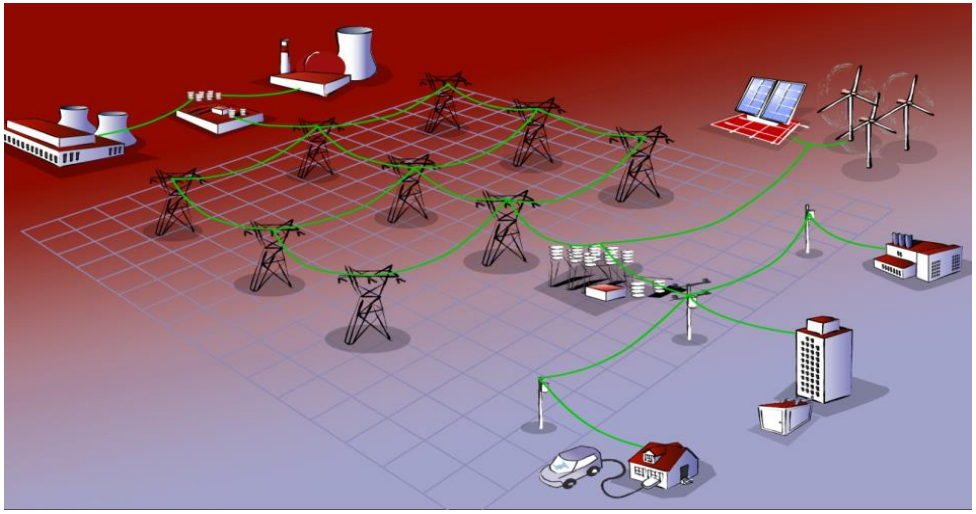


DOE ARRA Smart Grid Demonstration Program

Grid Modernization Summit

July 15-17,2015

Washington DC

Steve Bossart, Senior Energy Analyst

Topics

SGDP overview

Selected project results

Observations & going forward

SGDP
Overview

Smart Grid Demonstration Projects: The Portfolio

Regional Demonstration Projects (16): Quantify smart grid cost-effectiveness and verify technologies at a scale that can be readily replicated across the country.

Energy Storage Projects (16): Combines demonstrations of energy storage to support grid operations and laboratory R&D of new energy storage technologies. Includes advanced battery systems including flow batteries, ultra-capacitors, flywheels and compressed air energy systems.

The Smart Grid Demonstration Program

Regional Smart Grid Demonstrations

- Includes 16 projects
- Verify smart grid viability, quantify smart grid costs and benefits
- Validate new smart grid business models at scales that can be readily replicated across the country

Energy Storage Demonstrations

- Includes 16 projects
- Batteries, flywheels, ultracapacitors, and compressed air energy storage systems
- Functions include load shifting, ramping control, frequency regulation services, distributed applications, and integration of renewable resources

Program Duration: *2/1/2010–9/30/2015*
Some projects have now been extended through 2018

Program Value: *$1,522,759,421*
Government Share: $588,605,734
Participant Cost Share: $934,171,687

SGDP Technologies and Systems

Electric Transmission Systems	Electric Distribution Systems	Advanced Metering Infrastructure	Customer Systems
			
• Synchrophaser technologies • Communications infrastructure • Wide area monitoring and visualization • Line monitors	• Automated switches • Equipment monitoring • Automated capacitors • Communications infrastructure • Distribution management systems	• Smart meters • Communications infrastructure • Data management systems • Back-office integration	• In-home displays • Programmable communicating thermostats • Home area networks • Web portals • Direct load controls • Smart appliances

Smart Grid Assets and Programs

Technology	Quantity*
AMI ASSETS	
Smart Meters	297,238
CUSTOMER SYSTEMS ASSETS	
In Home Displays (IHD)	9,009
Programmable Communicating Thermostats	7,935
Direct Load Control Devices	3,679
Smart Appliances	511
ERT Bridges	2,717
Energy Management Devices/Systems	956
Web Portal Access	160,735
DISTRIBUTED ENERGY RESOURCES	
Distributed Generation Systems	293
Energy Storage Units	274
Plug-In Electric Vehicle Charging Points	1,231
DER/DG Interconnections	11

Technology	Quantity*
ELECTRIC DISTRIBUTION SYSTEM ASSETS	
Automated Feeder Switches/Reclosers	568
Automated Capacitors	420
Automated Regulators	128
Feeder Monitors	13,450
Remote Fault Indicators	411
Transformer Monitors (Line)	468
Smart Relays (Substation)	472
ELECTRIC TRANSMISSION SYSTEM ASSETS	
PMUs-EHV	19
DCRS-Transmission Lines	11
Phasor Data Concentrators	4
PRICING PROGRAMS	
Customers with Access to Programs**	482,069
Customers Enrolled in Programs	115,278

Distributed Energy Resource

RESOURCE	CAPACITY (KW)	ENERGY DELIVERED (MWH)	
		FY14 Q4	TO DATE
Distributed Generation	4,855	567	7,890
Energy Storage	76,511	6,338	33,103
Electric Vehicle Chargers	9,300	80	415

*Data as of FY2015 Q2, March 31, 2015

**Customers have access to multiple plans

Selected SGDP Project Results

Chevron Energy Systems	Microgrid
Oncor	Dynamic Line Rating
PNM	Energy Storage
AEP Ohio	Advanced Metering Infrastructure Customer Systems Volt-VAR Optimization Distribution Automation

Chevron Energy Solutions — Santa Rita Jail
A Consumer-based Microgrid

Santa Rita Jail Resource Portfolio

Resource	Capacity MW
Fuel cell (existing)	1
Photovoltaic system (existing)	1.2
Two 1.2 MW back-up diesel generators (existing)	2.4
CERTS-compliant power conversion system (2.5 MVA) with Lithium iron phosphate (LiFePO4) battery (4 MWh)	2
Five wind turbine generators (existing)	11.5 kW
Capacitor bank (900 kVAr)	
Total Capacity	6.6

Santa Rita Jail Results

Objective	Results
Reduce Peak Load	95% (facility) 15% (feeder)
Improve Reliability	0 outages since commissioning
Enable Integration of Renewables	✓
Enhance Security and Resiliency	✓
Increase Consumer Engagement	✓
Improve System Efficiencies	Not quantified
Create Economic Value	$110,000 (annual) BCR < 1 (estimated)

Key elements of AEP Ohio's gridSMART® project

Key Project Elements	AEP Ohio's gridSMART® Project	
Project partners	♦ Battelle Memorial Institute ♦ Electric Power Research Institute ♦ Lockheed Martin ♦ General Electric ♦ Opower	♦ PCS UtiliData (UtiliData) ♦ S&C Electric Company ♦ Schweitzer Engineering Laboratories, Inc. ♦ Silver Spring Networks, Inc.
Total installed cost	$65,706,647	
Total project budget	$148,821,823	
Project duration	1/1/10 – 12/31/13	
Project location	Areas in and near Columbus, Ohio	
Technologies demonstrated	♦ Advanced metering infrastructure (AMI) ♦ Consumer programs ♦ Real-time pricing with double auction ♦ Distribution Automation Circuit Reconfiguration (DACR) ♦ Volt-VAR optimization (VVO)	♦ Electric vehicles (EVs) ♦ Modeling and simulation of consumer programs, VVO, EVs, community energy storage (CES), sodium sulfur batteries, and photovoltaics (PV)
Project Outcomes	♦ Successfully integrated and conducted comprehensive analysis of a full suite of smart grid technologies and consumer programs ♦ Recorded savings of over $452,000 per year via avoided labor and vehicle operations costs ♦ Reduced the miles traveled by service vehicles per year by 68,328 miles, which resulted in carbon dioxide (CO_2) emissions reductions of 16.9 metric tons ♦ Reduced energy consumption by approximately 3% and peak demand by 2%-3% ♦ Achieved 95% meter data completeness for customer billing purposes, on average	

Four Foundational Technologies and Programs
AMI, Consumer, DACR, VVO

AMI

- Eliminated all of the 187 meter reading routes resulting in savings of over $452,000 per year
- Avoided 1,952 truck rolls per year, resulting in reduced vehicle emissions of 16.9 metric tons of CO_2 emissions
- Observed high customer satisfaction with the AMI technology, with less than 0.01% of consumers requesting to opt out

Consumer Programs

- Confirmed that consumers will participate in programs when given adequate information and enabling technologies
- SMART Shift customers lowered their electricity bills by 10%
  SMART Shift Plus customers saw a greater reduction of 25%

Four Foundational Technologies and Programs
AMI, Consumer, DACR, VVO

DACR

- Attributed significant reliability improvements to DACR, reducing CMI by 1,602,647 minutes, approximately a 9% improvement
- Improved SAIFI by 12.4% in 2012 and 24.5% in 2013 and SAIDI by 8.2% in 2012 and 19% in 2013
- Minimized impact of customer outages,

sometimes restoring service so quickly that

a sustained interruption was not experienced

VVO

- Enabled a reduction of the average voltage that each consumer on the circuit receives, thereby reducing annual energy consumption while maintaining quality of service
- Reduced energy consumption by approximately 3% and peak demand by approximately 2%-3%

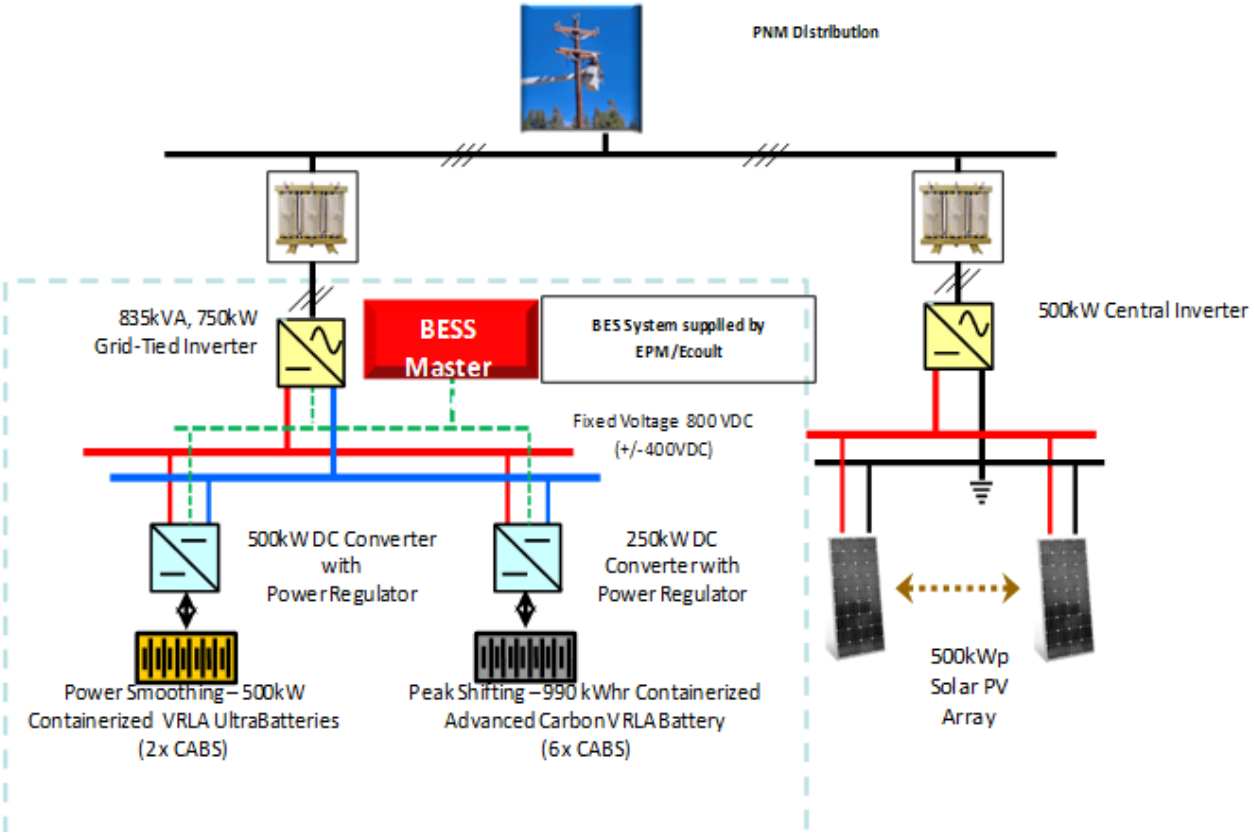
Oncor Dynamic Line Rating Project

Key Project Elements	Oncor's DLR Project
Project partners	♦ Nexans ♦ Promethean Devices ♦ EDM International, Inc. ♦ Southwest Research Institute (SwRI) ♦ Siemens Energy Inc. ♦ Chapman Construction Company ♦ Electric Reliability Council of Texas (ERCOT)
Total installed cost	$4,833,000
Total project budget	$7,279,166
Project duration	1/1/10 – 5/4/13
Project location	Five 345 kV and three 138 kV transmission line circuits in Texas
DLR equipment	♦ 27 Nexans CAT-1 units, including 45 load cells ♦ 5 Video Sagometer systems ♦ 2 Real-Time Transmission Line Monitoring Systems (RT-TLMS)
DLR software	♦ Nexans' proprietary IntelliCAT software
Average increased real-time capacity	♦ 8%-12% above ambient-adjusted rating (138 kV lines) ♦ 6%-14% above ambient-adjusted rating (345 kV lines)

Although Oncor could not quantify the congestion-related economic benefits of deploying DLR technologies, it was able to estimate the savings associated with the deferral of other transmission upgrades.

Line Type	Alternative Description	New Rating (% Static)	Cost per Mile
138 kV Lattice, Wood H-Frame	Reconductor Aluminum Conductor Composite Core (ACCC) cable	193%	$321,851
	DLR	**110%**	**$56,200**
138 kV Wood H-Frame	Rerate 125 °C Modify structures	130%	$10,561
	Rerate 125 °C Replace structures Rebuild	130% 209%	$6,919 $750,000
	DLR	**110%**	**$29,471**
138 kV Wood H-frame	Rebuild	140%	$237,871
	DLR	**110%**	**$16,767**
138 kV Wood H-Frame	Reconductor	212%	$750,000
	DLR	**110%**	**$28,323**

A diagram of PNM's PV-plus-battery system for peak shifting and voltage smoothing



Notes: "BESS" refers to "battery energy storage system." "CABS" refers to a container of advanced carbon battery cells mounted in racks complete with battery monitoring hardware, digital processing units used for battery management, and DC switchgear. "VRLA" refers to "valve-regulated lead acid" batteries.

Source: used with permission from PNM (PNM Final Technology Performance Report – PV Plus Battery for Simultaneous Voltage Smoothing and Peak Shifting, April 2014*)*

PNM PV-plus battery system

- PNM valued the distribution investment deferral at approximately $334,000 and the system electric supply capacity benefit at $177,000

- PNM observed the following emissions reductions:
  - 300 pounds of SO_2
  - 800 pounds of NO_X
  - 600 tons of CO_2

PNM PV-Plus Battery System

Smoothing

- Overall, the smoothing battery system appeared to effectively reduce PV output volatility; PNM confirmed that the system's smoothing effects were successful even on cloudy days and when the circuit's voltage fluctuated significantly
- Capacity utilizations of 40% or more had noticeable

effects on smoothing; capacity settings of 40%, 60%, 80%, and 100% all had similar smoothing effects

Peak Shaving

- The system successfully shaved the targeted 15% off of the feeder peak during hot days; during cooler periods, the load profile was too broad to achieve the 15% reduction target
- Firming functionality was demonstrated through the system, storing energy in the morning and discharging later in the day as needed
- Arbitrage functionality was achieved using the shifting algorithm to charge and discharge the battery in response to CAISO's real-time electricity prices

Observations & Going Forward

High Level Observations
RDSI/SGDP Regional Demos

- **11 of 16 projects are completed**
- **Microgrids**
  - Operated in grid-connected and islanded modes
  - Energy storage assisted in integration of renewable power
  - Specific circumstances needed to defend business case
    - Defer large capital investments, participate in ISO/RTO markets, high value for reliability
- **Confirmed value of AMI/DA**
  - Leverage AMR to perform AMI functions
  - Enabled remote meter reading, demand response, improved outage management, and customer renewables
- **Voltage management/conservation voltage reduction**
  - Improved reliability, reduced energy consumption, reduced demand
- **Cybersecurity upgraded; no adverse cyber security events**
- **Dynamic line rating used to increase transmission capacity**

High Level Observations
Energy Storage

- **Only 5 of 16 projects have been completed**
- **PNM demonstrated peak shaving and renewable smoothing**
- **Flywheels effectively providing regulation services to PJM and ERCOT**

Going Forward

- **Need continued attention to customer engagement**
  - Reliance on manual actions not effective in long-term
- **Substantial opportunities for smart grid technologies to leverage ISO/RTO markets**
- **Additional work needed on business case analysis for smart grid investments**
  - Issues include scale, methodology, baseline, value of reliability
- **Economics of energy storage still needs to be evaluated for cost-effectiveness**

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Key SGDP Resources:
Smart Grid www.smartgrid.gov

Interim and final project reports
Topical reports - microgrids, DLR, DER, transactive communications, CVR