Energy Storage Benefits for Renewable Energy Plants

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Who Is S&C Electric Company?

• Founded in 1911
• Specialists in electric power - switching, protection, and control
• Headquartered in Chicago, Illinois
• Six global business units
• Employee-owned
• 2650 employees
S&C’s Energy Storage Expertise

- First MW-scale system commissioned in 2006
- 25 grid-connected energy storage systems to date
  - 146 MWh = 20% of world’s total
  - 46 MW = 12% of world’s total
  - Dominant in North America with 52% of total capacity and 100% of NAS
- Five distinct storage technologies deployed with multiple vendors
  - Lithium-ion
  - NaS
  - NaNiCl
  - Lead acid (standard)
  - Lead acid (advanced)
- Other technologies in pipeline (flow batteries, flywheels, etc.)
Hierarchy of Grid-Purposed Energy Storage

- **Source Storage**: 100’s of MW (Pumped hydro/CAES)
- **Distribution Bulk Storage**: 10’s of MW (NaS, Li-Ion, Lead Acid)
- **Distribution Grid Edge Storage**: 10’s of kW (Li-Ion)
Grid Storage Benefits:

1. Strategic Benefits
   - Prepare for new Revenue Models
   - Prepare for new Renewable & Reliability Mandates
   - Prepare for new Customer Behaviors

2. Service Benefits
   - T&D Capital Deferral
   - Service Reliability (DA)
   - Improve System Efficiencies
   - Voltage Regulation

3. Market Benefits
   - Energy Arbitrage
   - Frequency Regulation
   - Generation Capacity

All three work together to justify widespread storage deployment
The Case for Energy Storage

**Renewables Integration**
- Time Shifting
- Capacity Firming
- Grid Interconnection

**Ancillary Services**
- Frequency Regulation
- Spinning Reserve
- Demand Response

**Utilities**
- Microgrid
- Islanding
- Voltage Support
- T&D Deferral
Stationary Applications Favor Molten Salt

Energy storage deployments in stationary applications from Q1 2011 to Q1 2014 (% of MWh)

- Molten salt: 52%
- Li-ion: 31%
- Lead-based: 9%
- Flow Flywheel: 5%
- Sodium-ion: 3%
- CAES: 0%

Source: Lux Research
Renewable Energy Integration Projects

- Peak Shaving
- Spinning Reserve
- Load Following & Balancing
- Renewable Smoothing & Dispatch

- Islanding
- Frequency Regulation
- Grid Stabilization
- Voltage & Power Factor Regulation

Energy Storage - Solar Hybrid Project

Energy Storage – Wind Hybrid Project
Effects of Distributed Generation (Wind/Solar) on Distribution Systems

- **Intermittency Issues**
  - Magnified on networks with low X/R ratios
- **Variability and Voltage Swings**
  - Problems with power quality due to voltage fluctuations
  - Problems with dispatch due to unpredictability of the load
- **Reverse Current Flow**
Significant Regulations & Energy Storage

• **CALF. - AB 2514** – Establishes that 1.3 GW of energy storage is mandated for investor-owned utilities, storage bought from 2014-2020 & installed by 2024

• **FERC Order 755** – Independent system operators (ISOs) to compensate frequency regulation services provided. PJM, NYISO, MISO, and CAISO

• **FERC Order 784** – Pay premium for speed and accuracy of regulation favoring storage

• **Self Generation Incentive Program (SGIP)** - $1.80/W incentive for behind the meter storage. 50% Up Front, 50% over 5-years
Energy Storage Growth – S&C Electric Company Forecast

Grid Level Energy Storage Market
(S&C’s View)

Year: 2012-2022

- 2012: $0.1
- 2013: $0.3
- 2014: $0.7
- 2015: $1.4
- 2016: $2.5
- 2017: $3.8
- 2018: $5.4
- 2019: $7.4
- 2020: $9.3
- 2021: $11.5
- 2022: $15.7
Renewable Power Challenges

CAISO Net Load --- 2012 through 2020

Typical March Day – significant change starting in 2015

Potential Over-generation

Chart Courtesy of CAISO
Real World Examples
Bulk Wind Generation to Distributed Storage

• Most wind generation happens during night time hours

• Demand at night is lower leading to the need for storage

• T&D is less constrained at night, allowing energy to be transferred over distance using T&D lines to energy storage

• Able to place energy storage closer to point of use
Luverne, MN (1 MW, 7.2 MW-hr)

- 12 MW wind farm with variable scale factor so the SMS operated as if connected to:
  - 1 MW wind farm
  - 5 MW wind farm
  - 10 MW wind farm
Operations Studied

- **Generation Storage (Time Shifting)**
  - Charge/discharge on/off peaks coincident with wind output
- **Wind Smoothing**
  - Limit wind power rate-of-change
- **Dispatched Wind Leveling**
  - Limit deviation between actual and scheduled wind output
- **Economic Dispatch (Not wind-related)**
  - Capture market-based arbitrage benefits
- **Frequency Regulation (Not wind-related)**
  - Follow area frequency regulation signal
Generation Storage (Time Shifting)

- Optimal ratio of wind plant to storage is between 5:1 and 10:1
Wind Smoothing

- Result for a 1 MW battery on a 5 MW wind plant
Dispatched Wind Leveling

-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500

13:00
13:30
14:00
14:30
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00

DESS (kW) Effective Wind (kW) SOC (%)
Wind Energy Institute of Canada

- Installed on Prince Edward Island
- 1MW, 2MWh GE Sodium Nickel Chloride installation
- S&C PureWave® SMS
- S&C responsible for EPC and integration
- Co-located with 10MW of on-site wind generation
PV Integration Issues

- Ramping and Smoothing – Rapid output variations
- PV Output and Customer Demand inequalities
- Voltage PQ Problems due to ramping & excess PV output
- Marine layer clouds – coastal installs
- “Monsoonal” clouds at heat of the day when demand is high
- “Cloud Edge Effect” – cloud edges amplify energy up to 25% for a few seconds
Energy Storage Solving Issues

- Localized Smoothing – the storage can be used as a ramping service
- Charge the storage at noon for late afternoon discharge
- Use storage with PV output to keep load draw from the utility closer to constant
- Reduce or eliminate current back flow (to the grid)
- Use 4-quadrant inverter to regulate voltage with VAR control
Duke Rankin Installation co-located with PV

**Auxiliary power load center**
120V/240V service

**Visible disconnect switches**
Isolates battery system from circuit

**Battery container**
402 kW/282 kWh NaNiCl batteries (12 cells)
Includes Batt. Management System

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

**1000 kVA transformer**
Steps up 480 V inverter output to 12.47 kV
Duke Rankin Installation co-located with PV

- 402 kW, 282 kWh FIAMM Sodium Nickel Chloride battery
- S&C PureWave® SMS
- Paired with 1.2 MW rooftop PV solar generation located approximately 3 miles away
- The main function of the battery is for power swing mitigation caused by varying cloud cover
- Was operational in 1Q 2012
- Won Renewable Integration project of the year at DistribuTech 2013
Duke Rankin Smoothing Example
BC Hydro- Field, British Columbia, Canada 1MW

- 1 MW, Sodium-Sulfur Battery Storage System back up power
- Turnkey installation by S&C Power Systems Services
- BC benefit from cleaner, more reliable power
UK Power Networks – Leighton Buzzard, UK

- 6MW, 10MWh Lithium ion installation
- Europe’s largest energy storage project
- S&C providing EPC, installation, integration & PureWave® SMS
UKPN Smarter Network Storage Use Cases

- Initially Distribution Use cases
- Followed by market
- Transmission support

![Smarter Network Storage Trials Diagram]

**Individual Service Trials**

**Phase 1**
DNO Services
1. Peak Shaving
2. Reactive Power Support

**Phase 2**
Wholesale Markets
1. Long Term Market Optimisation (Tolling)
2. Short-Term Market Optimisation (Arbitrage)

**Phase 3**
TSO Services
1. Dynamic Firm Frequency Response
2. Static Firm Frequency Response
3. Frequency control by Demand Management (FCDM)
4. Short Term Operating Reserve (STOR)- Committed and Flexible
Conclusion/Takeaways

- Energy Storage is still a developing Market
- In order for Renewables to Emulate traditional Generation Energy Storage is needed
- When a Grid hits 25 to 30% Renewable Sources the stability of the Grid is in Question
- Battery Systems are still a developing Market much like Solar the projections are for a reduction in cost over time
Questions?

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