Hosting Capacity & Interactive Maps

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MADRI Working Group Meeting #49

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Solar Utility Networks: Replicable Innovations in Solar Energy (SUNRISE)

Model-Based Integrated High Penetration Renewables Planning and Control Analysis
Award # DE-EE0006328

SunShot U.S. Department of Energy

edd

Rutgers Edward J. Bloustein School of Planning and Public Policy

Clean Power Research

State of New Jersey Board of Public Utilities

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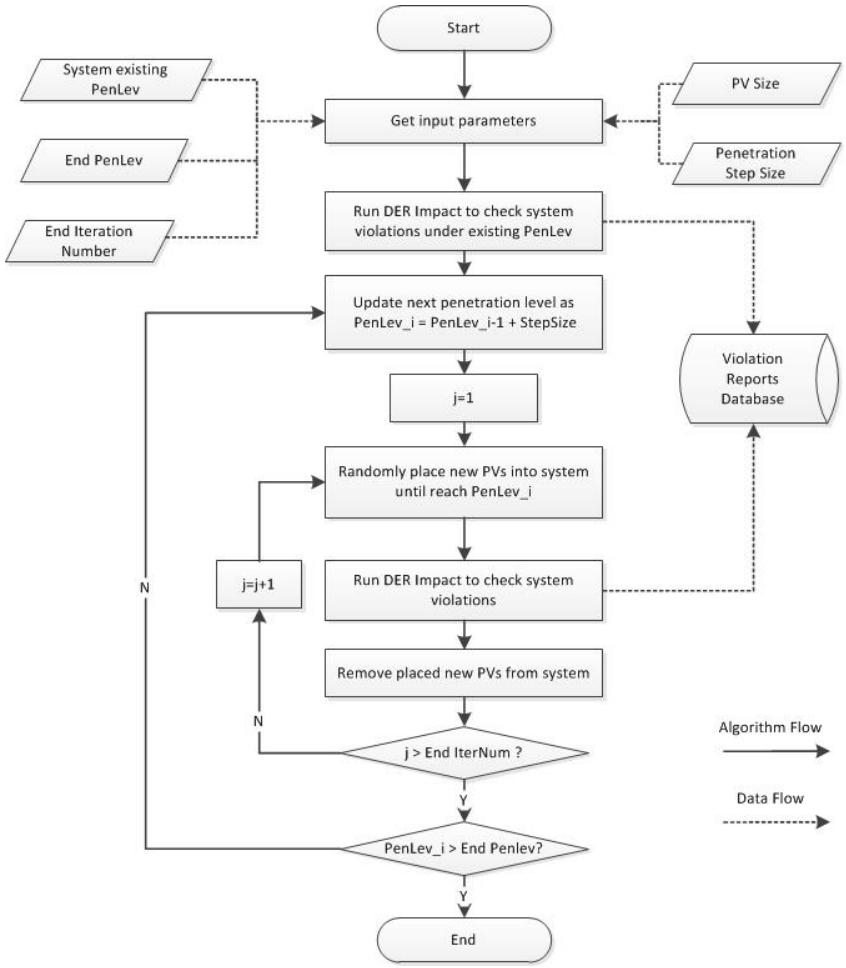
Hosting Capacity Analysis

- Place new PV sites at randomly selected customers on the circuit in order to satisfy the PV Penetration level under test.
- Once the PV is placed the circuit is tested for violations such as over/under voltage and overloads, flicker sensitivity, reverse flows (see table on next slide for full list of violations tested).
- This random placement process is repeated a number of times for each penetration level in order to build a stochastic set of results.
- Steps to the next PV Penetration Level and repeats the random placement and violation testing process
- The user is able to specify PV penetration levels to test, the size of the placed PV sites, the violations to check for and the number of placement iterations.



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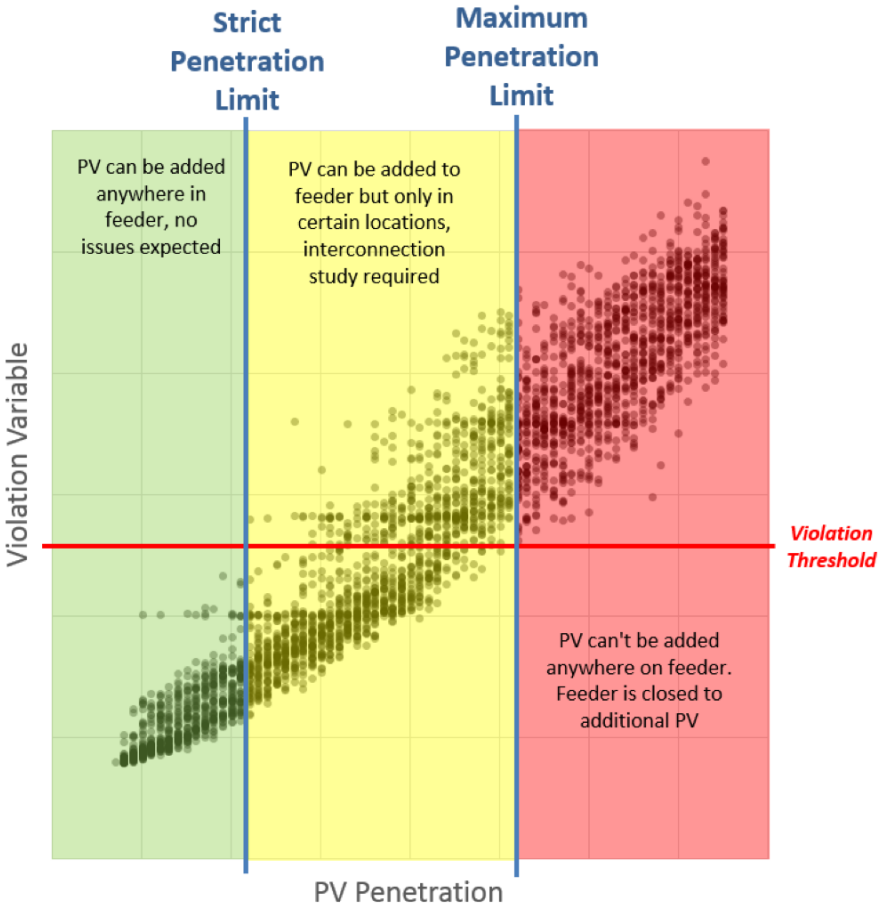
Hosting Capacity Violations

Violation Variable	Comparison	Threshold	Units	Comment
Customer Level Overvoltage (Steady-State)	>	123.5	Volts	Secondary
Customer Level Undervoltage (Steady-State)	<	116.5	Volts	Secondary
Line Transformer Overvoltage (Steady-State)	>	123.5	Volts	Primary
Line Transformer Undervoltage (Steady-State)	<	116.5	Volts	Primary
Line Transformer Temporary Overvoltage (During PV output Change)	>	126	Volts	Primary
Line Transformer Temporary Undervoltage (During PV output Change)	<	114	Volts	Primary
Generator POI Overvoltage (Steady-State)	>	126	Volts	at POI
Generator POI Undervoltage (Steady-State)	<	114	Volts	at POI
Generator POI Temporary Overvoltage (During PV output Change)	>	126	Volts	at POI
Generator POI Temporary Undervoltage (During PV output Change)	<	114	Volts	at POI
Generator POI Flicker Sensitivity (Irritability - PV Step Up)	>	2	Volts	at POI
Generator POI Flicker Sensitivity (Irritability - PV Step Down)	>	2	Volts	at POI
Voltage Change at Voltage Controller (During PV output Change)	>	1/2 BW	Volts	at Vreg or Cap
Voltage Regulator Reverse Flow	<	-0.1	kW	Reverse Power
Protective Device Reverse Flow	<	-0.1	kW	Reverse Power
Feeder Reverse Flow	<	-0.1	kW	Reverse Power
Feeder Current Imbalance	>	20	%	
Component Voltage Imbalance	>	3	%	
Component Overload	>	100	%	

PV output step change used for analysis: 100% - 20% on all PV sites (% of clear sky output)
Analysis performed at time point with maximum generation / load ratio

PV Penetration Limits

- Each point corresponds to one random placement of PV satisfying the PV Penetration on the Horizontal axis
- Vertical position of each point is the highest observed violation value for that placement of PV
- If the point falls above the violation threshold it represents a placement of PV which results in an issue on the circuit
- The ***Strict Penetration Limit*** occurs at the point below which all tested random placements are under the violation threshold
- The ***Maximum Penetration Limit*** occurs at the point past which all tested random placements are above the violation threshold



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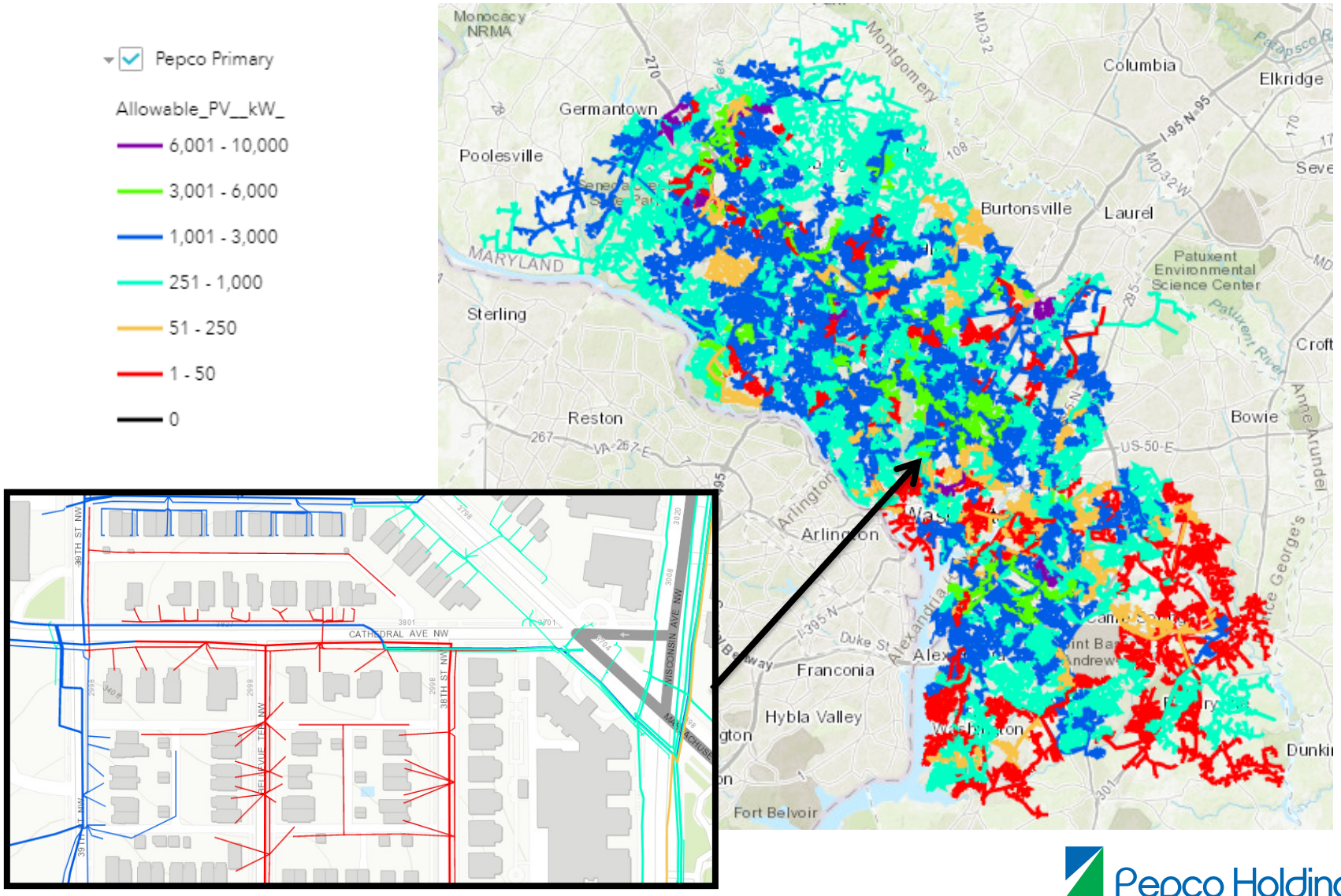
Hosting Capacity (Radial)



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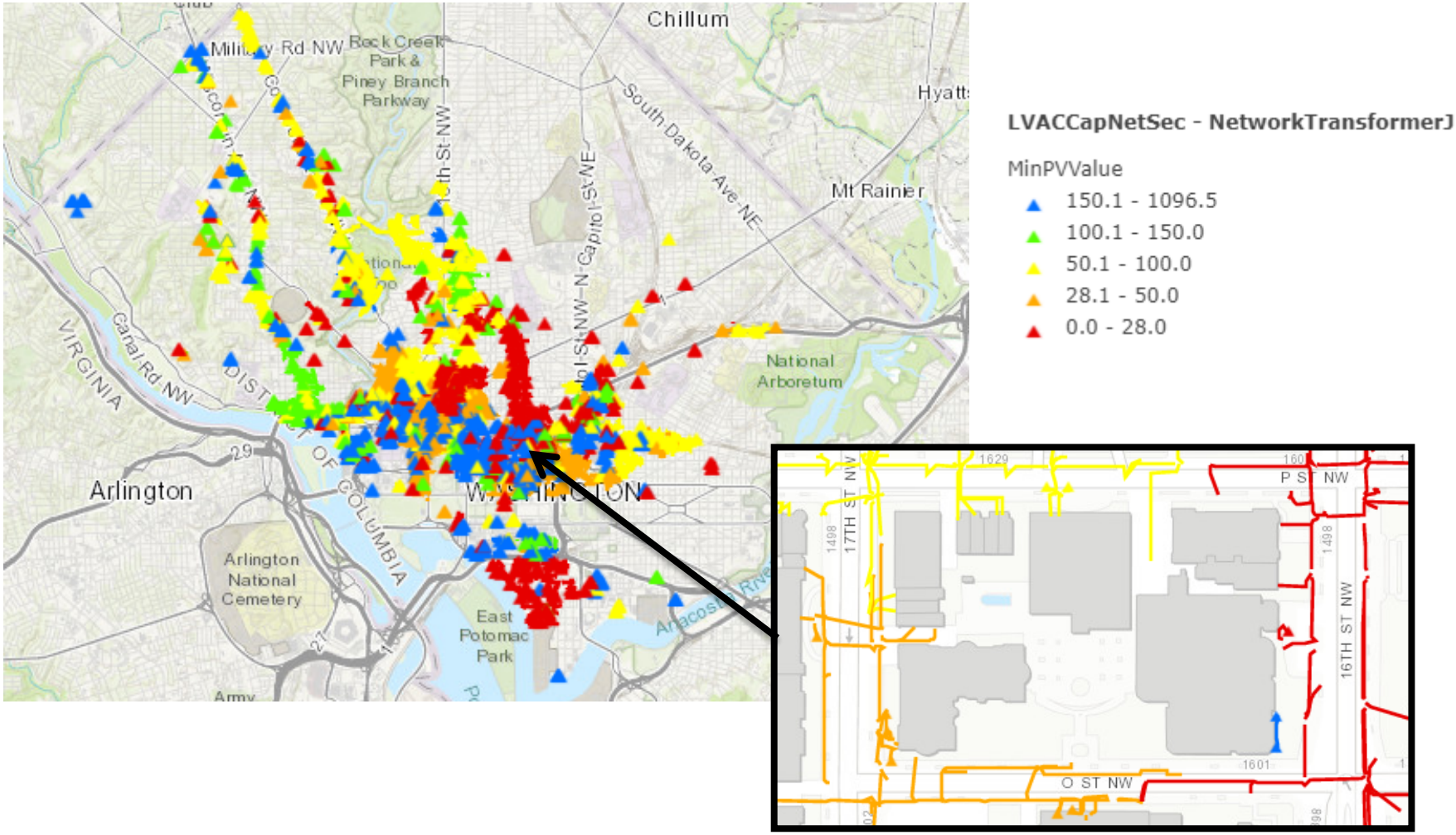
Hosting Capacity (Network)



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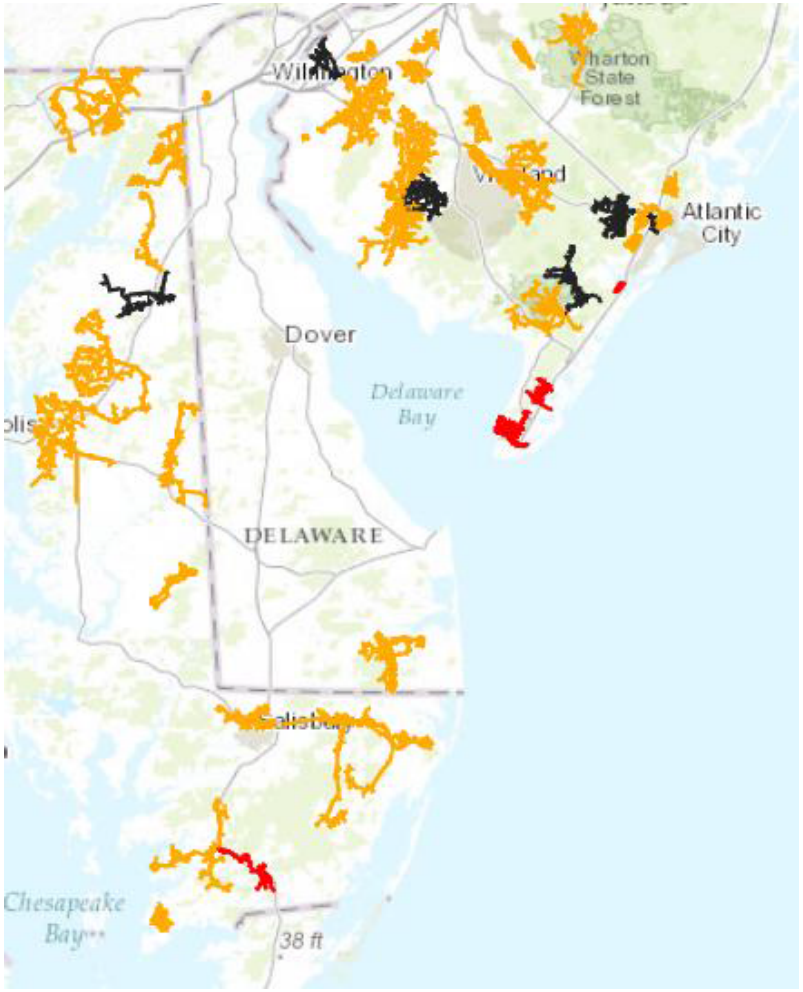
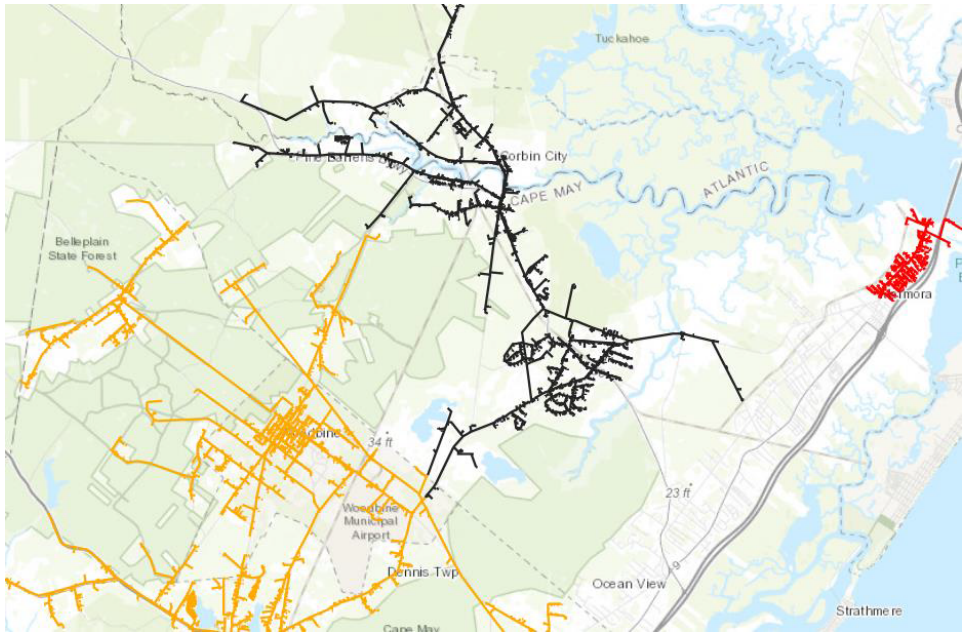
Restricted Circuit



Maximum System Size of 250kW

Maximum System Size of 50kW

Maximum System Size of 0kW



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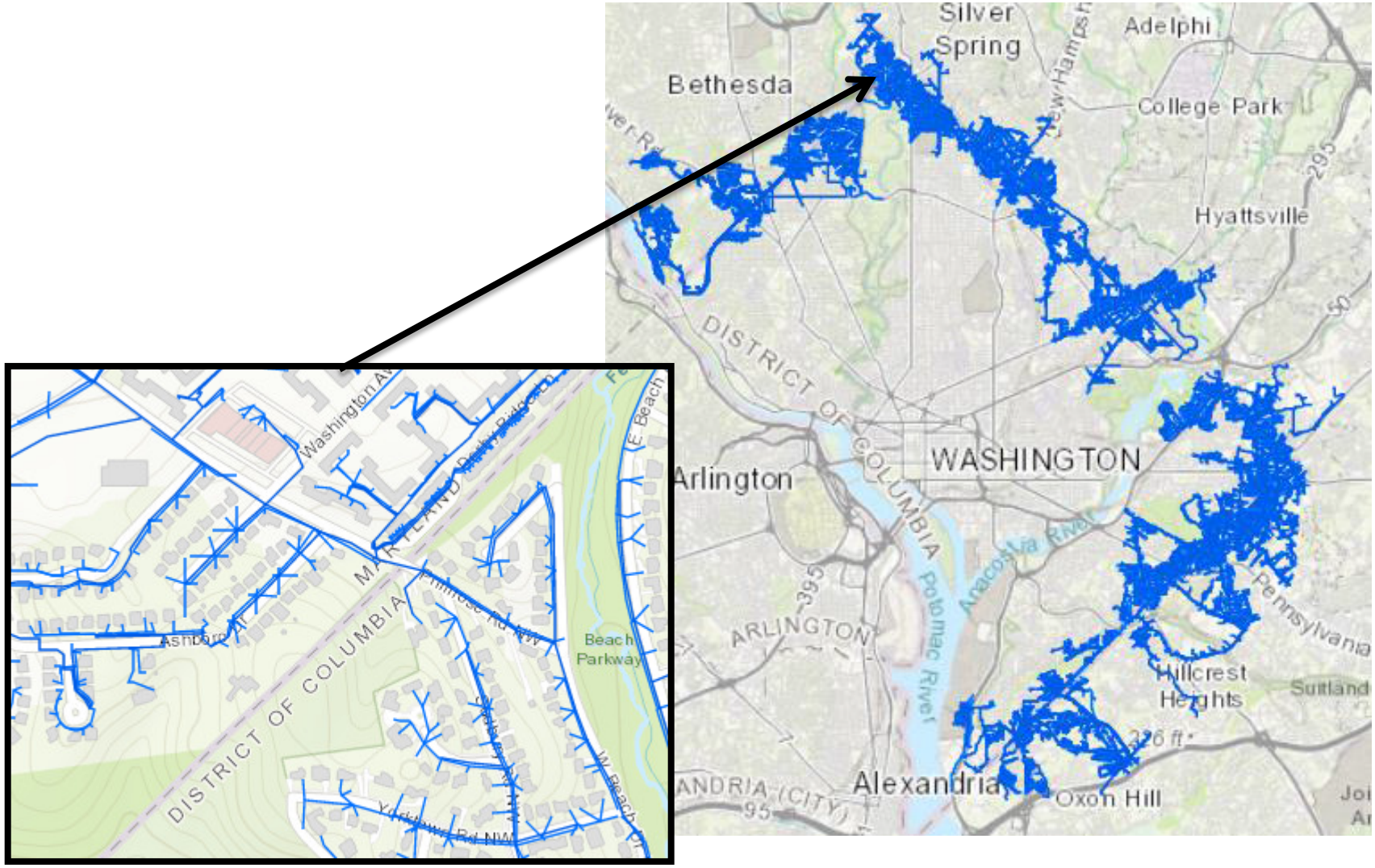
Cross-Border Map



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Solar Heat Map

Total PV - 4kV

Total PV
- 0 to 125 kW
- 125 to 250 kW
- 250 to 500 kW
- 500 to 1,000 kW
- 1,000 kW

Total PV - 23-25kV

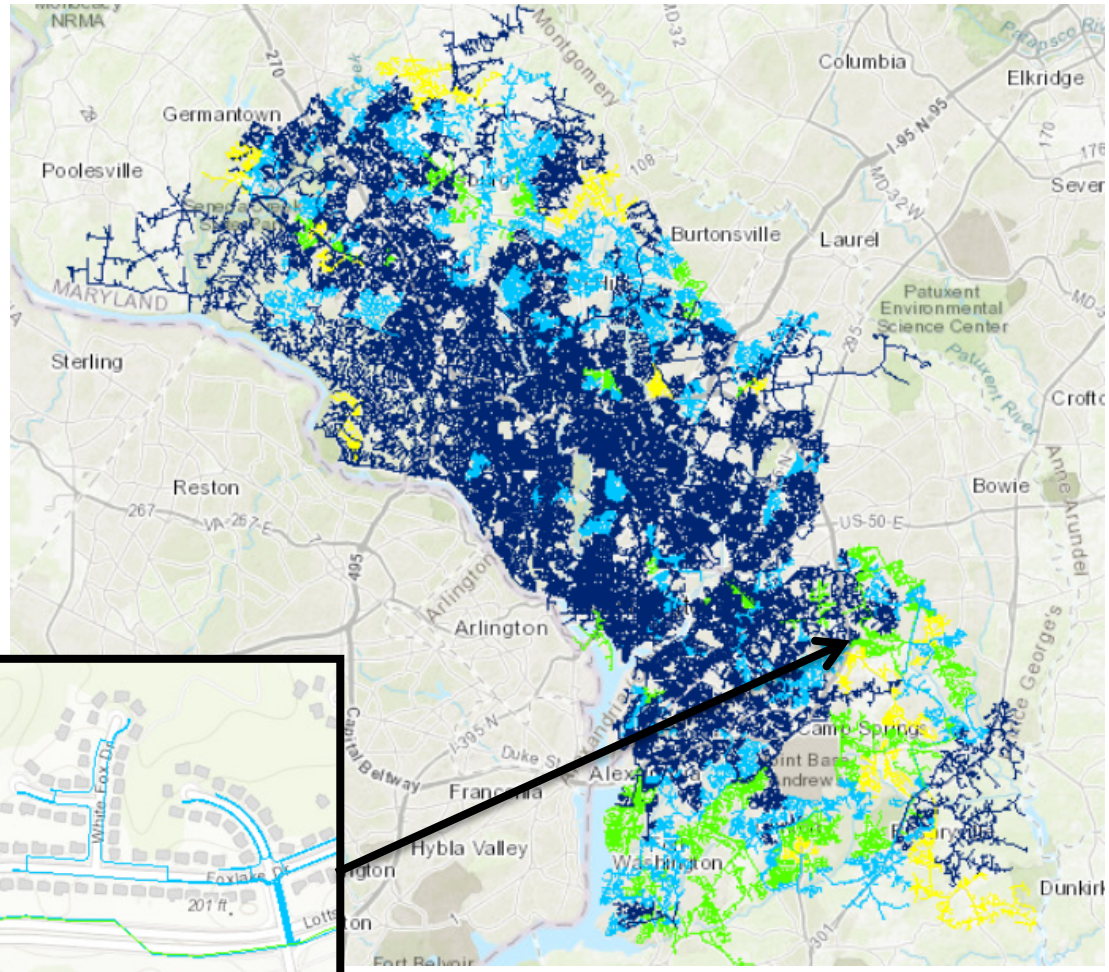
Total PV
- 0 to 1,000 kW
- 1,000 to 2,000 kW
- 2,000 to 4,000 kW
- 4,000 to 8,000 kW
- 8,000 kW

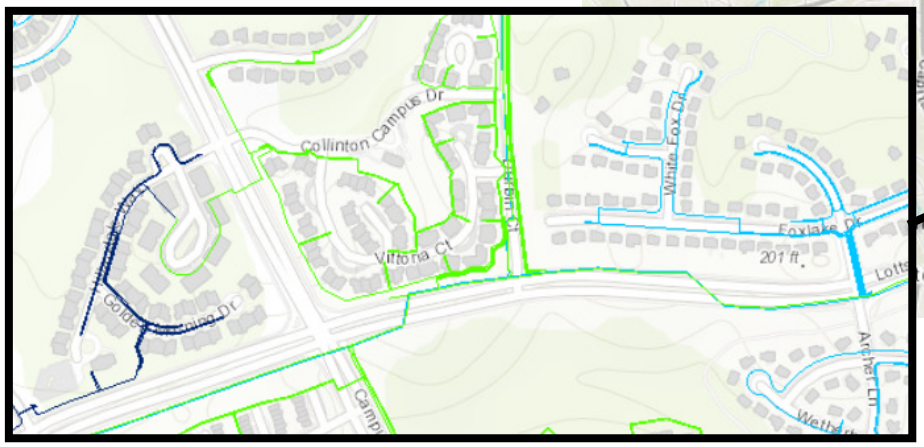
Total PV - 12-13kV

Total PV
- 0 to 500 kW
- 500 to 1,000 kW
- 1,000 to 2,000 kW
- 2,000 to 4,000 kW
- 4,000 kW

Total PV - 34kV

Total PV
- 0 to 1,750 kW
- 1,750 to 3,500 kW
- 3,500 to 7,000 kW
- 7,000 to 14,000 kW
- 14,000 kW





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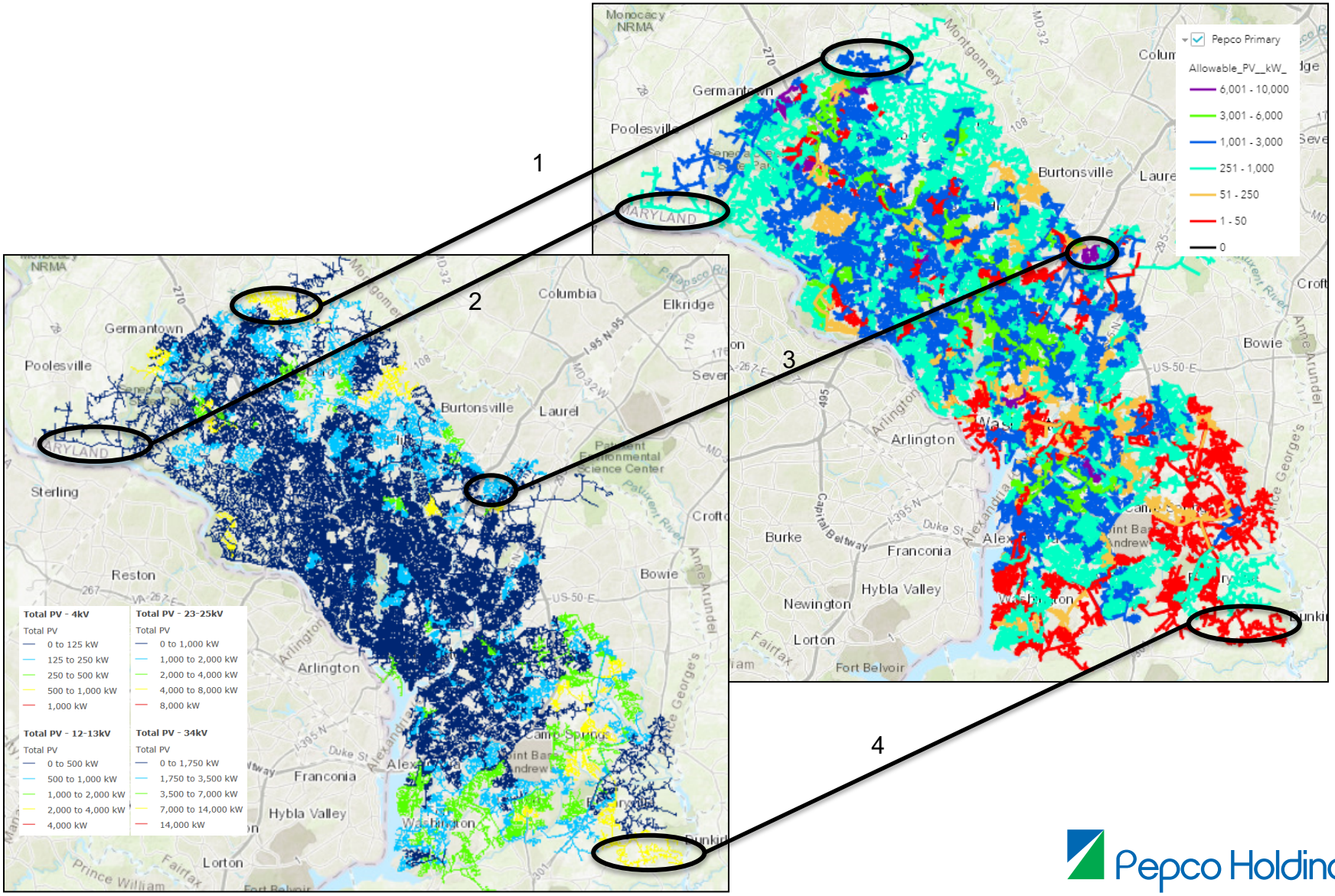
Solar Heat Map vs Hosting Capacity



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Example Feeder (Study Feeder 16)

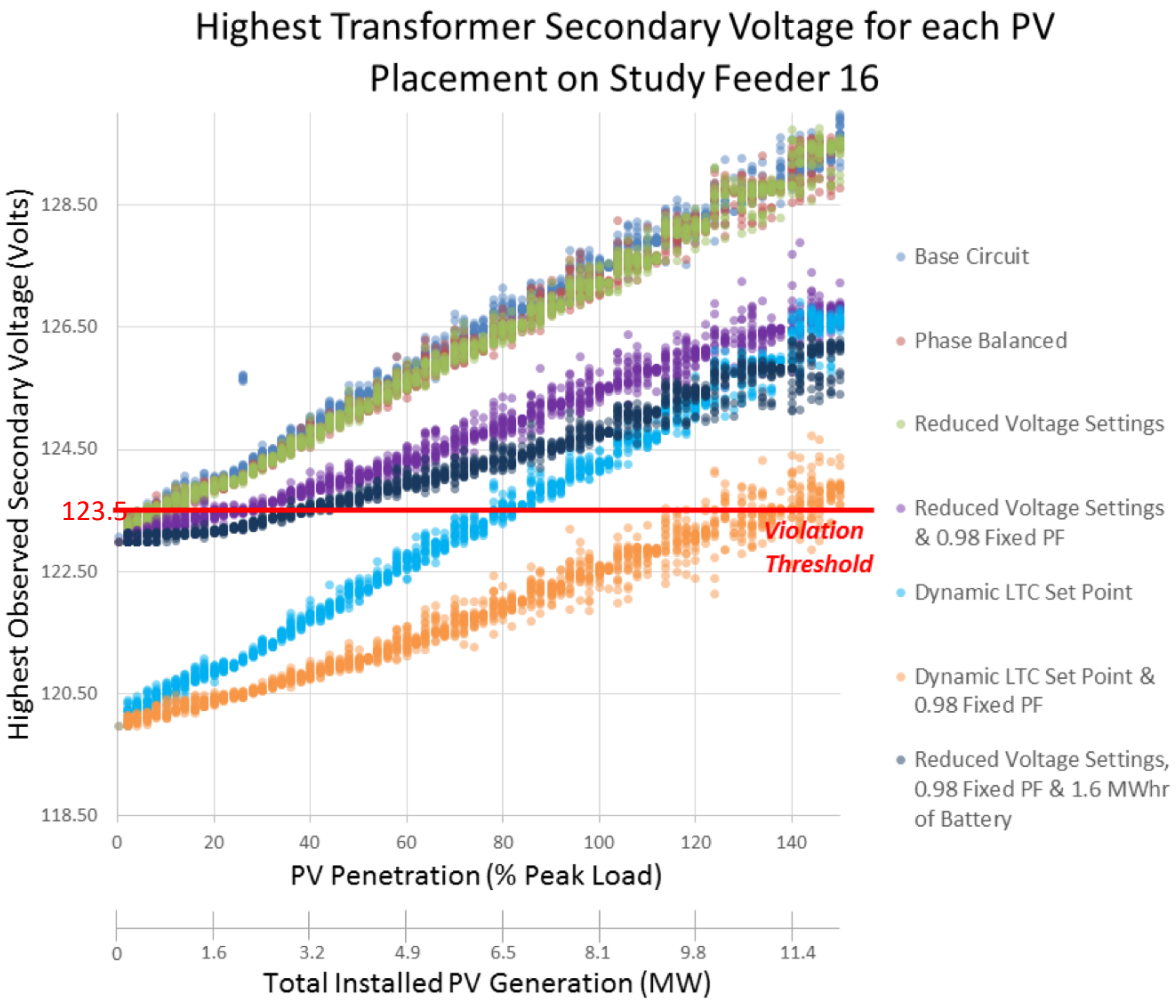
- Contains newer 34.5 kV primary out of sub and on most of backbone, also has several areas of older 4.15 kV primary connected through step transformers
- One of the longer feeders in the study, three voltage regulation zones (plus sub LTC), four voltage controlled switched cap banks, one fixed cap bank
- Poorer voltage regulation on the 4.15 kV sections and phase imbalances limit the PV penetration of base circuit to about **6%**, limited by customer steady-state high voltages

Study Feeder 16 Summary	
Feeder Type	Res
Primary Voltage	34.5 kV Y-G and 4.15 kV Y-G
Feeder Length (total circuit miles)	64 mi
Distance from Sub to Furthest Load	12.8 mi
Peak Load (SCADA)	8.1 MW
Minimum Daytime Load (SCADA)	2.4 MW
Number of Distribution Transformers	331
Connected KVA (total xfrmr rating)	65 MVA
Number of Capacitor Banks	5
Total Capacitor Bank Rating	7.8 MVAR
Number of Voltage Regulation Zones	3
Number of Existing PV Sites	2
Total Existing PV Generation	15 kW
Existing PV Penetration	< 1%

Feeder Improvements

- ***Base***: circuit as-is (existing PV included)
- ***Balanced***: phase balancing performed on the base case
- ***Capacitor Design***: moves existing or places additional capacitors in order to flatten feeder voltage profile and optimize the capacitor placement
- ***Reduced Voltage Settings***: voltage regulation and LTC set-points lowered as far as possible while still maintaining acceptable customer voltages at peak load.
- ***Dynamic Voltage Control***: voltage regulation and LTC set-points are adjusted over time to be as low as possible while still maintaining acceptable customer voltages at each time point (i.e. using FSMA tool to determine optimal Vreg settings over time).
- ***Fixed PF***: power factor of randomly placed inverters are set to a fixed, absorbing power factor of 0.98. Existing PV sites are unmodified (i.e. all new PV on feeder required to operate at 0.98 absorbing).
- ***Battery Storage***: battery storage in a daily charge/discharge schedule is added to circuit in order to add effective load at peak PV production times.

Example Feeder (Study Feeder 16)



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Strict Penetration Limit Increase for Each Feeder

Strict Penetration Limit (Before and After)						
Feeder	Base Case			Max. Penetration w/ Upgrades		
	PV (%)	PV (MW)	Cost (k$)	PV(%)	PV(MW)	Cost(k$)
1	29.7	1.0	0.0	167.9	5.9	60.2
2	29.7	1.5	0.0	197.1	10.4	32.5
3	53.6	2.2	67.9	264.7	10.9	149.3
4	34.9	1.2	0.0	134.5	4.8	22.0
5	43.7	2.0	67.3	193.7	8.7	96.8
6	38.9	2.6	0.0	219.6	14.5	78.5
7	36.9	1.9	0.0	92.7	4.7	131.4
8	23.8	1.4	0.0	129.2	7.6	2.0
9	1.9	0.1	0.0	161.3	8.1	21.0
10	12.8	0.3	0.0	62.9	1.6	27.5
11	39.0	2.0	37.2	61.0	3.1	178.3
12	8.0	0.7	37.2	11.9	1.0	118.7
13	2.9	0.2	0.0	104.9	5.8	150.2
14	15.9	1.5	0.0	18.0	1.7	33.0
15	20.0	1.6	0.0	76.0	6.2	21.5
16	5.9	0.5	59.7	63.9	5.2	167.1
17	17.0	2.0	0.0	104.9	12.1	31.0
18	42.9	2.8	0.0	336.7	22.2	25.0
19	25.9	1.6	74.0	67.8	4.1	80.0
20	44.9	2.7	0.0	184.6	11.0	2.5
AVERAGE	**26.4**	**1.5**	**17.2**	**132.7**	**7.5**	**71.4**

← Minimum

← Maximum

Notes: The above does not include battery deployment
The above feeders represent different voltage levels.

Conclusions

- Every feeder is unique and can have a different hosting capacity
- Small differences in feeder set up, can make big hosting capacity differences
- There are a number of methods to leverage existing equipment to increase Hosting Capacity and provide Voltage Head Room
- Phase Balancing shows little direct impact, but it is important to keep the circuit balanced as PV penetration increases
- Dynamic Volt/VAR will take new controls, communications and central logic to run. Some utilities have already implemented Volt/VAR control, but may need some new logic
- Smart Inverters have a lot of promise but modeling and operation at high penetration levels still poses some unknowns
- Even after resolving Voltage issues, reverse power on V. Regulators and Power transformers, Distribution Automation Schemes, Protection and Coordination issues will make analysis more complex
- For higher penetration levels on the distribution system, it will be important to keep an eye on the Transmission system

Questions / Comments