PV Hosting Capacity on Distribution Feeders

Jeff Smith, Matt Rylander
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Key Factors that Determine How Much PV a Feeder Can Accommodate (Hosting Capacity)

- Size of PV
- Location of PV
- Feeder characteristics
- Electrical proximity to other PV
- Unique solar resource characteristics in the area
- PV control

![Diagram showing voltage rise and "headroom" near substation and at the end line.](image)
Key Requirements to Determine Hosting Capacity

• Distribution characteristics
  – Voltage response
  – Short-circuit response
  – Locational information
  – Accurate feeder Models
  – Proxy feeders aren’t sufficient

• PV characteristics
  – Location
  – Size
  – What about time?

*all simulations performed with OpenDSS
Feeder Hosting Capacity: A Brief Primer

Baseline – No PV
PV Penetration 1
PV Penetration 2
PV Penetration 3
Beyond…

Increase Penetration Levels Until Violations Occur
- voltage
- protection
- power quality
- thermal

Process is repeated 100’s of times to capture many possible scenarios
Hosting Capacity

Overvoltage Results Shown for Feeder J1

Minimum Hosting Capacity

Maximum Hosting Capacity

2500 cases shown
Each point = highest primary voltage

Maximum Feeder Voltages (pu)

Increasing penetration (kW)

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

ANSI voltage limit

Voltage violation
Industry-Wide Assessment

Collaborative Effort

- >30 feeders to date throughout US
- Methodology
  - Consistent
  - Transparent
- Open-source tools
- Advanced application of traditional planning techniques

Details on analysis method:
Sample Results from Single feeder
Small-Scale (Residential/Commercial)

Feeder Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>kV</td>
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<tr>
<td>Pk Ld</td>
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<td>Min Ld</td>
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<td>Total Regs</td>
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<td>Setpoint</td>
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<tr>
<td>Band</td>
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<td>Total Caps</td>
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<td>Avg Z</td>
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<td>Min Z</td>
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<tr>
<td>Max XR</td>
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<td>Total Miles</td>
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<td>End of Line Length</td>
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<td>Avg R</td>
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<td>End of Line MVA</td>
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<td>Min Headrom</td>
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<td>Load Center R</td>
<td>5.90</td>
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Hosting Capacity Results

Feeder Issue

- Overall
- OpenPhaseV
- FFault
- FuseSave
- MaxV
- RedReach
- SymTrp
- SecondaryOV
- SecondaryVdev
- PrimaryImb
- PrimaryRegVdev
- PrimaryVdev
- PrimaryOV

Hosting Capacity (MW)
Summary of Results from 18 Feeders

Research results found here:


*Voltage-based hosting capacity shown.
Summary of Results from 18 Feeders

Research results found here:

<table>
<thead>
<tr>
<th>Feeder</th>
<th>Small-Scale Distributed</th>
<th>Large-Scale Distributed</th>
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</table>

- 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

*Voltage-based hosting capacity shown*
Detailed Hosting Capacity Analysis

Can load be used to predict hosting capacity?

No correlation between hosting capacity and peak load

Not without knowledge of other feeder characteristics
How Effective are Current Screening Practices?
Keeping in mind, “screens” should be conservative by nature…

Feeders at risk for PV to pass through screens without issues being flagged

15% peak and 100% minimum load overestimates hosting capacity on many feeders
Correlation to Feeder Characteristics
Small-Scale PV, Primary Voltage Deviation Hosting Capacity

• Strong correlation
  – Number of line regulators
  – Total circuit length
  – End of line length
  – Load Center Location
  – PV Center Location
Next Step Applications

- Developing better screening techniques for solar PV
- Developing streamlined methods for determining hosting capacity
  - Application across entire service territory (100’s to 1000’s of feeders)
  - Commercial software
- Identifying technical solutions for accommodating higher penetration levels
Conclusions

• **Consistent and repeatable** methodology allows greater understanding of impacts due to
  – Location of PV
  – Feeder characteristics
• Many of issues start arising at secondary level
  – Models typically don’t go there!
• Trends in hosting capacity dependency are found
  – Regulation, line impedance, and load location
  – Load level not so much
• Other factors play in as well
  – How close to thresholds in basecase (headroom)
Questions

Contact:
Jeff Smith
Manager, Power System Studies
EPRI
jsmith@epri.com