Ensuring Grid Reliability with Increased Distributed Energy Resources

Rebecca (Becky) Wingenroth
Electric Power Research Institute (EPRI)

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EPRI: Born in a Blackout

Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research

New York City, The Great Northeast Blackout, 1965
Three Key Aspects of EPRI

**Independent**
Objective, scientifically based results address reliability, efficiency, affordability, health, safety, and the environment

**Nonprofit**
Chartered to serve the public benefit

**Collaborative**
Bring together scientists, engineers, academic researchers, and industry experts
Our Members…

- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding – nearly 25% of EPRI’s research, development, and demonstrations
About Our Research

Power Delivery & Utilization
Transmission, Distribution, and Substations

Power Delivery & Utilization
Distributed Energy Resources and the Customer

Nuclear

Generation

Energy and Environment

Technology Innovation
Distributed Energy Resources...Who has Interest?

- Customers (lower costs)
- ISOs (lower peak)
- Vendors, Manufacturers (increase markets)
- Other Stakeholders (environmental, etc.)
- Distribution Utilities
Ensuring Grid Reliability…Who is Responsible?

The Distribution Utility

“Utilities are responsible for reliability, and the functions needed to enable distributed markets are integrally bound to the functions needed to ensure reliability. “ NYPSC Order for Reforming the Energy Vision issued 2015
Industry is starting embrace the change…

Figure 1. Q1 2018 Legislative and Regulatory Action on Grid Modernization

Courtesy NC Clean Energy Technology Center
50 States of Grid Modernization Q1 2018 Quarterly Report
Utilities turning a corner….but not a U-turn
Non Wires Alternatives (NWAs)

Simulated Participation

Brooklyn Queens Demand Management

Pending: Clean Virtual Power Plant (VPP)

~300 x 6kW / 19.4kWh
(1.8MW, 4.7MWh total)

Battery load relief
12PM-6PM
June – September

2MW/12MWh (usable) capacity
Research Questions

▪ Where can DER be located for the greatest benefit?

▪ How to ensure that DER will be available to support the larger grid when necessary?

▪ What are the gaps between theory and practical implementation?
Energy and Natural Resource Systems are Integrated to Provide Reliable, Safe, Affordable, Cleaner Energy and Expanded Customer Choice
EPRI/Industry Conducting Research to Optimize DER

Some Grid Considerations:

– Location of DER
– DER Technology(ies) and Incorporation of Energy Storage
  ▪ Sizing
  ▪ Integration
– Smart Inverters to Optimize the DER
– Duration of Reliability
– Cost Benefit Analysis
Location

Hosting Capacity: What is it?

The amount of Solar PV or other (Distributed Energy Resources) that can be accommodated without impacting power quality or reliability under existing control and infrastructure configurations.

The impact from DER is dependent on the unique feeder and DER characteristics.
PV Hosting Capacity Explained

Minimum Hosting Capacity

Maximum Hosting Capacity

Total PV: 1173 kW

Total PV: 540 kW

No observable violations regardless of size/location

Possible violations based upon size/location

Observable violations occur regardless of size/location

2500 cases shown
Each point = highest primary voltage

ANSI voltage limit

Increasing penetration (kW)

Voltage violation
Hosting Capacity Maps Inform DER Developers
Load peak shaving lowers the electric bill by reducing the peak demand based charge. Battery is charged during light load hours and discharges in peak load hours when the load is above the peak shaving target.
Peak Shaving with Different PV Generation

- PV generation reduces the peak demand and as a result, less or no power is needed from battery to keep the peak demand below the target.
- Battery mitigates the load variations above the target in highly variable solar day.
Dispatch Hours Can Vary from Year to Year

Load Profiles on Peak Load Days for May of Each Year

- 2013 (May 2)
- 2014 (May 15)
- 2016 (May 12)
- 2017 (May 19)
- 2018 (May 15)

2017 Dispatch Hours: 11, 12, 13
2018 Dispatch Hours: 14, 15
ESS Will Not Reduce Peak Load if Demand Target is Too High or Low

If demand target is set too low:
- ESS dispatches its capacity before peak demand occurs
- From prior example:
  - Ideal demand target 5/18/18 was 4,309 kW
  - If demand target set 54 kW lower at 4,255 kW, ESS would have dispatched its capacity before the peak load at 15:00

If demand target is set too high:
- ESS does not dispatch because demand target is not reached
- From prior example:
  - Ideal demand target 5/18/18 was 4,309 kW
  - If demand target set 100 kW higher at 4,409 kW, ESS would not dispatch
Determining Smart Inverter Setting based on Feeder Performance

Analysis method:

- **Solar variability conditions**
  - Clear day
  - Overcast day
  - Highly variable day

- **Load variability conditions**
  - Peak load day
  - Minimum load day

- **Smart inverter settings**
  - Volt-var
    - Multiple volt-var curves with varying slope, varying deadband and varying mid point in a band that covers \( (V_{\text{min}}, V_{\text{max}}) \) are analyzed.
  - Off-nominal power factor (0.9 – 0.99 absorbing)

- Select the best setting by ranking the feeder performance
Smart Inverter Settings – Reducing Voltage Variability

**Voltage variability index**

\[
VI = \frac{\sum_{k=2}^{n} \sqrt{(V1_k - V1_{k-1})^2 + \Delta t^2}}{\sum_{k=2}^{n} \sqrt{(V0_k - V0_{k-1})^2 + \Delta t^2}}
\]

V1 is the voltage curve being evaluated and the V0 is the reference voltage, which is normally the voltage without PV.

Voltage variations add additional “length” to the voltage curve and larger voltage variability index indicates more variations.
**Duration**

**Operation without Diesel generator**

- The microgrid site has a 100 kW 2 hours battery and 101 kW of PV capacity
- Assuming a PV+ES microgrid only, the islanding duration that the microgrid allows is very short

<table>
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<th>Islanding (hours)</th>
<th>Probability of Serving load</th>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
<td>87%</td>
</tr>
<tr>
<td>6</td>
<td>71%</td>
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<tr>
<td>8</td>
<td>24%</td>
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<tr>
<td>10</td>
<td>18%</td>
</tr>
<tr>
<td>12</td>
<td>11%</td>
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</table>
Duration
Operation including Diesel generator

- The microgrid considered for the site includes a 30 kW Diesel generator
- Allowing the Diesel generator to operate at full capacity during islanding, yields a very high probability of serving an outage
- After three days, probability of serving loads diminishes to less than 80%

<table>
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<th>Islanding (hours)</th>
<th>Probability of Serving load</th>
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<td>100%</td>
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<tr>
<td>10</td>
<td>99.6%</td>
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<td>98.7%</td>
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<td>24</td>
<td>94%</td>
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<tr>
<td>48</td>
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<td>72</td>
<td>80%</td>
</tr>
<tr>
<td>168</td>
<td>75%</td>
</tr>
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</table>
EPRI’s Benefit-Cost Framework

Commendation by the National Association of Regulatory Utility Commissioners
Integrated Grid Cost-Benefit Framework

“Stacking Order” for DER and Microgrids

Business Arrangements
Alternative Ownership, Pricing at connection point, Operating Objectives

• Δ op costs
• other costs

Microgrid Controls & Equipment, DER for Capacity

• Δ reliability
• Δ resiliency
• Avoided/Incurred Upgrades

Energy-Producing DER
DER optimized with surrounding system’s marginal cost

• Reliability (unchanged)
• Avoided Energy
• Avoided Capacity
• Avoided Emissions
• Avoided/Incurred Upgrades

Base Layer w/o Microgrid
Existing system: customers, loads, existing DER, and service levels.

• CBA1: What is the net value of the energy-producing DER?

• CBA 2: Does the value of incremental reliability/resiliency outweigh the incremental cost?

• CBA 3: Does the total value of the DER outweigh its cost?

EPRI is not proposing to analyze alternative business arrangements.
Modeling & Tools
DER-CAM Modeling Overview

Inputs
- Electrical & Thermal Loads
- Electricity & Gas tariff data
- DER data
- Site Weather Data

Objectives
- Minimize Cost
- Minimize Emissions
- Renewable Penetration
- Outage Duration

Constraints
- Cost/Emissions Cap
- Zero Net Energy
- Specify DER types/size/models

Outputs
- Optimal DER Mix & Capacity
- DER Dispatch
- Investment & Financing
- Quantitative Cost/Benefit

Optimization/Search Engine
Questions?
Together…Shaping the Future of Electricity