Residential Solar-Storage Systems
Critical Load Analysis and Incremental Cost of Energy Storage

DNV KEMA
June 4th, 2013
## Contents

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Motivations

- Recent natural disasters have exposed “gaps” in grid reliability.

- Increased focus on utilization of distributed generation assets, notably PV, to address these gaps.

- An area of particular interest is allowing distributed generation assets to “island” from the grid during an outage.

*After the storm, the long wait for power*

It took utilities in New York and New Jersey nearly two weeks to restore power to 95 percent of customers who lost it after Superstorm Sandy. That’s among the longest outages since 2004, but restoration was slower after several other storms.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>STORM</th>
<th>STATE</th>
<th>DAYS TO RESTORE POWER TO 95% OF THOSE WHO LOST IT</th>
<th>PEAK OUTAGES IN MILLIONS (AND % OF CUSTOMERS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Katrina</td>
<td>Louisiana</td>
<td>23*</td>
<td>0.91 (42%)</td>
</tr>
<tr>
<td>2005</td>
<td>Rita</td>
<td>Texas</td>
<td>16</td>
<td>0.78 (8%)</td>
</tr>
<tr>
<td>2005</td>
<td>Katrina</td>
<td>Mississippi</td>
<td>15</td>
<td>1.00 (70%)</td>
</tr>
<tr>
<td>2005</td>
<td>Wilma</td>
<td>Florida</td>
<td>14</td>
<td>3.25 (36%)</td>
</tr>
<tr>
<td>2008</td>
<td>Ike</td>
<td>Texas</td>
<td>14</td>
<td>2.47 (23%)</td>
</tr>
<tr>
<td>2012</td>
<td>Sandy</td>
<td>New York</td>
<td>13</td>
<td>2.10 (23%)</td>
</tr>
<tr>
<td>2012</td>
<td>Sandy</td>
<td>New Jersey</td>
<td>11</td>
<td>2.62 (65%)</td>
</tr>
<tr>
<td>2004</td>
<td>Ivan</td>
<td>Florida</td>
<td>10</td>
<td>0.44 (5%)</td>
</tr>
<tr>
<td>2012</td>
<td>Sandy</td>
<td>West Virginia</td>
<td>10</td>
<td>0.27 (27%)</td>
</tr>
<tr>
<td>2004</td>
<td>Charley</td>
<td>Florida</td>
<td>9</td>
<td>1.60 (18%)</td>
</tr>
<tr>
<td>2004</td>
<td>Frances</td>
<td>Florida</td>
<td>8</td>
<td>3.50 (40%)</td>
</tr>
<tr>
<td>2004</td>
<td>Ivan</td>
<td>Alabama</td>
<td>8</td>
<td>1.07 (46%)</td>
</tr>
<tr>
<td>2011</td>
<td>Irene</td>
<td>New York</td>
<td>7**</td>
<td>0.94 (12%)</td>
</tr>
<tr>
<td>2012</td>
<td>Sandy</td>
<td>Pennsylvania</td>
<td>6**</td>
<td>1.27 (20%)</td>
</tr>
<tr>
<td>2011</td>
<td>Irene</td>
<td>New Jersey</td>
<td>6**</td>
<td>0.81 (18%)</td>
</tr>
<tr>
<td>2012</td>
<td>Sandy</td>
<td>Connecticut</td>
<td>6**</td>
<td>0.63 (31%)</td>
</tr>
</tbody>
</table>

*Louisiana had restored power to 75 percent of customers after Katrina when Hurricane Rita arrived and knocked out more customers.

**Selected recent outages of less than eight days listed for comparison.

Sources: U.S. Department of Energy; Ventyx; AP analysis.
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2 Residential Critical Load Analysis and Storage Requirements
3 Incremental Cost of Energy Storage
4 Conclusions
Critical Loads

- It is not practical to design backup systems to support all electrical loads in a typical residence

- Customers and installers need to agree on which loads and circuits require backup during an outage
  - Capacity of the backup system is based on the power and energy requirements of the critical loads
  - Expected demand serves as baseline to specify inverter and battery-capacity requirements

- The analysis here draws from Northeast residential load shapes for: heating, cooling, refrigeration, cooking, water heating, and misc. chargers and plug loads

- The data draws from the DNV KEMA load profile data base for New York:
  - Electric Water Heater – DNV KEMA study for Northeast Energy Efficiency Partnership (NEEP)
  - Central A/C – DNV KEMA source
  - Electric Heating – DNV KEMA study for NEEP
  - Non-electric Heating (pumps, fans) – DNV KEMA study for NEEP
  - Lighting – DNV KEMA study for NEEP
  - Refrigerator – Northwest Regional Technical Forum Data
  - Cooking – Northwest Regional Technical Forum Data
  - Misc Chargers, plug loads – DNV KEMA source
Summer Peak Residential Critical Load

- Graph shows hourly critical kW demand / kWh energy for a peak Summer day
- Central A/C and electric hot water heating excluded from critical load
Summer Excess Generation

- Typical NY State Summer PV profile matched to critical load profile
- Assumes 5 kW PV installation

Excess PV generation
Summer Peak with Central A/C

- Backup solar-storage system cannot support air-conditioning load in the event of an extended outage

Insufficient excess for charging
Winter Peak Residential Critical Load

- Graph shows hourly critical kW demand / kWh energy for a peak Winter day
- Electric heating and electric hot water heating not included
Winter Excess Generation

- Typical NY State Winter PV profile matched to critical load profile
- Assumes 5 kW PV installation

Reduced PV in winter
Winter Peak with Electric Heating

- Backup solar-storage system cannot support whole home electric heating load during an extended outage
State-of-charge of Storage for Critical Load Support

- During Summer, excess PV generation is sufficient to levelize storage state-of-charge for 10kWh storage capacity.
- Winter load may require larger capacity and greater critical load management.
Storage Requirements and Recommendations

Sizing Recommendations

- DNV KEMA recommends sizing storage and interconnection components at a minimum of 5kW for residential backup in New York
- DNV KEMA recommends a minimum of 10 kW-hrs for residential back-up in New York
  - alternative to larger storage capacity is a reduction in critical load usage during the outage
  - Infeasible to supply central A/C or electric heating

Balance of Plant and Control Recommendations

- DNV KEMA recommends solar-storage backup systems provide a means to monitor storage state-of-charge during backup operation
- Advanced functionality such as automated and/or remote control of critical loads, through the system gateway or home EMS controller, can further improve survivability
Case Study: California

- Comparison of the “installed cost” of PV systems in California with and without energy storage over the last seven years.

- PV installations w/ battery averages 0.4% of total PV installations in California

<table>
<thead>
<tr>
<th>Year completed</th>
<th># of systems</th>
<th>$/Watt</th>
<th># of systems</th>
<th>$/Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>11</td>
<td>$11.61</td>
<td>3,420</td>
<td>$9.94</td>
</tr>
<tr>
<td>2008</td>
<td>52</td>
<td>$13.14</td>
<td>7,613</td>
<td>$9.90</td>
</tr>
<tr>
<td>2009</td>
<td>75</td>
<td>$12.30</td>
<td>12,628</td>
<td>$9.58</td>
</tr>
<tr>
<td>2010</td>
<td>38</td>
<td>$12.07</td>
<td>16,058</td>
<td>$8.49</td>
</tr>
<tr>
<td>2011</td>
<td>38</td>
<td>$10.26</td>
<td>21,411</td>
<td>$8.25</td>
</tr>
<tr>
<td>2012</td>
<td>29</td>
<td>$7.74</td>
<td>28,301</td>
<td>$7.06</td>
</tr>
<tr>
<td>2013</td>
<td>10</td>
<td>$7.88</td>
<td>4,729</td>
<td>$6.21</td>
</tr>
</tbody>
</table>
Case Study: California

- Cost of installed PV in CA, with and without a battery, has been declining over the last several years at an average rate of 7% per year
- Incremental cost for adding storage to PV has been declining at average rate of 11% per year
- Detailed data for each installation unavailable, but belief is these system include supplying critical load
Breakdown of Costs

- Depending on the type and size of PV, inverter, and batteries, the cost components vary but, on average, they may be generalized as follows:
  - Installation is about ½ the cost of an installed PV+ES system
  - Adding battery could double the PV hardware cost but its impact on the total installed cost is about 25 - 30%, depending on its capacity and capabilities.
  - Adding islanding capability to help PV system serve as a backup power could increase the installed cost by about 10%
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Conclusions

- DNV KEMA recommends sizing storage and required interconnection components at a minimum of 5 kW with 10 kWh capacity for residential backup in New York. Advanced control and monitoring can improve survivability.

- Packaged solutions meeting these requirements exist, but little operating experience exists in the New York.

- Incremental cost of installed systems in California is currently at $1400/kW about cost of solar only installations.

- Hurdles to overcome for the backup application include minimizing cost of the module that is either part of a future product or retrofitted to an existing product.

- Incentive mechanisms to propel unique financing will require added feature to provide consistent value that can be monetized. As backup alone, this will not provide consistent revenue but rather avoided cost. Allowing system to capture benefits during normal grid connected operation can enable this value stream.
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<td>6</td>
<td>Incentives, Policy and Funding</td>
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</table>
Existing Solutions

- **Component Vendors**
  - SMA America [http://www.sma-america.com](http://www.sma-america.com)
  - OutBack Power Technologies [http://www.outbackpower.com](http://www.outbackpower.com)
  - Schneider Electric [http://www.schneider-electric.com](http://www.schneider-electric.com)

- **Integrators (packaged solutions)**
  - Sunverge [http://www.sunverge.com](http://www.sunverge.com)
  - SolarCity [http://www.solarcity.com](http://www.solarcity.com)

- **Demo projects**
  - EcoCutie (Japan)
Sunverge Energy

- Sunverge solar integration system (SIS) consists of a 6 kW Schneider hybrid inverter and 10.77 kWh Li-Ion storage (capacity available up to 15.1 kWh)
  - unit is self-contained and sits behind the meter, NEMA 3 enclosure for indoor or outdoor installation

- Gateway used by the consumer to select loads that will operate in back-up mode

- Inclusion of storage allows for participation in utility demand response programs, even when not convenient for consumers
Sunverge Energy

- Currently 38 installations on-line, with 184 planned by June, and 400 by end of 2013

- Software application for remote monitoring of resources and storage state-of-charge
SolarCity

- Developed a wall mounted residential storage product, selling residential product today
  - 5 kW, 10 kWh, primarily Li-Ion with some advanced lead acid installations

- Interconnection built around SMA Sunny Island platform

- Primarily selling in CA because of SGIP funding for energy storage
  - SGIP rebate has made system installation cost-effective
  - System operates in parallel with the grid but also provides battery back-up,
  - Where allowed by tariffs, the system can perform market participation

- Over 70 SGIP applications for storage installations in 2012

- Solar lease program has signed on 21,000 customers in 2012

- Have not focused on Eastern US markets on residential, because lack of incentives

SOURCE: SolarCity
EV Based Home Backup

- "LEAF to Home" power supply system
  - supply from batteries onboard Nissan LEAF electric vehicles (EV) to homes during an outage
  - used with the "EV Power Station" unit developed by Nichicon Corporation

- Industry first backup power supply system that can transmit the electricity stored in the large-capacity batteries of Nissan LEAFs to a residential home.

- Available in Japan in 2013
- 6 kW, 24 kWh backup power
- $6000 system on top of the cost of the vehicle

SOURCE: Nissan
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</tbody>
</table>
Policy Recommendations

Addressing Cost Barriers

- One hurdle for ES+PV is to minimize the cost burden of the module that is either part of a future product or retrofitted to an existing product. *It appears that this module could be separated out to be incentivized.*

- For the incentive mechanism to propel unique financing, the added feature will need to provide a consistent value that can be monetized. As the additional feature essentially acts as an emergency back, i.e. will not provide consistent revenue but rather an avoided cost, it would appear that a straight up incentive would be required.

- As we are looking at a product that would have relatively low technology risk and entering a mass adoption rather than early adoption phase, NYSERDA should look at incentive mechanisms that can meet the needs for what financing agencies require but also be available to the wide number of potential adopters.

Addressing Lack of Knowledge

- Though training programs exist, it appears that additional educational support for designers and installers could help lower barriers to market adoption by enabling more providers to discuss options with customers and to more effectively install ES+PV systems.

- Support could take the form of financial incentives for training, or the distribution of information about training opportunities.
Policy Recommendations

Addressing Lack of Knowledge (con’td)

- It also appears that customers could benefit from educational programs that:
  - Provide clarity about what PV options actually can deliver for customers (versus PV + ES systems)
  - Assist customers in understanding the differences among PV + ES offerings (e.g., AC vs. DC; one product versus another)
  - Inform customers about the potential benefits and costs of ES + PV systems versus stand-alone PV systems
  - Assist customers in selecting installers or contractors who can provide the design and installation services for PV + ES systems

Addressing Component Compatibility

- Component compatibility appears to be a hurdle for PV + ES systems, limiting options among consumers and increasing the complexity among installers and designers.
- Currently, standards are underway that could potentially help address some compatibility issues.
- However, in the meantime, education among buyers, designers and installers could help.