Energy Storage at Duke Energy

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ETO Technology Screening Funnel
Energy Storage Current State

Integration of Energy Storage into the vertically integrated utility ecosystem to maximize value is still under development.

Simple function applications (frequency regulation) have started to be deployed in certain markets (ie. PJM, ERCOT, CAISO) – Duke Energy’s Notrees’ Project.
## Energy Storage Benefits

<table>
<thead>
<tr>
<th>Generation</th>
<th>T &amp; D</th>
<th>End User</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Regulation</td>
<td>Defer System Upgrades</td>
<td>Provide Back Up Power</td>
</tr>
<tr>
<td>Renewable Smoothing</td>
<td>Improve Reliability</td>
<td>Utilize lower retail rates</td>
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<tr>
<td>Energy Shifting</td>
<td>Renewable Smoothing</td>
<td></td>
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<tr>
<td>Spinning and Non-spinning Reserves</td>
<td>Improve Power Quality</td>
<td></td>
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<tr>
<td>Limit Peaker Plant Builds</td>
<td>(Volt / VAR management)</td>
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Through pilots we understand...  

- Capital Costs  
- O & M Costs  
- Installation Hurdles  
- Operational Issues  
- Value Streams  

...to develop  

- Business models  
- Regulatory models  
- Understand benefits
How did Duke Energy get here?
Over 25 unique demonstration projects installed

Six different battery chemistries tested

How did Duke Energy get here?

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

Benefit:

Diverse chemistries in different capacities

How do benefits chemistries in different capacities enable value?

<table>
<thead>
<tr>
<th>SIZE</th>
<th>LOCATION</th>
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<tbody>
<tr>
<td>kW</td>
<td>kWh</td>
</tr>
<tr>
<td>200</td>
<td>400</td>
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<td>400</td>
<td>600</td>
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<td>600</td>
<td>800</td>
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<table>
<thead>
<tr>
<th>CHEMISTRY</th>
<th>FUNCTION</th>
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<tbody>
<tr>
<td>Lithium Ion</td>
<td>25kW/25kWh</td>
</tr>
<tr>
<td>Lithium Polymer</td>
<td>250kW/750kWh</td>
</tr>
<tr>
<td>Advanced Lead Acid</td>
<td>36MW/24MWh</td>
</tr>
<tr>
<td>Li Iron Phosphate</td>
<td>200kW/500kWh</td>
</tr>
<tr>
<td>Sodium Nickel</td>
<td>75kW/42kWh</td>
</tr>
<tr>
<td>Lithium Titanate</td>
<td>200kW/500kWh</td>
</tr>
</tbody>
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on the grid 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
- 50:50 Cost share with DOE

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.
Example: Texas and ERCOT (Electric Reliability Council of Texas)

• Texas has seen a large amount of wind growth over the past 10 years.

• This has created the need for fast responding resources such as energy storage to help stabilize the grid.

Texas alone has more wind than France.
Wind is highly variable (the graph to the right shows a daily wind profile in Texas) which makes balancing supply and demand very difficult. Fast responding resources such as battery energy storage can help solve this problem.

(from NREL’s Analysis of Wind Power Ramping Behavior...)

Example of Daily Wind Output in ERCOT
Example of Battery’s Output and Response Time

Duke Energy’s 36 MW / 24 MWh battery charging and discharging based off market signals to help with grid stability

Discharging

Charging
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 one 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

System attributes
• In service 4Q 2012

Applications being tested
1 – consolidated inverter/battery construction at a low price
2 – energy shifting applications
  a) dispatched based on schedule, local load peaks, etc
3 – integration with solar in a microgrid
  a) will be configured with switches, solar, and load to create an autonomous microgrid that disconnects from the circuit
4 – solar output smoothing/firming
Islandable Microgrid Schematic

Equipment Legend
- Existing
- New
- Sense & Control

Microgrid Controller
- Fire Station
- 24 kV
- 120/208 V
- 75 kVA (3 x 25 kVA)
- 480/277 V
- 500 kVA

SS McAlpine Crk. Retail
- Ckt 2414
- Manual Disconnect
- Point of common coupling

Electronic switch to disconnect from grid: “Islanding Switch” Normally Closed

Electronic switch w/ DG protective settings: “DG Switch” Normally Closed

Battery
- 200 kVA
- 500 kWh
- 50 kW

Solar

Inverter
- AC
- DC

Inverter
- AC
- DC
Microgrid Controller HMI
**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

**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**

1. **centralized solar-induced power swing mitigation**
   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

2. **active VAR/power factor management**

3. **combined watt/VAR voltage control**
   a) compensation for rapid solar-induced voltage changes
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
1 – energy shifting
   a) for system-level arbitrage
   b) for local operational constraint management
   c) based on forward-looking economic algorithm
2 – solar output smoothing and firming
   a) for local feeder voltage management
   b) solar-induced power swing mitigation
3 – active VAR/power factor management
4 – combined algorithms / optimization
   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**

1. **active management of combined solar, storage and PEV charging**
   - testing energy management system and sizing of a behind-the-meter system

2. **energy shifting**

3. **customer-sited installation aspects**
Battery Responding to DC Charge Event
**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**

1 – **automatic voltage management**
   a) automatically injects/consumes VARs to maintain voltage within a specified setpoint

2 – **islanding/back-up power**
   a) automatic islanding during a grid outage

3 – **distributed energy shifting**
   a) various energy shifting applications using a network of distributed batteries

4 – **control system for distributed storage**
   a) using distributed communications network to monitor and dispatch the battery
Need to Consider

• Physical vs. Virtual Energy Storage
• How will energy storage compete / work together with:
  – Smart Invertors
  – Demand Response
  – Devices which perform autonomous frequency regulation
Conclusions

• The electric grid is changing: Electric generation is becoming more “de-centralized” – moving closer to the end user
• Balancing supply and demand requires a highly interconnected ecosystem with constant communication between assets
• Understanding how energy storage can seamlessly be integrated in this ecosystem is still under development