INNOVATIVE CLEAN TECHNOLOGY (ICT) PROJECTS

2009 Colorado Solar Integration Project
(Grand Junction, Colorado)

Parabolic trough solar plant with turbine capacity 2 MW

2012 Community Energy Storage Project
(Aurora, Colorado)

• 25kW/50kWh Sodium-Nickel-Chloride BESS
• ΣPV = 19.5 kW

2015 Panasonic Project
(Denver)

• 1MW/2MWh Li-Ion BESS
• ΣPV = 1.5MW
• Microgrid

2015 Stapleton Project
(Denver)

• Six utility-sited BESS
• Six BTM BESS
• High PV feeder
PANASONIC PROJECT
PEÑA STATION/PANASONIC PROJECT

3.376 kVA PV on feeder
PANASONIC PROJECT OBJECTIVES

• Microgrid/Islanding of Panasonic building
• Peak Demand Reduction
• Energy Arbitrage
• Frequency Response
• Voltage Regulation
• PV smoothing/Ramp Rate Limiting
Eclipse 08/21/2017 Panasonic Project

PV Max Ramp Rate ~ 48 kW/s

PV Output

Battery Output

Time of Day

Power (kW)
PV “SMOOTHED” OUTPUT 8/21/17

08/21/2017 "Smoothed" Power Output

Time of Day

Power (kW)

PV Output
PV+BESS Output
PV & PRIMARY VOLTAGE
NO RAMP RATE LIMITING

PV and Primary Voltage March 18

$V_{mean} = 13.6$ kV

$\Delta V_{max} = 0.21$ kV
PV & PRIMARY VOLTAGE WITH RAMP RATE LIMITING

PV and Primary Voltage April 18

$V_{\text{mean}}=13.6\text{kV}$

$\Delta V_{\text{max}}=0.2\text{kV}$
PV RAMP RATE LIMITING

PV Ramp Rate Limiting Apr 18

- $V_{mean} = 13.6 \text{kV}$
- $\Delta V_{max} = 0.21 \text{kV}$
Example Volt-VAR

- Nominal voltage = 13.2kV, i.e. voltage at the transformer primary
- Deadband = ±2.5% of nominal voltage
- $V_{\text{min}} = 0.8 \, V_{\text{nominal}}$
- $V_{\text{max}} = 1.2 \, V_{\text{nominal}}$
OVERVOLTAGE ON PRIMARY 4/17-4/24
VOLT-VAR BY BESS 4/17-4/24

3Phase Voltage & $Q_{output}$ 4/17

Voltage (V) vs. Time (ms) for 3P Voltage and $Q$(kVAR)
EXPECTED VS ACTUAL OUTPUT

3Phase Q Expected vs Actual

$Q_{output}$(kVAR)

Time(min)

Actual
Expected
STAPLETON PROJECT
STAPLETON NEIGHBORHOOD

- Stapleton feeder has ~18.5% PV penetration (2017)
- Utility-Sited Systems:
  - Six Li-Ion battery energy storage systems
  - Sited along the feeder at two different phases
- Behind-the-Meter Systems:
  - Six Li-Ion battery energy storage systems
  - Sited in a customer’s home
STAPLETON UTILITY SITED OVERVIEW

Objectives/Use Cases:
- Peak Demand Reduction
- Voltage Regulation
- Solar Time Shifting
- Energy Arbitrage

Northern Reliability Modular Units:
- 2 x 18 kW/69 kWh
- 2 x 36 kW/138 kWh
- 2 x 54 kW/207 kWh
STAPLETON BEHIND-THE-METER OVERVIEW

• Sunverge SIS units
  – 6 x 6 kW/15.5 kWh

• Objectives/Use Cases:
  – Providing Residential Backup Power
  – Peak Demand Reduction
  – Solar Time Shifting
  – Volt-Watt Operation (?)
CHARGING FROM PV AT HIGH VOLTAGE
CHARGING FROM PV AT HIGH VOLTAGE

BTM Unit BESS + Voltage

- Voltage Limits
- Charge from PV

Power (W)
-2000
0
2000
4000
6000

Voltage (V)
114
116
118
120
122
124
126
128

Time (min)
0
200
400
600
800
1000
1200
1400

BESS
Voltage

Xcel Energy®
SAMPLE TEST
SOLAR TIME SHIFTING

- Solar PV Production
- (Battery-PV)

Charge battery

Discharge battery
TEST SAMPLE RESULTS

Test Results for BTM Unit

- Set Site Meter to 500 W
- PV Charging
- Set Site Meter to 0 W
- Charge from Grid

Power (W) vs Time of Day

- Site
- PV
Thank you
• Environmental controls
  – Panasonic: Multiple cold-temperature alarms. Solution: Use the inverters to output reactive power (~50 kVAR) to ensure heating stays on.
  – Sunverge: Cold temperatures kicks the units into self-preservation mode, disrupting schedule. Solution: Sunverge has updated the control logic to allow heaters to come on at specific times.

• Lack of standardization across vendor platforms
  – Control algorithm for the modes of operation
  – Communication protocol (all support DNP3 but Xcel is connecting to all the systems in different ways)

• Lessons Learnt:
  – Make sure data is captured consistently (scaling factors, polling time, latency etc)
  – Make sure vendor understands specific operation/mode/use case
• Treated site as a substation
• Fiber to site with multiple security zones
• 2 RTU’s
  – One for SCADA
  – One for DNP3 to Modbus
• Battery control is through vendor UI
• Islanding control utilizes SCADA
• Stapleton will be controlled through SCADA (no vendor UI)
Panasonic One-Line
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Apparent Power</td>
<td>1,000 kVA</td>
</tr>
<tr>
<td>Rated Real Power</td>
<td>1,000 kW</td>
</tr>
<tr>
<td>Rated Energy</td>
<td>2,100 kWh</td>
</tr>
<tr>
<td>Available Energy</td>
<td>1,690 kWh</td>
</tr>
<tr>
<td>Round-Trip Efficiency</td>
<td>85.5 %</td>
</tr>
<tr>
<td>Voltage Range</td>
<td>432-528 V</td>
</tr>
<tr>
<td>Rated Continuous AC Current</td>
<td>1,200 A</td>
</tr>
<tr>
<td>Operating Temp. Range</td>
<td>-10°C - 45°C</td>
</tr>
<tr>
<td>Physical Dimension</td>
<td>42’ x 10’</td>
</tr>
</tbody>
</table>
## NRI ENERGY STORAGE PARAMETERS

<table>
<thead>
<tr>
<th>Description</th>
<th>18 kW System</th>
<th>36 kW System</th>
<th>54 kW System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Apparent Power</td>
<td>18 kVA</td>
<td>36 kVA</td>
<td>54 kVA</td>
</tr>
<tr>
<td>Rated Real Power</td>
<td>18 kW</td>
<td>36 kW</td>
<td>54 kW</td>
</tr>
<tr>
<td>Rated Energy</td>
<td>69 kWh</td>
<td>138 kWh</td>
<td>207 kWh</td>
</tr>
<tr>
<td>Round-Trip Efficiency</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Range</td>
<td></td>
<td>172 – 264 V</td>
<td></td>
</tr>
<tr>
<td>Rated Continuous AC Current</td>
<td>94 A</td>
<td>187 A</td>
<td>281 A</td>
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<tr>
<td>Operating Temp. Range</td>
<td>-30°C -50°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Dimension</td>
<td>56” x 52.75” x 53”</td>
<td>112” x 52.75” x 53”</td>
<td>159” x 52.75” x 53”</td>
</tr>
</tbody>
</table>
SUNVERGE SIS UNIT

Hybrid Inverter
(4.5kW or 6kW rated)

IO Board

Solar Charge Controller
(150V or 600V MPPT)

Distribution Panel

Application Gateway

Outdoor rated cabinet

Lithium-ion Battery
(Scaleable to 19.4 kWh)

Polycrrete pad
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Apparent Power</td>
<td>6 kVA</td>
</tr>
<tr>
<td>Rated Real Power</td>
<td>6 kW</td>
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<tr>
<td>Rated Energy</td>
<td>15.5 kWh</td>
</tr>
<tr>
<td>Available Energy</td>
<td>11.64 kWh</td>
</tr>
<tr>
<td>Round-Trip Efficiency</td>
<td>92.5 %</td>
</tr>
<tr>
<td>Voltage Range</td>
<td>233 – 247 V</td>
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<tr>
<td>Rated Continuous AC Current</td>
<td>25 A</td>
</tr>
<tr>
<td>Operating Temp. Range</td>
<td>-20°C - 50°C</td>
</tr>
<tr>
<td>Physical Dimension</td>
<td>76” x 34” x 14”</td>
</tr>
</tbody>
</table>
1. SUNVERGE AC SOLAR INTEGRATION SYSTEM (SIS).
2. NOT ALWAYS REQUIRED. CONSULT LOCAL CODE AND AHJ.
3. NOT INCLUDED WITH SIS UNIT.
4. MUST BE POWERED BY CLP.
5. HARDWIRED CONNECTION TO INTERNET.
6. NEW PANEL (OPTIONAL).
7. 50A CIRCUIT BREAKER.
8. TOTAL LOAD CANNOT EXCEED RATING OF SIS INVERTER.
9. 15A CIRCUIT BREAKER FOR VOLTAGE REFERENCE.
10. SPLIT-CORE AC CURRENT SENSOR.
11. MUST NOT EXCEED 200A.
12. NO = NORMALLY OPEN; NC = NORMALLY CLOSED.
13. MAX CAPACITY 6KW.
14. OPTIONAL 3G MODEM FOR INTERNET CONNECTION.