Distributed Generation: Feeder Hosting Capacity

Dean E. Philips, P.E.
FirstEnergy Service Corp
Manager, Distribution Planning & Protection
Factors that contribute to a reduced hosting capacity

- Voltage
  - Profiles (steady state)
  - Flicker
  - Over-voltage (during faults)
- Overcurrent
- Fault Current
  - Protective device capacities
  - Protective device coordination
- Power Quality
- Islanding Studies
- System Operations Studies
FirstEnergy Facts at a Glance

• Headquartered in Akron, Ohio
• 6 million customers served
• $50 billion in assets
• $15 billion in annual revenues
• 16,500 employees

www.FirstEnergyCorp.com
<table>
<thead>
<tr>
<th>Location</th>
<th>Customers</th>
<th>Square Miles</th>
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</thead>
<tbody>
<tr>
<td><strong>Ohio</strong></td>
<td></td>
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</tr>
<tr>
<td>Ohio Edison</td>
<td>1,035,836</td>
<td>7,000</td>
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<tr>
<td>The Illuminating Company</td>
<td>752,173</td>
<td>1,600</td>
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<tr>
<td>Toledo Edison</td>
<td>309,793</td>
<td>2,300</td>
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<td><strong>Pennsylvania</strong></td>
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<tr>
<td>Met-Ed</td>
<td>549,574</td>
<td>3,300</td>
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<td>Penelec</td>
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<td>17,600</td>
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<td>West Penn Power</td>
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<td><strong>West Virginia/ Maryland/ Virginia</strong></td>
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<td>Mon Power</td>
<td>385,504</td>
<td>13,005</td>
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<td>Potomac Edison</td>
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<td>5,182</td>
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<td><strong>New Jersey</strong></td>
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<tr>
<td>Jersey Central Power &amp; Light</td>
<td>1,094,195</td>
<td>3,200</td>
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Distributed Generation at FirstEnergy (Year end 2013)

<table>
<thead>
<tr>
<th>Region</th>
<th>Projects</th>
<th>Capacity (MW)</th>
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<tbody>
<tr>
<td>Ohio Edison</td>
<td>362</td>
<td>14.40</td>
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<tr>
<td>The Illuminating Company</td>
<td>174</td>
<td>7.94</td>
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<td>Toledo Edison</td>
<td>142</td>
<td>15.46</td>
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<td>Pennsylvania</td>
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<td>Met-Ed</td>
<td>1625</td>
<td>31.70</td>
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<tr>
<td>Penelec</td>
<td>403</td>
<td>8.23</td>
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<td>Penn Power</td>
<td>61</td>
<td>1.25</td>
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<td>West Penn Power</td>
<td>404</td>
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<td>West Virginia/Maryland/Virginia</td>
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<tr>
<td>Mon Power</td>
<td>109</td>
<td>0.57</td>
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<tr>
<td>Potomac Edison</td>
<td>871</td>
<td>11.36</td>
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<tr>
<td>New Jersey</td>
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<tr>
<td>Jersey Central Power &amp; Light</td>
<td>10,434</td>
<td>244.70</td>
</tr>
</tbody>
</table>

Total Projects: 14,586
Total Capacity: 340.78 MW

Data submitted for the DOE EIA 826 Report
Distributed Generation: Feeder Hosting Capacity

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  - Protective device coordination
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- Islanding
- System Operations
Distributed Generation: Feeder Hosting Capacity
Distributed Generation: Feeder Hosting Capacity
So what is the problem?

Most DG Applications are small
- We are sneaking up on the problem
Hosting capacity is location dependent
Most DG projects are @ fixed location
- Net Metered projects need to go in at the customer location
- Installers are often in process before approval is given

Customers will not understand why their project is denied, but their brother’s a few miles down the road is not.
Solar Energy Measurement Data – NE USA

May 2012

Sun  Mon  Tue  Wed  Thu  Fri  Sat

1  2  3  4  5

6  7  8  9  10  11  12

13  14  15  16  17  18  19

20  21  22  23  24  25  26

27  28  29  30  31
Why Regulation and Caps are “locked in place”

Solar Ramping
EPRI has measured up to 50kW/sec (1MW/20seconds) for distributed-connected MW systems

Analysis
Worst-case would be to assume PV ramp from zero to full output BEFORE regulation equipment operates

Voltage Impacts
- Solar PV can change voltage faster than feeder regulation equipment can respond, thus resulting in potential overvoltages
- Can result in excessive regulator operations
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Distributed Generation: Feeder Hosting Capacity

- Distributed Generation
- Feeder Hosting Capacity

With DG
- With DG @ PF
- Without DG

Normal Planning Limit

Voltage
- 105%
- 95%

Distance from Substation
Distributed Generation: Feeder Hosting Capacity
Distributed Generation: Feeder Hosting Capacity
EPRI Feeder Modeling
1. OpenDSS is used for feeder modeling
2. Models are solved without PV
3. Regulator and Capacitor controls are “locked in place”
4. A little distributed PV is added
5. Model is solved with distributed PV
6. Overvoltage and voltage flicker conditions are assessed
7. Go back to step 4 and repeat
Hosting Capacity: Maximum Feeder Voltage Violations

Solar Inverters Generate kW only (Standard)

Maximum Feeder Voltages (pu)

5000 cases shown
Each point = highest primary voltage

Increasing penetration (kW)

ANSI voltage limit
Hosting Capacity: Maximum Feeder Voltage Violations

- Feeder D3
- Feeder D2
- Feeder D1
- Feeder P5
- Feeder P4
- Feeder P3
- Feeder P2
- Feeder P1
- Feeder G1
- Feeder T2
- Feeder T1
- Feeder R4
- Feeder R3
- Feeder R2
- Feeder R1
- Feeder J1

Small Scale (MW)

- All penetrations in this region are acceptable, regardless of location
- Some penetrations in this region are acceptable, site specific
- No penetrations in this region are acceptable, regardless of location
Increasing Hosting Capacity

Smart Inverter Functions
• Remote connect/disconnect
• Maximum Generation Limits
• Ramp Rates / Storage
• Fixed Power Factor
• Volt-var – Variable var output, based on local voltage
• Volt-Watt – Variable watt output, based on local voltage
• Fast Volt-var – Fast Response to changing voltage
• Fast Volt-Watt – Fast Response to changing voltage
• Watt based Power Factor control
Increasing Hosting Capacity

Smart Inverter Functions

- Remote connect/disconnect
- Maximum Generation Limits
- **Fixed Power Factor**
  - Volt-var – Variable var output, based on local voltage
  - Volt-Watt – Variable watt output, based on local voltage
  - Fast Volt-var – Fast Response to changing voltage
  - Fast Volt-Watt – Fast Response to changing voltage
  - Watt based Power Factor control
Distributed Generation: Feeder Hosting Capacity

[Diagram showing voltage levels with and without distributed generation (DG) at points along a feeder.]
Hosting Capacity: Minimizing Feeder Voltage Violations

Solar Inverters Generate kW and Consume vars
Hosting Capacity: Maximum Feeder Voltage Violations

- Distributed Generation – Feeder Hosting Capacity

EAP Meeting
March 2014

FirstEnergy
Hosting Capacity: Fixed Power Factor

The optimal Power Factor for mitigation of voltage fluctuation:
• Varies by location on feeder & per feeder
• Will change over time as system configuration changes

\[ PF_{DG} = \frac{X/R}{\sqrt{(X/R)^2 + 1}} \]
Increasing Hosting Capacity – Solution for Voltage Profile

Issues with Distributed Generation Operation at a Fixed Power Factor:

• Every PV project needs to operate at a fixed power factor
• A “default” power factor needs to be developed for small projects
• The utility needs to be able to “specify” an operating power factor for larger projects
• The Utility needs to be able to make this requirement for all DG, not just the last guy that broke the system
Distributed Generation: Feeder Hosting Capacity

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References

- Distributed PV Monitoring and Feeder Analysis Web Page, EPRI.com
- Impact of High-Penetration PV on Distribution System Performance: Assessment of Regulation Control Options for Voltage Mitigation, Document Number 1024355, EPRI, Palo Alto, CA, 2012.
Distributed Generation: Feeder Hosting Capacity

- Applications are reviewed and approved on a first-in first-out basis (§ 75.13)
- Level 1 (<= 10 kW, UL Listed, Inverter-based) (§ 75.34)
  - 10 days, application complete (§ 75.37 (c)(1))
  - 15 days, verification dg can be interconnected (§ 75.37 (c)(2))
- Level 2 (<= 2 MW, UL Listed, Inverter-based) (§ 75.34)
  - 10 days, application complete (§ 75.38 (c)(1))
  - 20 days, verification dg can be interconnected (§ 75.38 (c)(1))
Distributed Generation: Feeder Hosting Capacity

• Level 3 (<= 2MW, not Level 1 or 2) (§ 75.34)
  – 10 days, application complete (§ 75.39 (b)(2))
  – 10 days, Scoping Meeting (after app, or failing other level) § 75.39 (b)(4)
  – Feasibility Study (can include multiple locations) (§ 75.39 (c))
  – System Impact Study (§ 75.39 (d))
  – Facilities Study (§ 75.39 (e))
• Level 4 (no export, not Level 1 or 2) (§ 75.34)
Distributed Generation: Feeder Hosting Capacity

- Review typical technical constraints on feeder hosting capacity
- Level 1
  - <15% of line section peak
  - <5% of spot network peak
  - <20 kW of on shared secondary line
  - <20% transformer imbalance on single-phase service
  - No EDC construction
Distributed Generation: Feeder Hosting Capacity

• Review typical technical constraints on feeder hosting capacity

  • Level 2
    – <15% of line section peak
    – <5% of spot network peak
    – <10% contribution to circuit’s max fault current at POC
    – Protective devices <85% of interrupting capacity
    – <20 kW of on shared secondary line
    – <20% transformer imbalance on single-phase service
    – Aggregate DG < 2 MW in vicinities of transient stability limitations