State & Federal Energy Storage Technology Advancement Partnership (ESTAP) Webinar:

Duke Energy's Energy Storage Projects

November 13, 2013

Clean Energy States Alliance

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

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Thank You:

Dr. Imre Gyuk

U.S. Department of Energy,
Office of Electricity Delivery and
Energy Reliability

Dan Borneo

Sandia National Laboratories

ESTAP is a project of CESA

Clean Energy States Alliance (CESA) is a non-profit organization providing a forum for states to work together to implement effective clean energy policies & programs:

- Information Exchange
- Partnership Development
- Joint Projects (National RPS Collaborative, Interstate Turbine Advisory Council)
- Clean Energy Program Design & Evaluations
- Analysis and Reports

CESA is supported by a coalition of states and public utilities representing the leading U.S. public clean energy programs.

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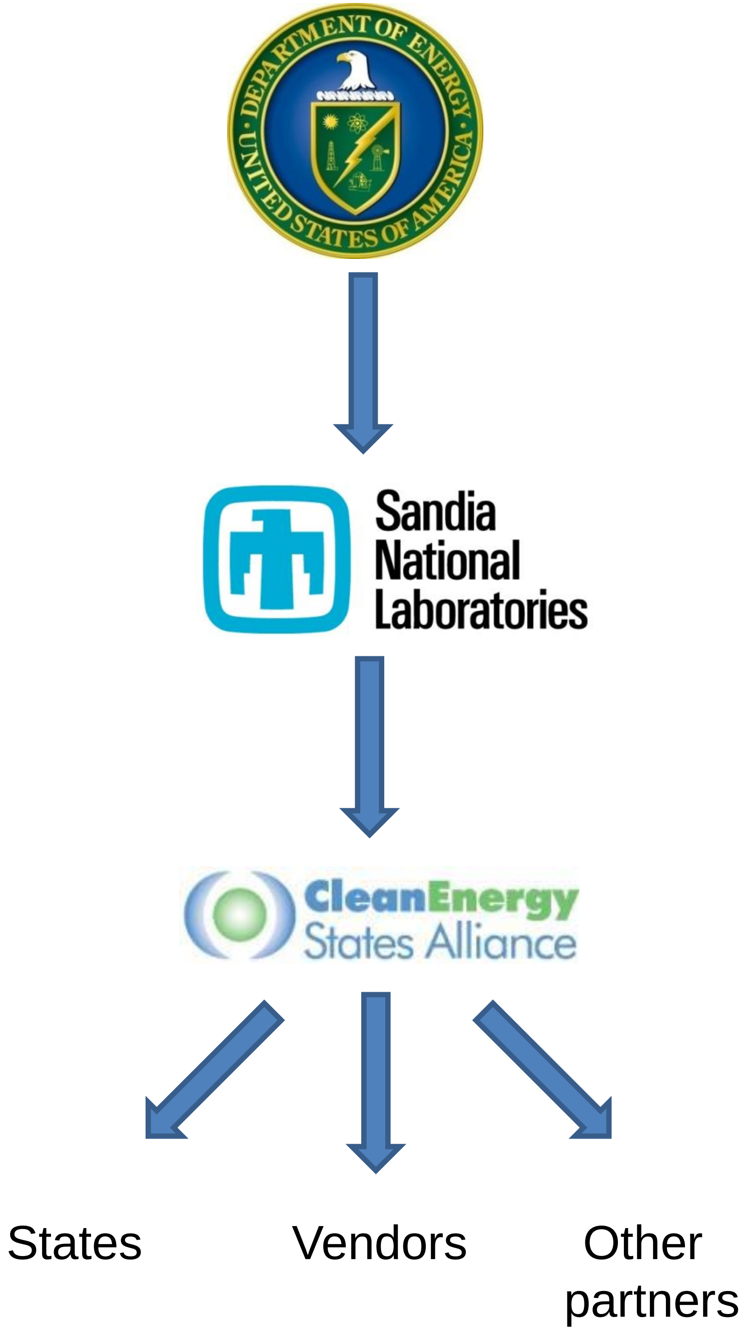
ESTAP* Overview

Purpose: Create new DOE-state energy storage partnerships and advance energy storage, with technical assistance from Sandia National Laboratories

Focus: Distributed electrical energy storage technologies

Outcome: Near-term and ongoing project deployments across the U.S. with co-funding from states, project partners, and DOE



* **(**Energy Storage Technology Advancement Partnership)

ESTAP Key Activities

1. Disseminate information to stakeholders

   - ESTAP listserv >500 members
   - Webinars, conferences, information updates, surveys

2. Facilitate public/private partnerships at state level to support energy storage demonstration project development

   - Match bench-tested energy storage technologies with state hosts for demonstration project deployment
   - DOE/Sandia provide $ for generic engineering, monitoring and assessment
   - Cost share $ from states, utilities, foundations, other stakeholders

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ESTAP Webinars

Policy Webinars:

- Introduction to the Energy Storage Guidebook for State Utility Regulators
- Briefing on Sandia's Maui Energy Storage Study
- The Business Case for Fuel Cells 2012
- State Electricity Storage Policies
- Highlights of the DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA

Technology Webinars:

- Smart Grid, Grid Integration, Storage and Renewable Energy
- East Penn and Ecoult Battery Installation Case Study
- Energy Storage Solutions for Microgrids
- Applications for Redox Flow Batteries
- Introduction to Fuel Cell Applications for Microgrids and Critical Facilities
- UCSD microgrid

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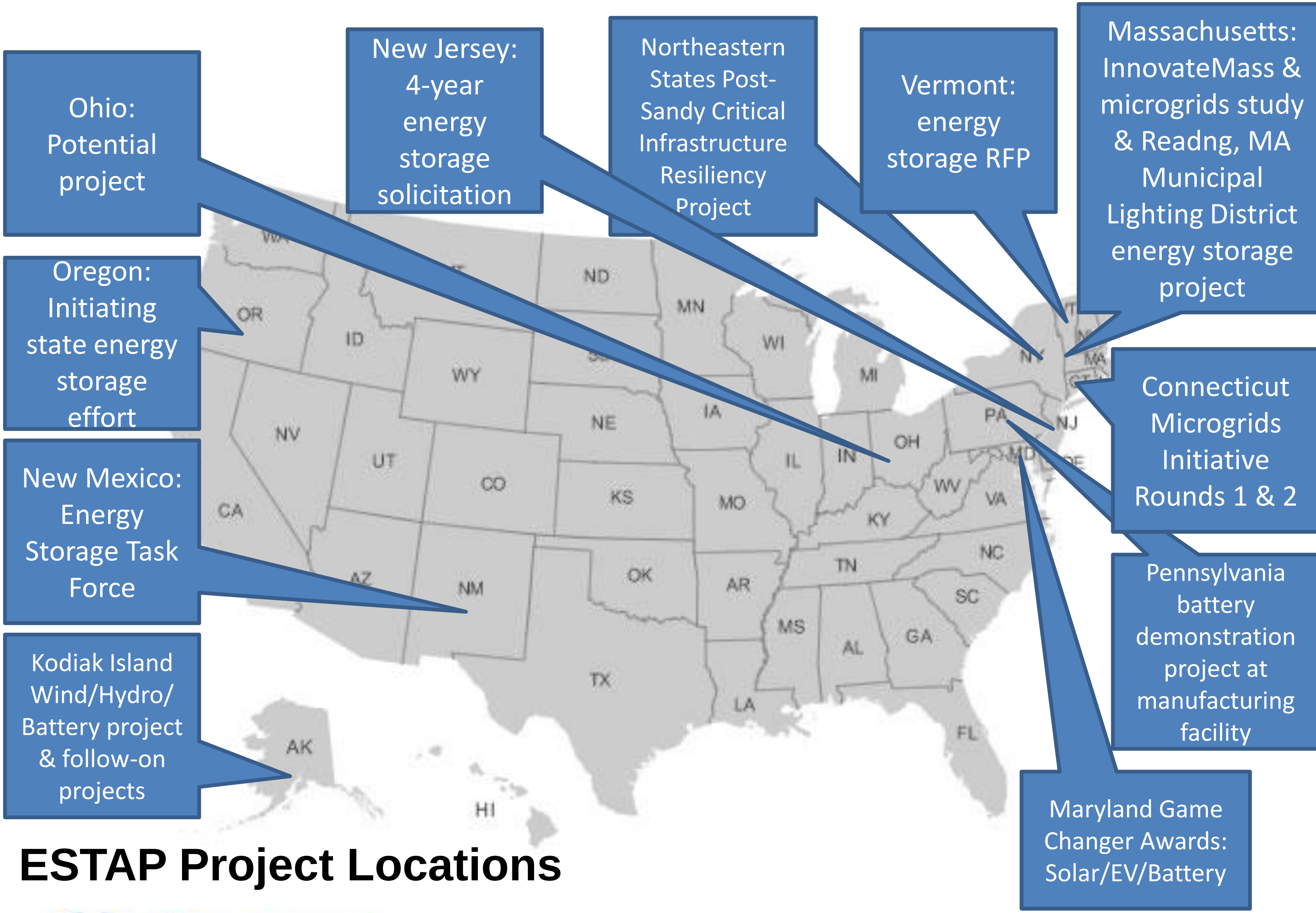

ESTAP Project Locations

Clean Energy States Alliance

Sandia National Laboratories

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Today’s Speakers

Todd Olinsky-Paul, CESA, on behalf of
Dr. Imre Gyuk, U.S. Department of Energy,
Office of Electricity Delivery and Energy Reliability

Dan Sowder, P.E., Senior Project Manager, Duke Energy’s
Emerging Technology Office

Clean Energy States Alliance

Sandia National Laboratories

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www.cleanenergystates.org/webinars

Progress Towards Commercial Grid Energy Storage:

IMRE GYUK, PROGRAM MANAGER
ENERGY STORAGE RESEARCH, DOE

ARRA Stimulus Funding for Storage Demonstration Projects

Leveraged Funding: $185M vs. $585M

4 of 16 Projects completed

- Show technical feasibility
- Gather cost data
- Stimulate regulatory changes
- Generate follow-on projects

Policy Decisions are as important as Technological Progress!

FERC 755: Pay for Performance
California AB2514: PUC to Develop Targets
CA PUC Order: Deploy 50MW Storage!
CA PUC Proposal: 1,325MW by 2020!!
Wyden Bill: 20-30% Investment Tax Credit

Regulatory Policy will co-evolve with Technology and Deployment

Two of the DOE Project
have been singularly successful at
generating Regulatory Change:

The 20MW Flywheel Installation by Beacon

The 36MW Notrees Installation by Duke

Beacon Frequency Regulation Projects

DOE Loan Guarantee – Beacon:
20MW Flywheel Storage for
Frequency Regulation in NY-ISO
Commissioned July 2011
240,000 MWh of FrequReg delivered!

ARRA Project – Beacon
Hazleton, PA.
20MW Frequency Regulation for PJM.
Groundbreaking June 21, 2013
4 MW installed and providing Revenue

►► : PAY FOR PERFORMANCE!

ARRA – Duke Energy / Xtreme Power

36MW / 40 min battery plant – Remote Operation
Frequency Regulation, Smoothing, Ramp Control,
Linked to 153MW Wind farm at No-Trees, TX

Ribbon Cutting
March 28, 2013

Clean Tech 100 in 2010 / 11

ESNA Best Project 2013

►► : PAY FOR PERFORMANCE!

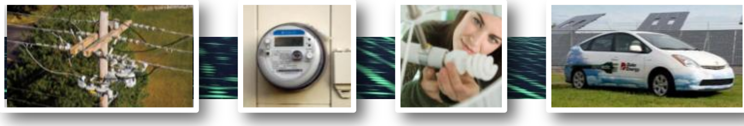
Frequency Regulation using Energy Storage is now a Commercially viable Business in ERCOT and FERC compliant Regions!

Energy Storage at Duke Energy
CESA Webinar – November 13th, 2013

Dan Sowder, P.E.

Emerging Technology Office

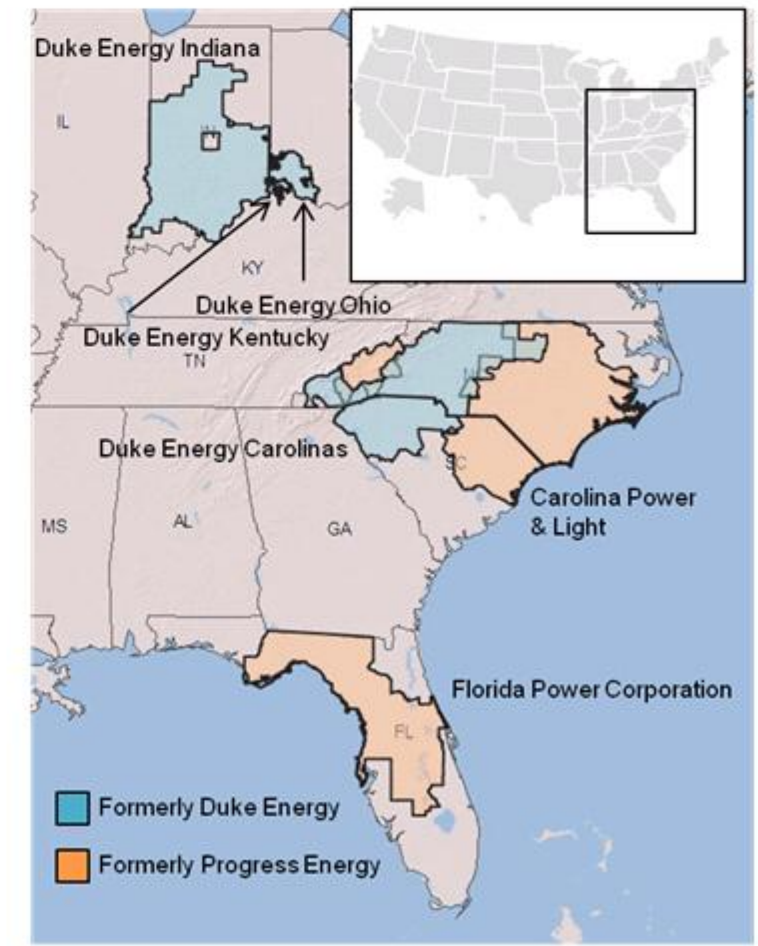
DUKE ENERGY®

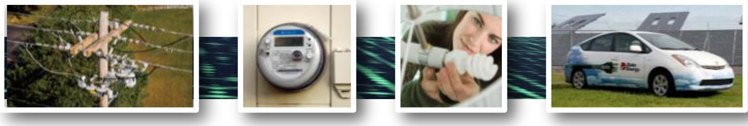


About Duke Energy

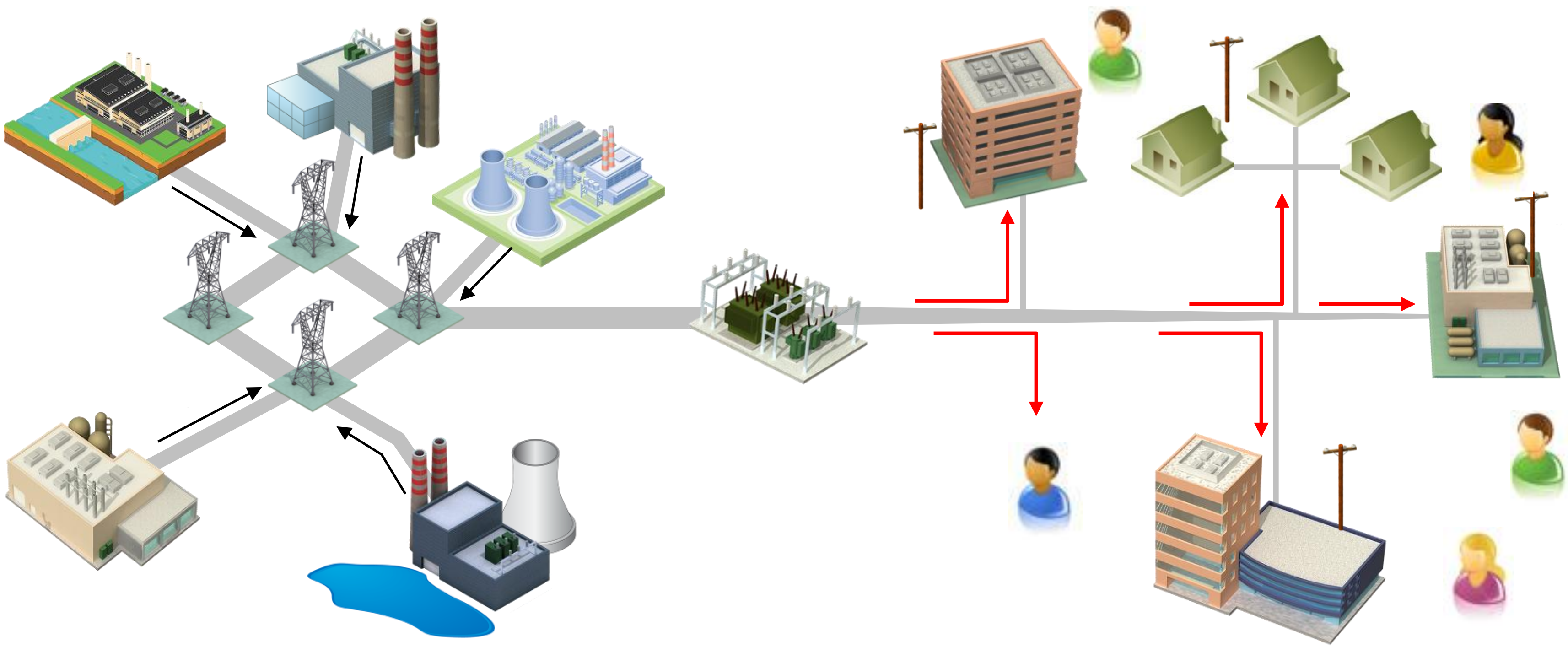
- Largest Electric Holding Company in the United States
- Electric Utility operations in North and South Carolina, Indiana, Ohio, Kentucky and Florida serving 7.1 million customers
- Over 58,000 MW of Regulated Generation
- 8,000 MW of commercial generation capacity including ~1700 MW of wind and 105 MW of solar located throughout the United States
- Duke Energy International principally operates and manages almost 4,300 MW of owned capacity (primarily in Latin America)

Duke Energy Corporation's new service territory

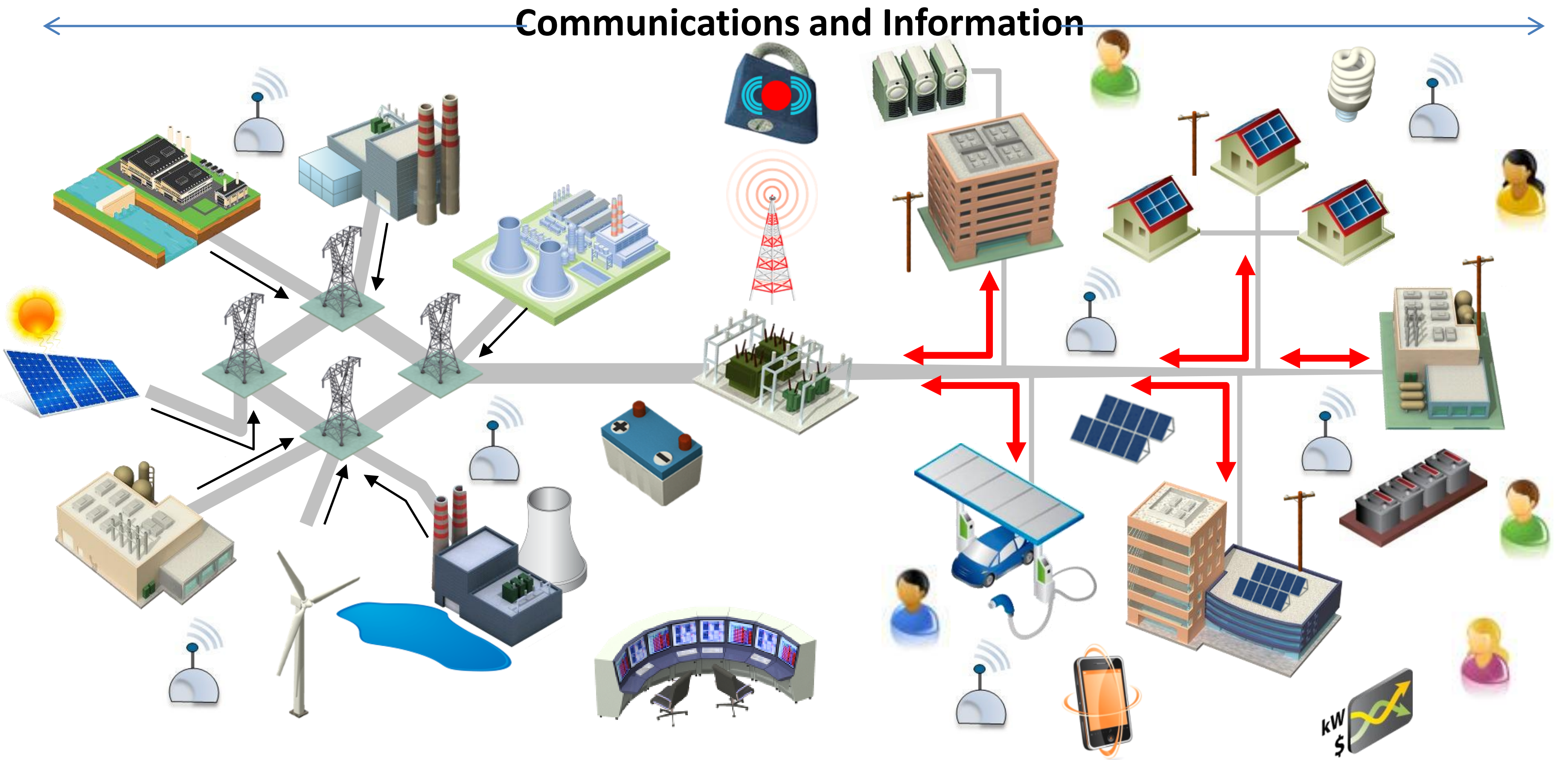




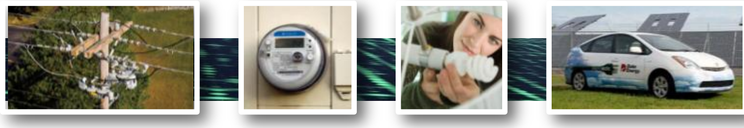
Today's Power System



Transformation of the Power System



A Highly Interconnected Power System that Optimizes Energy Resources



How can energy storage create the most value as an integral part of the grid?

How do

SIZE LOCATION

CHEMISTRY FUNCTION

enable value?

Benefits: Diverse chemistries in different capacities

How did Duke Energy get here?

Connected on:
- Transmission
- Distribution
- Customer
- With renewables

Generation Transmission Distribution Customer

kWh 800 600 400 200

kW 200 400 600 800

36MW/24MWh
Advanced Lead Acid

250kW/750kWh
Lithium Polymer

25kW/25kWh
Lithium Ion

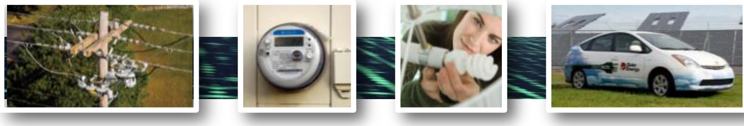
200kW/500kWh
Li Iron Phosphate

200kW/500kWh
Sodium Nickel

75kW/42kWh
Lithium Titanate

5 ... on the grid

>25 functions demonstrated



Notrees Wind Farm Project

Notrees, TX

Major system components:

- 36 MW / 24 MWh
- Xtreme Power Advanced Lead Acid Technology
- Co-located at site of 156 MW Wind Farm in Notrees, Texas
- Began commercial operation in December 2012
- Significant support from DOE

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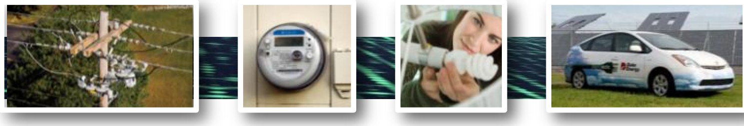
Applications being tested

1 – Ancillary Services: participating in a series of ERCOT (Texas ISO) market tests to learn how to structure an efficient market that enables energy storage to provide ancillary services to the grid.

2 – Energy Shifting: Charging and discharging to maximize the value of energy delivered to the grid based on timing.

3-Avoiding Wind Curtailment : Using storage to store wind energy in order to avoid orders to cease providing power to the grid.



Marshall Energy Storage System

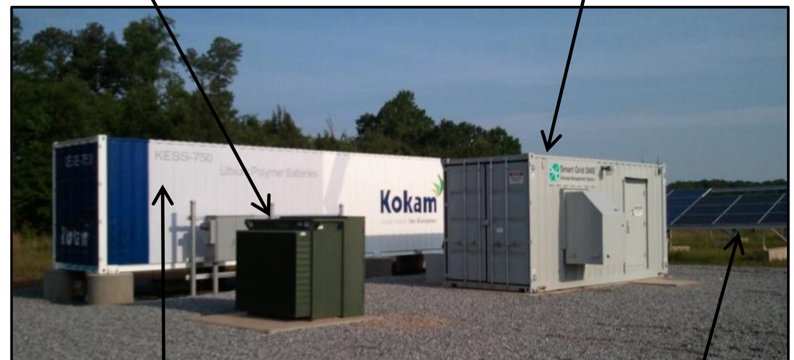
Marshall Steam Station, Sherrills Ford, NC

Major system components:

- 750 kWh / 250 kW system capacity
- Kokam Superior Lithium Polymer Batteries
- 1.25 MVA S&C Electric Company Inverter (SMS)

Interconnection:

- Located on a 12.47 kV distribution circuit
- Separate but adjacent medium-voltage interconnection from 1.0 MW solar facility
- Located at the end of a distribution feeder



System attributes

- Installed May 2012, in service July 2012
- Remotely operable
- Battery and inverter independently sourced (both vendors to Duke)
- Located at the Marshall solar test site where multiple solar technologies are being field tested on a sealed coal-ash landfill

Applications being tested

<u>1 – energy shifting</u>

a) for system-level arbitrage
b) for local operational constraint management
c) based on forward-looking economic algorithm

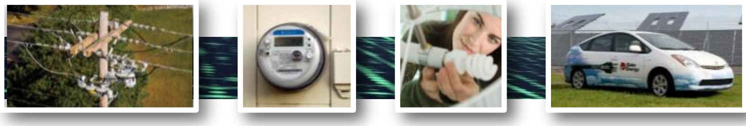
<u>2 – solar output smoothing and firming</u>

a) for local feeder voltage management
b) solar-induced power swing mitigation

<u>3 – active VAR/power factor management</u>

<u>4 – combined algorithms / optimization</u>

a) combined energy shifting and smoothing algorithm
b) use of distributed logic with economic, substation, and local input parameters



Clay Terrace Energy Storage System

Clay Terrace Mall, IN

Major system components:
- 75 kW / 42 kWh system capacity
- Toshiba lithium titanate battery
- 10 kW roof-mounted solar
- Eaton 50 kW, Siemens 3.3 kW PEV charging stations

Interconnection:
- Behind a commercial meter (customer sited)
- Interconnected at 480V, 3-phase transformer
- Located in the parking lot of a shopping mall

System attributes

- Installed 3Q 2012, in service 4Q 2012

- Designed to manage and optimize the combined energy profile of solar, PEV charging, and storage.

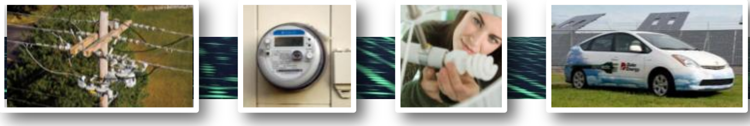
Applications being tested

<u>1 – active management of combined solar, storage and PEV charging</u>

a) testing energy management system and sizing of a behind-the-meter system

<u>2 – energy shifting</u>

<u>3 – customer-sited installation aspects</u>



Community Energy Storage Systems

Two units installed

McAlpine 24 kV circuits, Charlotte, NC

Major system components:

- 25 kVA inverter system – S&C Electric Company
- Kokam 25 kWh / 25 kW lithium ion battery
    - Battery located in underground vault

Interconnection:

- Interconnected at 120V/240V split single phase
- Configured to serve up to five customers on 50 – 75 kVA padmount transformers
    - Initially connected to one customer each for testing

System attributes

- Installation: unit 1 - Oct 2011; unit 2 - Dec 2011

- Remotely operable and monitored via DMS
- Demonstrating underground battery vault configuration

Applications being tested

<u>1 – automatic voltage managment</u>

a) automatically injects/consumes VARs to maintain voltage within a specified setpoint

<u>2 – islanding/back-up power</u>

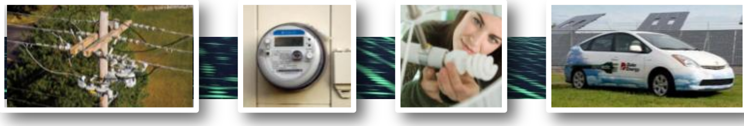
a) automatic islanding during a grid outage

<u>3 – distributed energy shifting</u>

a) various energy shifting applications using a network of distributed batteries

<u>4 – control system for distributed storage</u>

a) using distributed communications network to monitor and dispatch the battery



Community Scale Second Life Battery

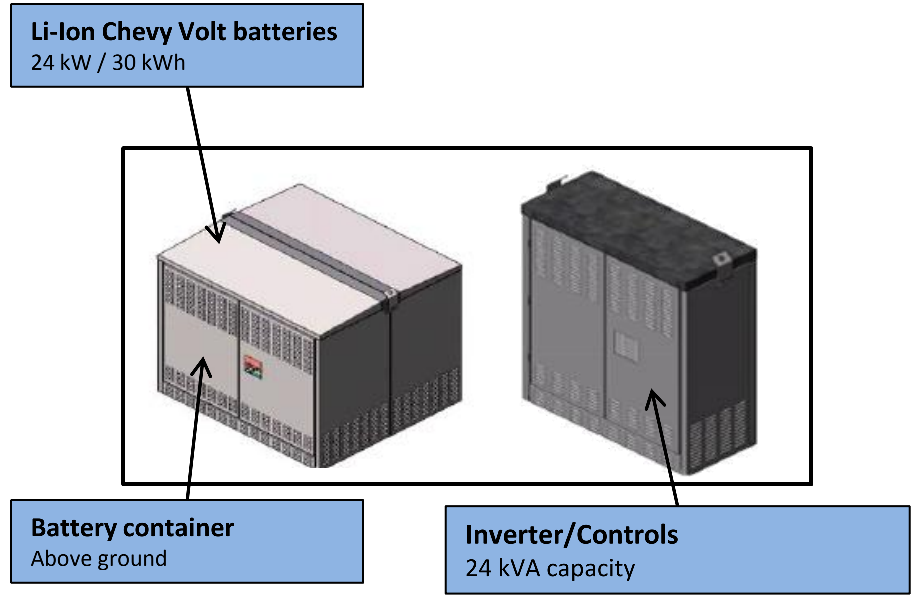
University of Florida

Major system components:

- 24 kW / 30 kWh system capacity
- Li-ion batteries designed for use in a Chevy Volt
- 24 kVA inverter system – provided by ABB

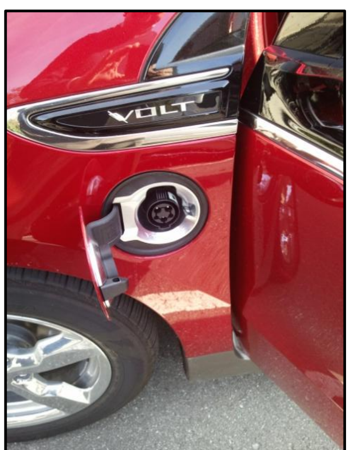
Interconnection:

- Located on a 120V/240V split single phase service
- At least one customer will be connected via the CES unit
- Specific customer TBD



System attributes

- Planned installation in 2-3Q 2013



- Will demonstrate a potential "second-life" battery application.
- Increases residual value of PEV's and may provide low cost source of utility stationary storage.

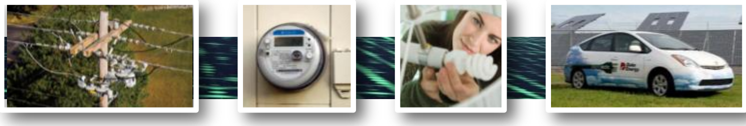
Applications being tested

<u>1 – use of recycled electric vehicle batteries</u>

a) represents a potential low cost source of utility storage
b) supports PEV economics

<u>2 – community-scale storage applications</u>

a) energy shifting
b) islanding/back-up power
c) automatic voltage control



McAlpine Energy Storage System

McAlpine Creek Retail Substation, Charlotte, NC

Major system components:
- 200 kW / 500 kWh system capacity
- BYD battery and inverter system
    - All components integrated within on container
- Lithium-iron-phosphate battery (BYD)

Interconnection:
- Located on a 24 kV distribution circuit
- Interconnected immediately outside of the substation
- Adjacent to 50 kW solar facility on McAlpine test circuit

BYD battery
200 kW/500 kWh $LiFePO_4$

Inverter/Controls
Integrated within one container

System attributes

- Installation Sep - Oct 2012, planned in service 4Q 2012

- Interconnected next to a 50 kW solar facility in a planned islandable micro-grid scheme that will use the battery for grid frequency/voltage regulation.

Applications being tested

<u>1 – consolidated inverter/battery construction at a low price</u>

<u>2 – energy shifting applications</u>

a) dispatched based on schedule, local load peaks, etc

<u>3 – integration with solar in a microgrid</u>

a) will be configured with switches, solar, and load to create an autonomous microgrid that disconnects from the circuit

<u>4 – solar output smoothing/firming</u>

Rankin Energy Storage System

Rankin Ave. Retail Substation, Mount Holly, NC

Major system components:

- 402 kW / 282 kWh system capacity
- FIAMM sodium nickel chloride battery
  - 12 Zebra bus batteries connected in parallel
- 1.25 MVA S&C Electric Company Inverter (SMS)

Interconnection:

- Located on a 12.47 kV distribution circuit
- Interconnected immediately outside of the substation
- Circuit contains a 1.2 MW solar facility ~3 miles away

Auxiliary power load center
120V/240V service

1000 kVA transformer
Steps up 480 V inverter output to 12.47 kV

Battery container
402 kW/282 kWh NaNiCl batteries (12 cells)

Inverter/Controls
Storage Management System (SMS)
1.25 MVA capacity/1.0 MVAR capacity

System attributes

- Installed Dec 2011, in service Mar 2012

- Remotely operable
- ZEBRA bus batteries by FIAMM for stationary application development
- Contains fiber connection to substation relaying; no connection to the solar facility on the circuit

Applications being tested

<u>1 – centralized solar-induced power swing mitigation</u>

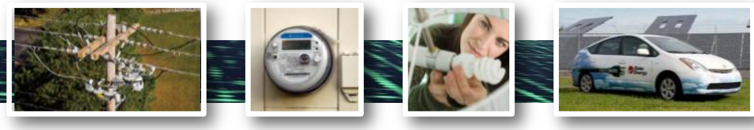
a) senses substation real power loading and uses battery to "smooth" rapid ramp rates caused by cloud-induced solar intermittency

b) no direct connection to the solar – designed to smooth power swings from multiple dispersed solar sites on a circuit

<u>2 – active VAR/power factor management</u>

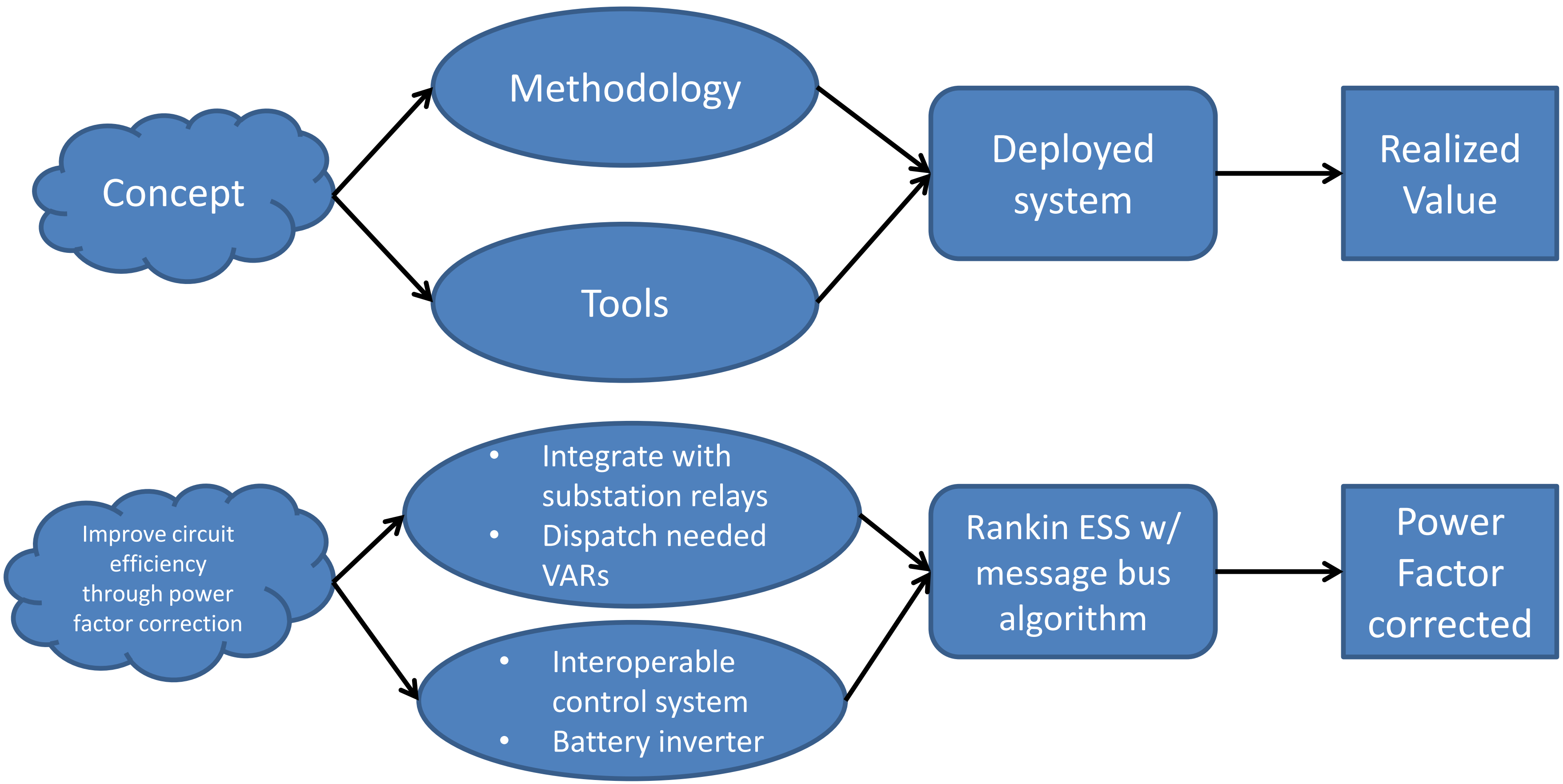
<u>3 – combined watt/VAR voltage control</u>

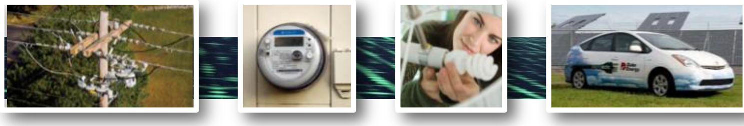
a) compensation for rapid solar-induced voltage changes



Applying energy storage to the grid: the algorithms

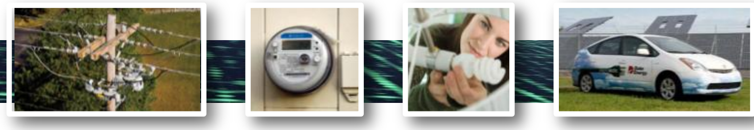
Energy storage is only as valuable as the benefit that it creates on the grid.





Applying energy storage to the grid: the algorithms

- **Combined, simultaneous functionalities**
  - Combined solar output smoothing and energy shifting: McAlpine, Marshall
  - Combined power swing mitigation and power factor correction: Rankin
- **Optimized within the utility ecosystem**
  - Rankin distribution circuit optimization study: Sandia National Lab
  - Marshall circuit voltage optimization study: Univ. North Carolina, Charlotte
- **Bulk system benefits using distributed resources**
  - System frequency regulation via AGC signal: Rankin
  - Constraint avoidance through energy shifting: Marshall, McAlpine
  - ISO market formation for frequency regulation: Notrees
- **Realizing full potential for customer and utility benefits**
  - Critical facility back-up and grid-support functions: McAlpine fire station microgrid
  - Back-up power and grid services: Community Energy Storage units



The algorithms: four examples

1. Combined energy shifting and solar smoothing

- Running today on the McAlpine Energy Storage System

2. Combined power swing mitigation and power factor correction

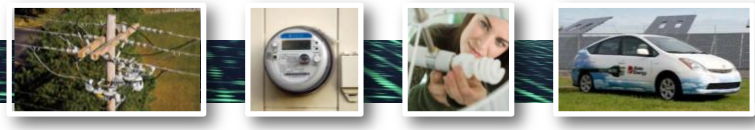
- Running today on the Rankin Energy Storage System

3. Circuit optimization using energy storage

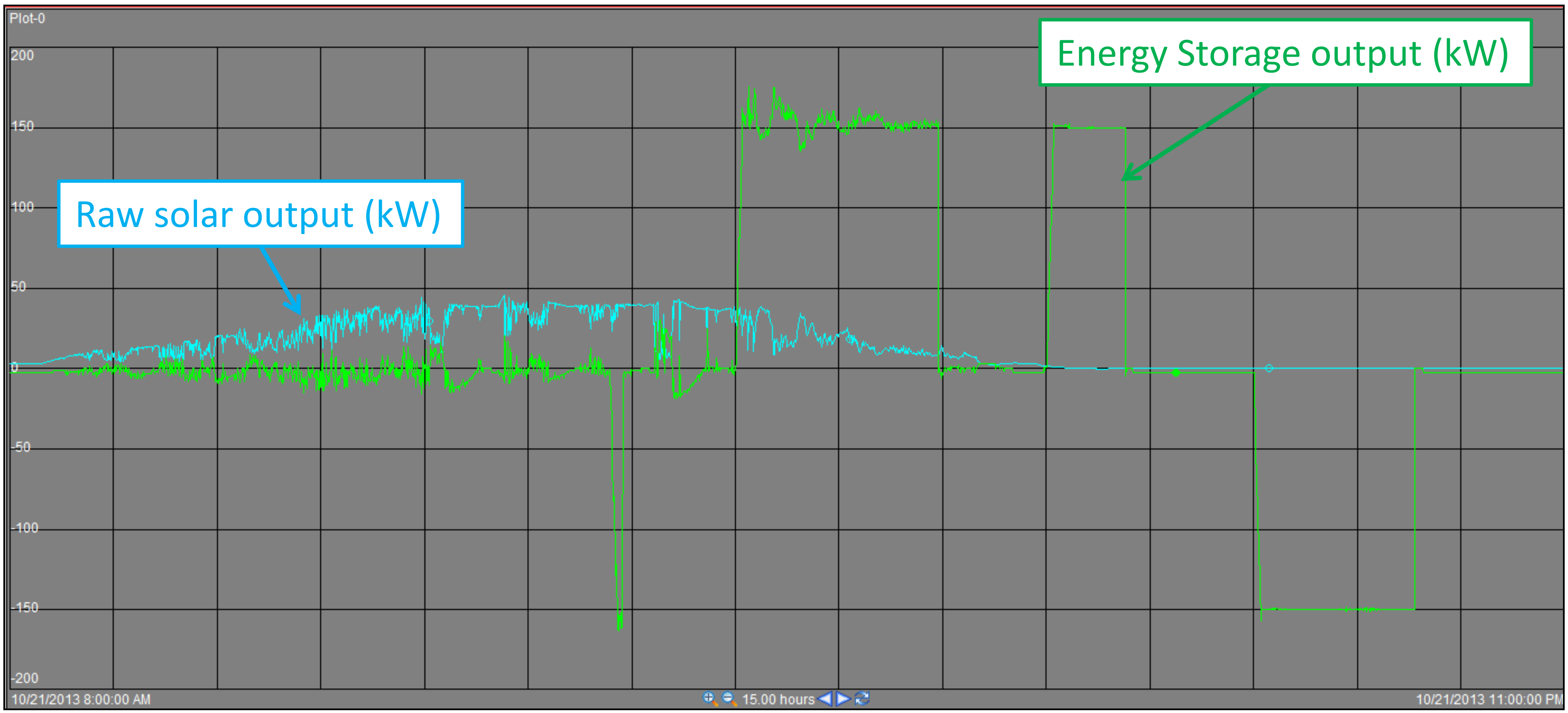
- A joint study with Sandia National Labs
- In progress utilizing the Rankin Energy Storage System

4. Seamlessly islandable microgrid

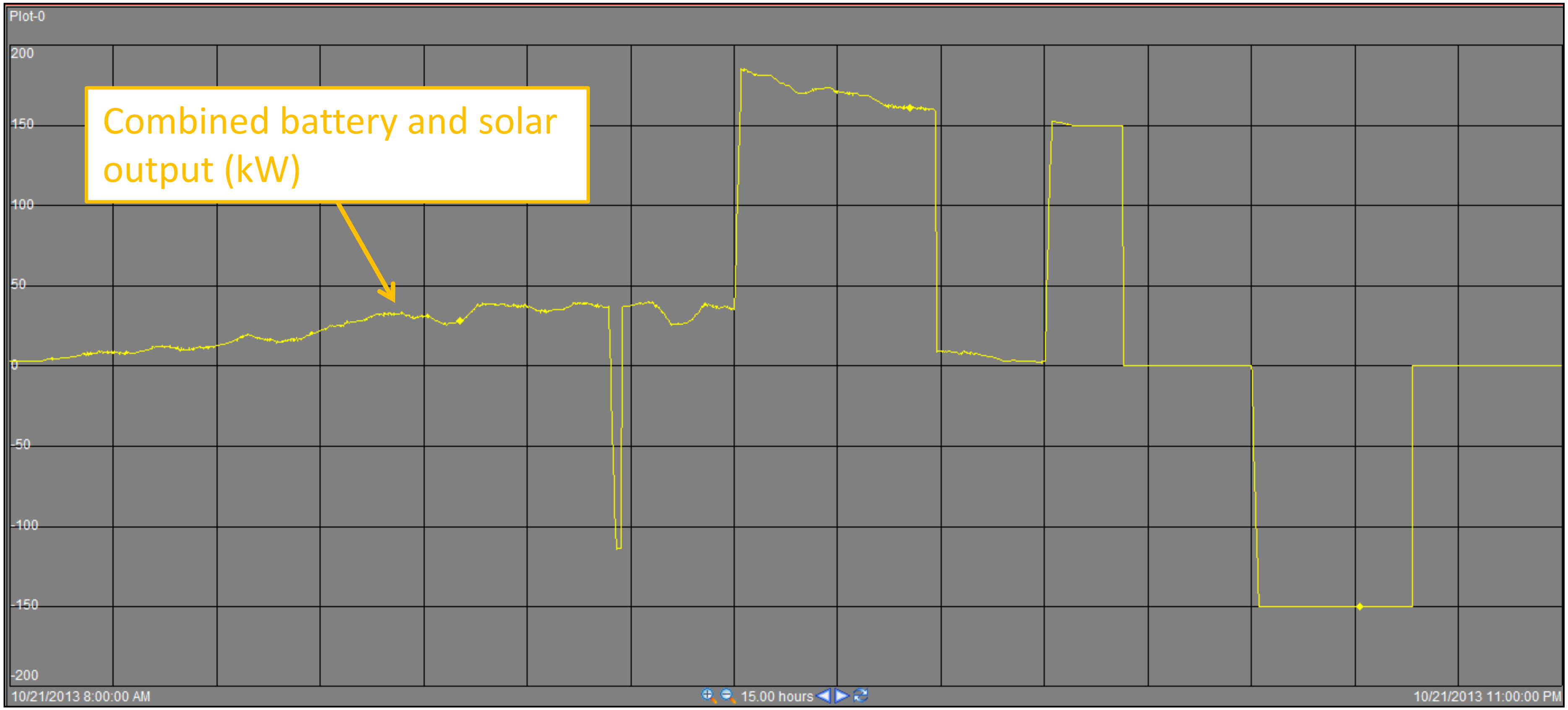
- In progress utilizing the McAlpine Energy Storage System

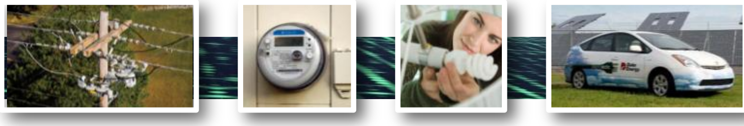


Example 1: combined smoothing and shifting

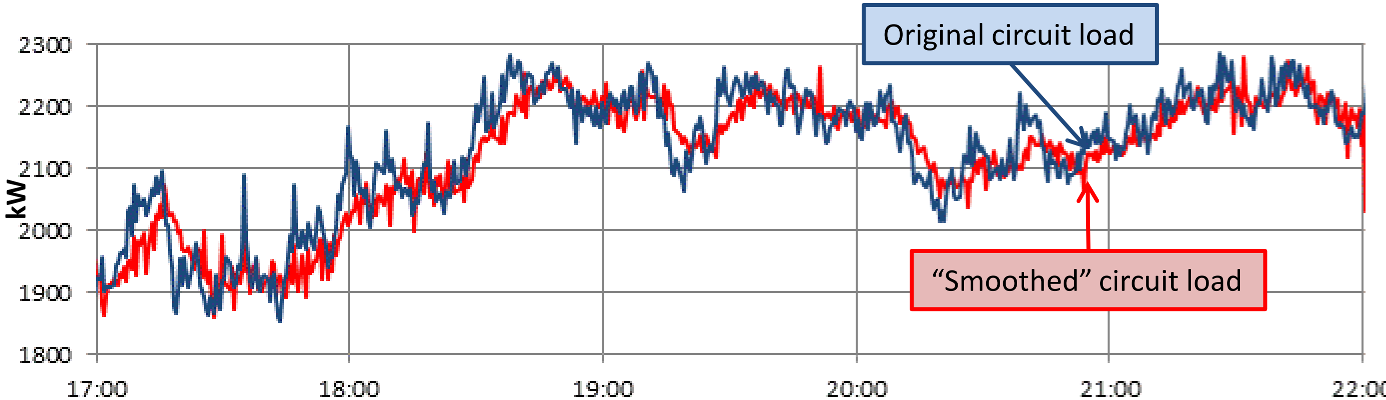


What the grid saw – simultaneous smoothing and shifting



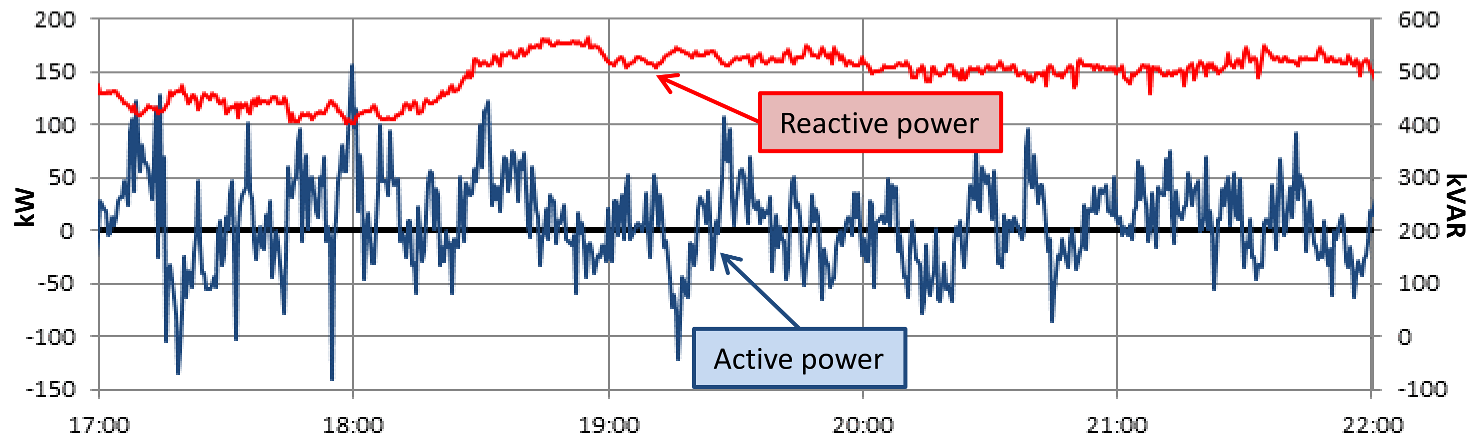


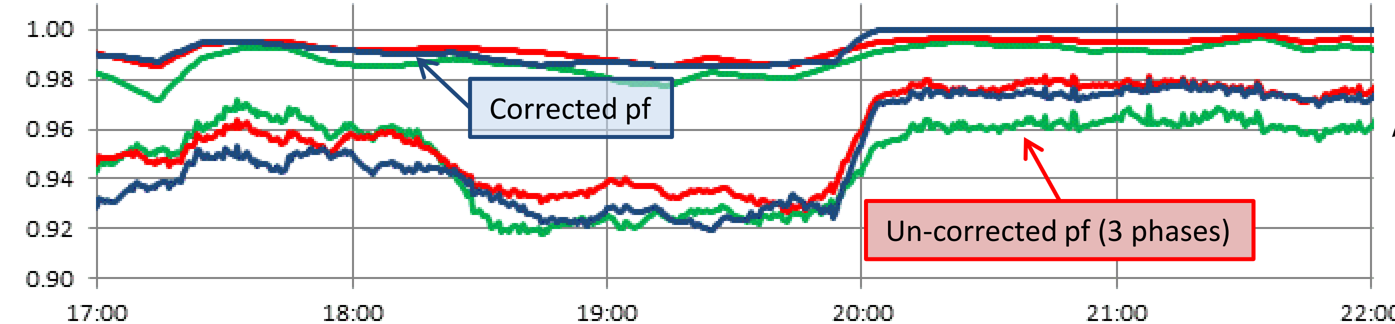
Example 2



Benefit #1:

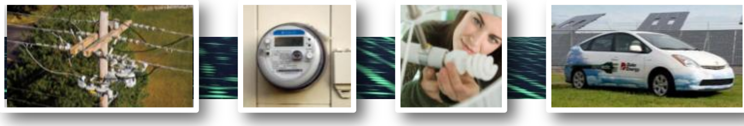
Less rapid intermittency in circuit load





Benefit #2:

Greater system efficiency through power factor correction



DUKE ENERGY

Example 3: How can substation-based ESS support a distribution circuit?

Dan Sowder, Curtis Watkins — Duke Energy
Dave Schoenwald, Dakota Roberson, Dan Borneo — Sandia National Labs

Background:

Duke has installed a 402 kW/282 kWh, NaNiCl ESS (FIAMM) as a centralized substation-based distribution ckt asset

Goals:

Using centralized ESS, Duke and Sandia will design and test algorithms to:

- Mitigate PV-induced power swings on the distribution circuit
- Protect substation assets from PV-induced power swing impacts

Next Steps:

- Design ESS control algorithm to react to voltage changes on the circuit
- Implement active VAR/power factor management using the ESS

We gratefully acknowledge the support of Dr. Imre Gyuk, DOE Energy Storage Program.

Sandia National Laboratories

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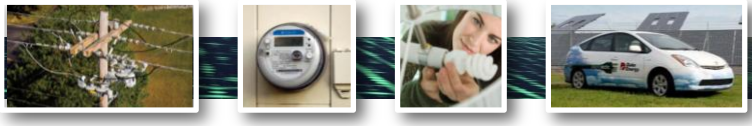
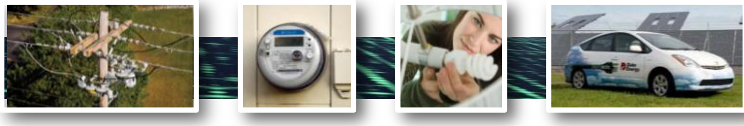
Sandia National Labs and Duke Energy have a Non-Disclosure Agreement (NDA) in place which covers, among other items, the conditionsfor public dissemination of intellectual property by each entity. This NDA was adhered to regarding the content of this communication.



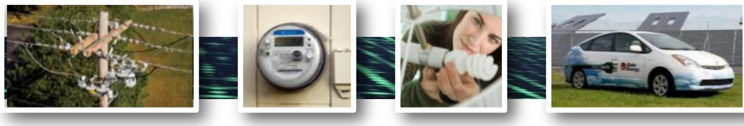
Example 4:
Seamlessly Islandable Microgrid

- **Provide resiliency to a critical facility**
  - Fire station will be able to operate during periods of prolong grid outages.
- **Utilize utility-owned, utility sited assets**
  - All equipment is owned and operated by Duke Energy. No alterations behind the customer meter.
- **Demonstrate ancillary and grid stability services:**
  - Frequency regulation
  - Circuit voltage support (VAR dispatch)
  - Demand response through islanding
  - Mitigating solar intermittency at the source



What’s next

- **Great progress to date, especially on the hardware**
  - Utility-industry partnerships have been key
  - Work still needed to reduce non-recurring engineering and O&M expenses
- **To optimize value, storage needs to be viewed an extension of the electric grid, not a stand alone asset**
  - Just like other assets, energy storage must compliment the diverse technology ecosystem of the grid
  - Interoperability with other grid assets is key
- **Multiple functionalities enhance value, especially on the distribution system**
- **Next step: tools to optimize energy storage on the grid**
  - Methodology and controls to enable energy storage to work together and compliment existing grid assets are needed
  - Utility engineers are just as important as battery technology specialists
  - How do we fully unlock the value of this new tool?



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Emerging Technology Office