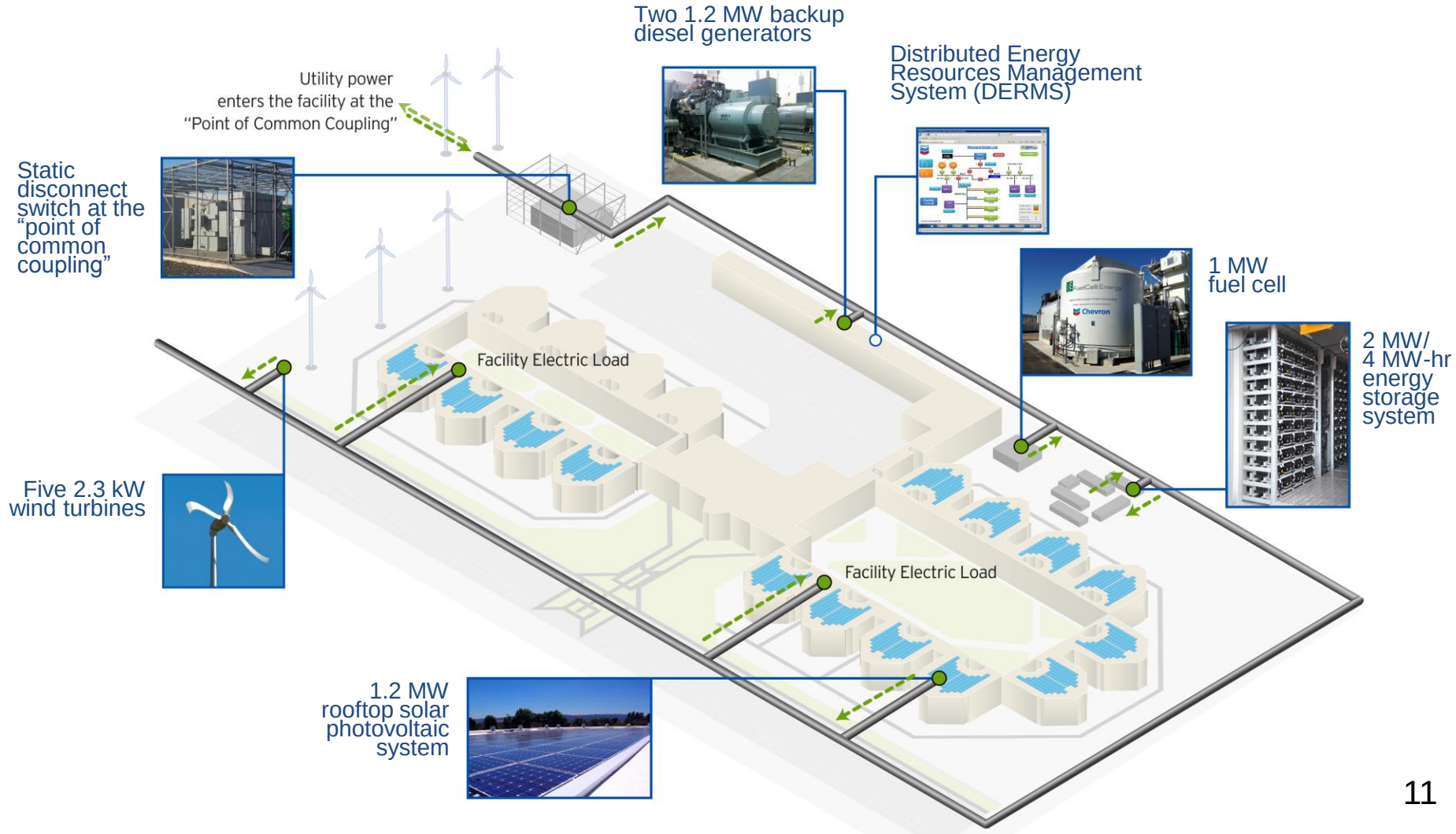


CEC PIER 2001-2006
DOE RDSI 2006-2009
DOE Smart Grid/HQ 2009-present

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

Santa Rita Jail Microgrid
March 2012

When a disturbance to the utility grid occurs, the automatic disconnect switch enables the facility to "island" itself from the main utility grid.



"Microgrid-cogen system from Tecogen comes through for Greenwich Village Co-op building during superstorm Sandy"

Summary

CERTS Microgrids work and adds value

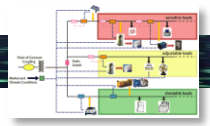
- *Customer benefits include:* bill savings, price certainty, reliability (including power quality), energy independence.
- *Grid benefits includes:* a well-behaved electrical "citizen" and a ancillary resource to the grid.
- *Societal benefits include:* more resilient local energy infrastructure and increased environmental benefits.

"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, "Distributed Generation," September/October 2011

Questions?

http://certs.lbl.gov/certs-der-pubs.html
lasseter@engr.wisc.edu



Key DDS Principles

More reliable/efficient systems using 1000's of DER near loads

- Increase efficiencies and reduced emissions through use of waste heat
- Reduced transmission losses
- More resilient system using local generation, microgrids & network reconfiguration

Economic efficiencies via distribution-based marketplace

- Independent Distribution System Operator
- Local balancing authority
- Local marketplace

Simplify the central generation planning and operation

- Handle distribution system's dynamics locally (minimize volatility at the T-D interface)
- Improve efficiencies by increasing base load operation.
- Constant/contracted wholesale energy transactions.
- Minimize CO_2 content