CSI3 RD&D3: Screening Distribution Feeders: Alternatives to the 15% Rule

Task 6 Update: PV Hosting Capacity Analysis of *SDG&E Feeders*

10/21/2014

Overview

- **Background**
  - **More PV interconnected at distribution level than any other DG**
    - **Small rooftop PV**
    - **Large, MW-class systems**
  - **Increased pressures for utilities to**
    - **accommodate higher levels of PV**
    - **expedite interconnection process**
- **Project Objective:** Develop new methods to quickly and accurately determine the capacity of individual feeders for PV generation
  - **Consider size/location of PV and specific feeder characteristics**
  - **Evaluate impact on voltage (overvoltage, voltage fluctuations), regulation equipment, protection, thermal loading/reverse power**

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Why Consider Alternatives to Existing Screening?

- Feeder's ability for hosting PV w/o adverse impact on performance depends upon many feeder-specific factors
- 15% "rule-of-thumb" is not very accurate in determining whether an issue may arise
- Simple characteristics used to classify/screen feeders (i.e. peak load level) may not be sufficient
- Example illustrates different hosting capacity for "similar" circuits

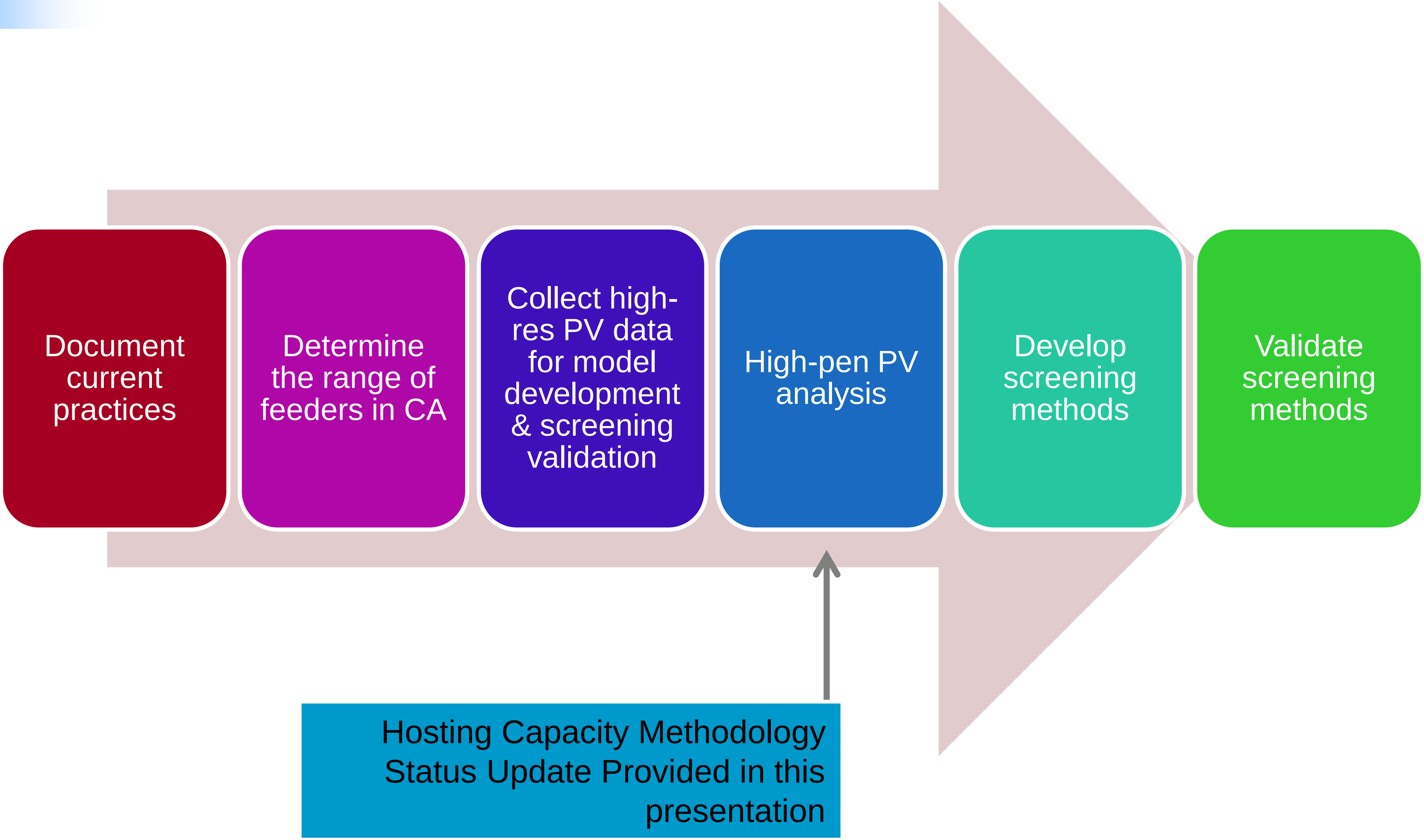
Sample feeders from DOE-funded VT/EPRI Hi-Pen Project

Feeder Characteristics	Feeder A	Feeder B
Voltage (kV)	13.2	12.47
Peak Load	5 MW	6 MW
Minimum Load	0.8 MW	0.7 MW
Minimum Daytime Load	1.1 MW	0.7 MW
Existing PV (MW)	1.0	1.7
Feeder Regulation	Only @ Substation	Yes, highly regulated
Total Circuit Miles	28	58
Feeder "Footprint"	7 mi^2	35 mi^2
Minimum Hosting Capacity		
Due to Voltage Impacts	**>3500 kW**	**250 kW**

70% of Peak Load (Feeder A)

4% of Peak Load (Feeder B)

Approach



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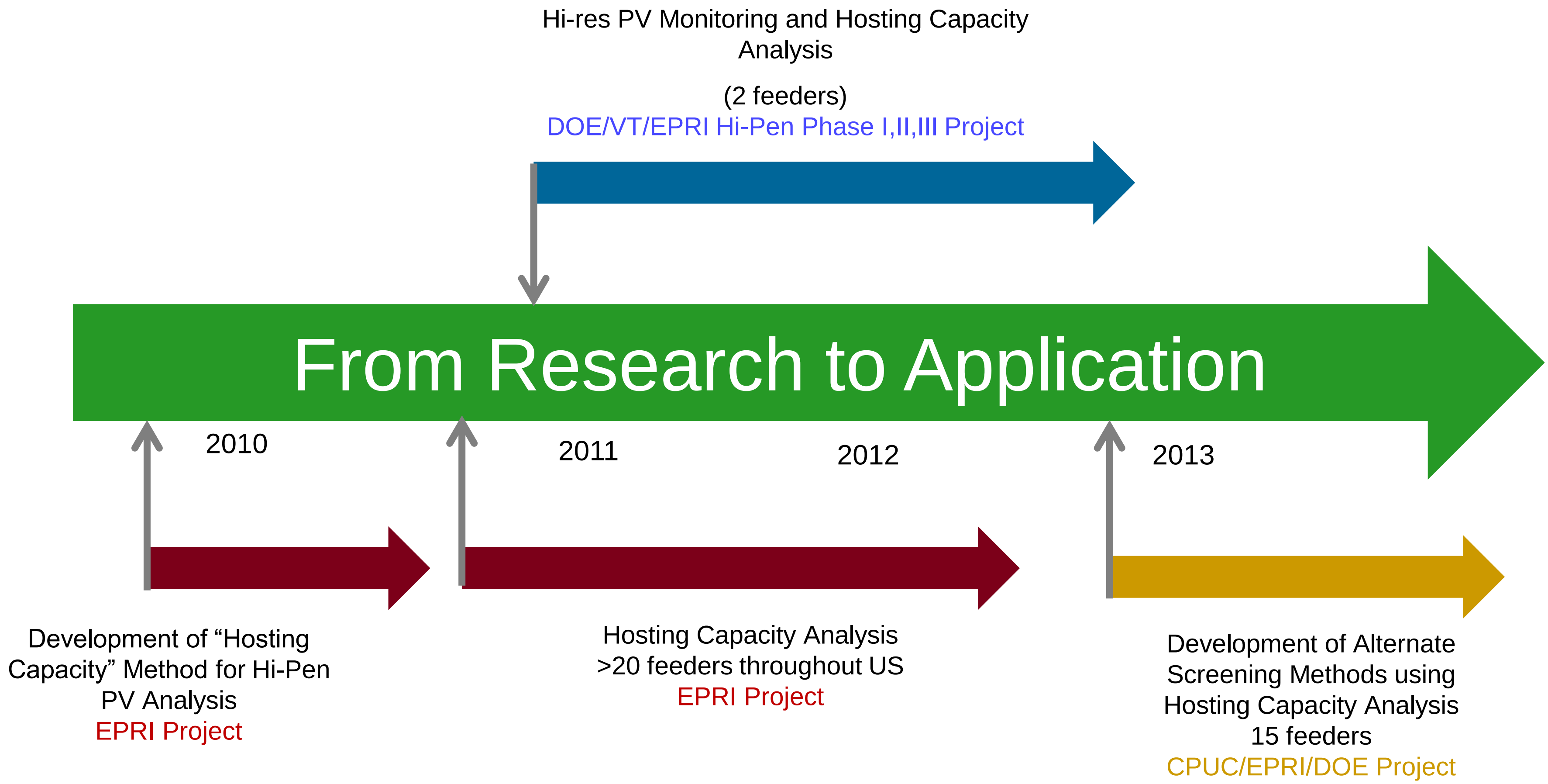
Leveraging Work Throughout Industry



Project Partners

SOUTHERN CALIFORNIA EDISON
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PG&E Pacific Gas and Electric Company®

SDG&E
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Agenda

- CPUC CSI3 Project Update
- Distributed PV Study Overview
- Study Feeders
- Results
- Simplified screening

Project Status

		PG&E	SDG&E	SCE
Feeder data collection	Clustering analysis to identify general differences **			
	Select one feeder from each cluster to ~~represent~~ span a range of feeder characteristics			
Feeder analysis	Model feeders in OpenDSS			
	Run detailed PV hosting capacity analysis			
	Aggregate results			
Develop Improved PV Screen				

**Clustering Method and Representative Feeder Selection for the California Solar Initiative, Authors: Robert J. Broderick, Joseph R. Williams, Karina Munoz-Ramos (SAND2014-1443, 1.41MB)

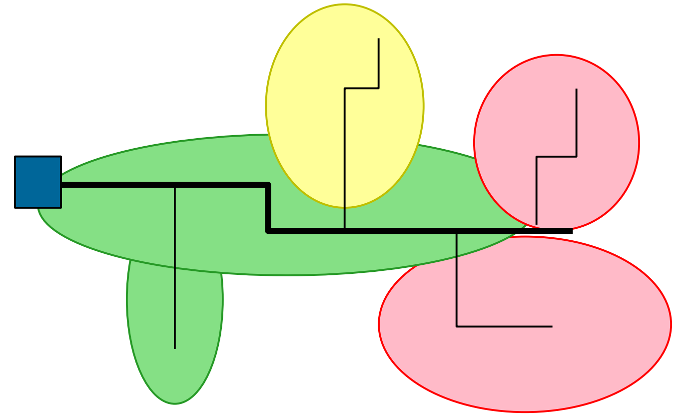
Detailed Feeder Study Overview

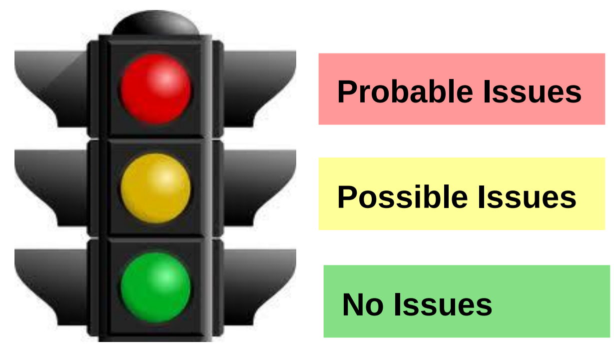
Methodology Utilized in Industry-Wide Distributed PV (DPV) Study

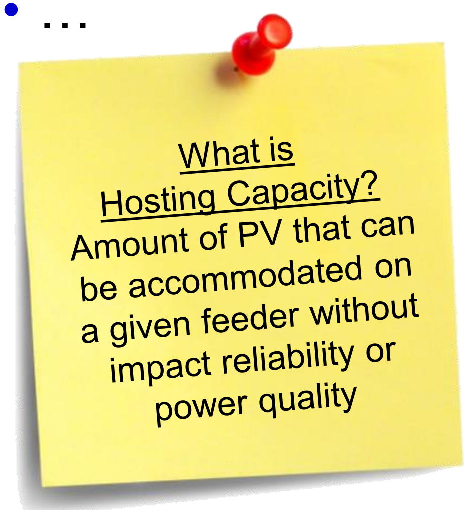
DPV Feeder Analysis: Hosting Capacity

What are we trying to achieve?

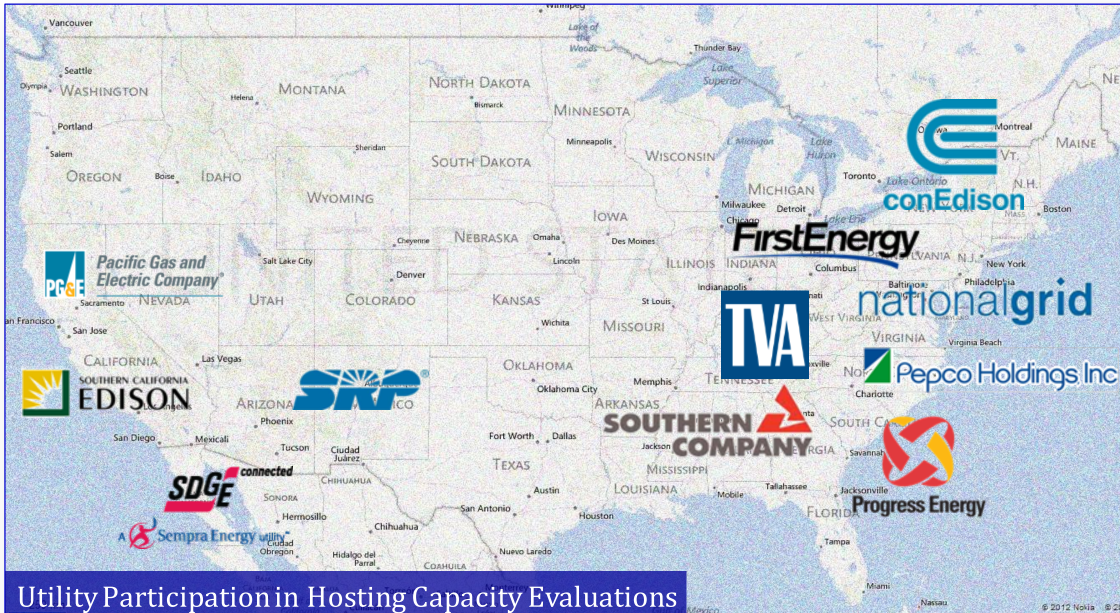
- Better understanding of when, where, and why problems might occur on my feeder
- What are the limiting factors
- Why can one feeder accommodate more than another
- What makes one feeder more problematic than another
- …







Leveraging Hosting Capacity Work Throughout US



Main map: © 2012 Microsoft Corporation. Imagery © Microsoft – available exclusively by DigitalGlobe (Bing Maps Terms of Use: http://go.microsoft.com/?linkid=9710837). Inset map: Map data © 2012 Google

Details on analysis method:
Stochastic Analysis to Determine Feeder Hosting Capacity for Distributed Solar PV. EPRI, Palo Alto, CA: 2012. 1026640.

Collaborative Effort

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

Evaluation Criteria

Voltage

- Overvoltage
- Voltage deviations
- Unbalance

Protection

- Increased fault current contribution
- Unintentional islanding
- Sympathetic tripping
- Fuse saving
- Reduction of reach

Power Quality

- Total harmonic distortion
- Individual harmonics

Loading

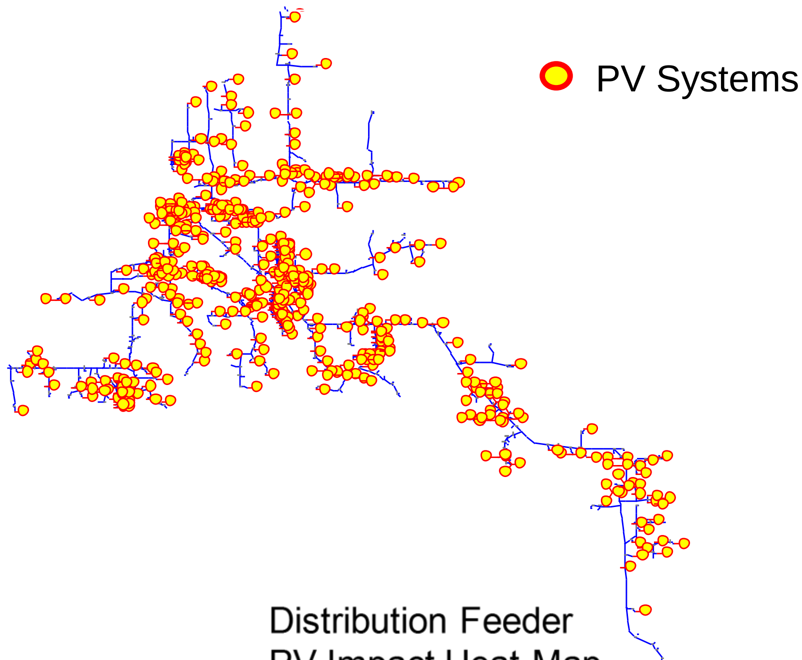
- Thermal overloads

Feeder Impact

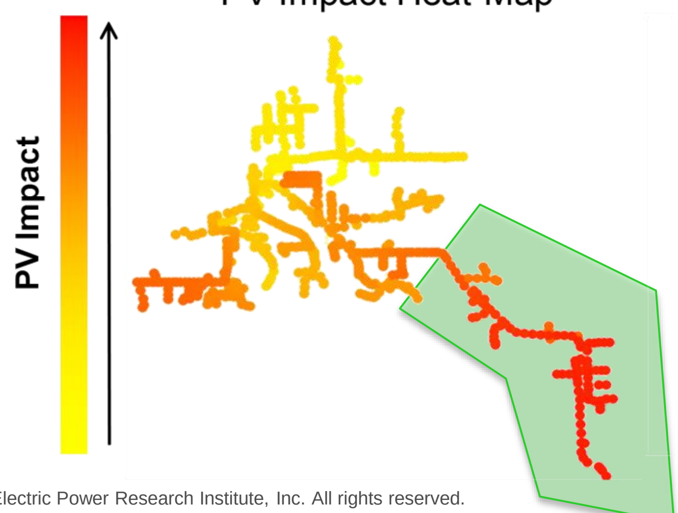
Hosting Capacity Response Thresholds

Category	Criteria	Basis	Flag
Voltage	Overvoltage	Feeder voltage	≥ 1.05 Vpu
	Voltage Deviation	Deviation in voltage from no PV to full PV	≥ 3% at primary ≥ 5% at secondary ≥ ½ band at regulators
	Unbalance	Phase voltage deviation from average	≥ 3% of phase voltage
Loading	Thermal	Element loading	≥ 100% normal rating
Protection	Element Fault Current	Deviation in fault current at each sectionalizing device	≥ 10% increase
	Sympathetic Breaker Tripping	Breaker zero sequence current due to an upstream fault	≥ 150A
	Breaker Reduction of Reach	Deviation in breaker fault current for feeder faults	≥ 10% decrease
	Breaker/Fuse Coordination	Fault current increase at fuse relative to change in breaker fault current	≥ 100A increase
Harmonics	Individual Harmonics	Harmonic magnitude	≥ 3%
	THDv	Total harmonic voltage distortion	≥ 5%

Stochastic PV Deployment



Distribution Feeder
PV Impact Heat Map



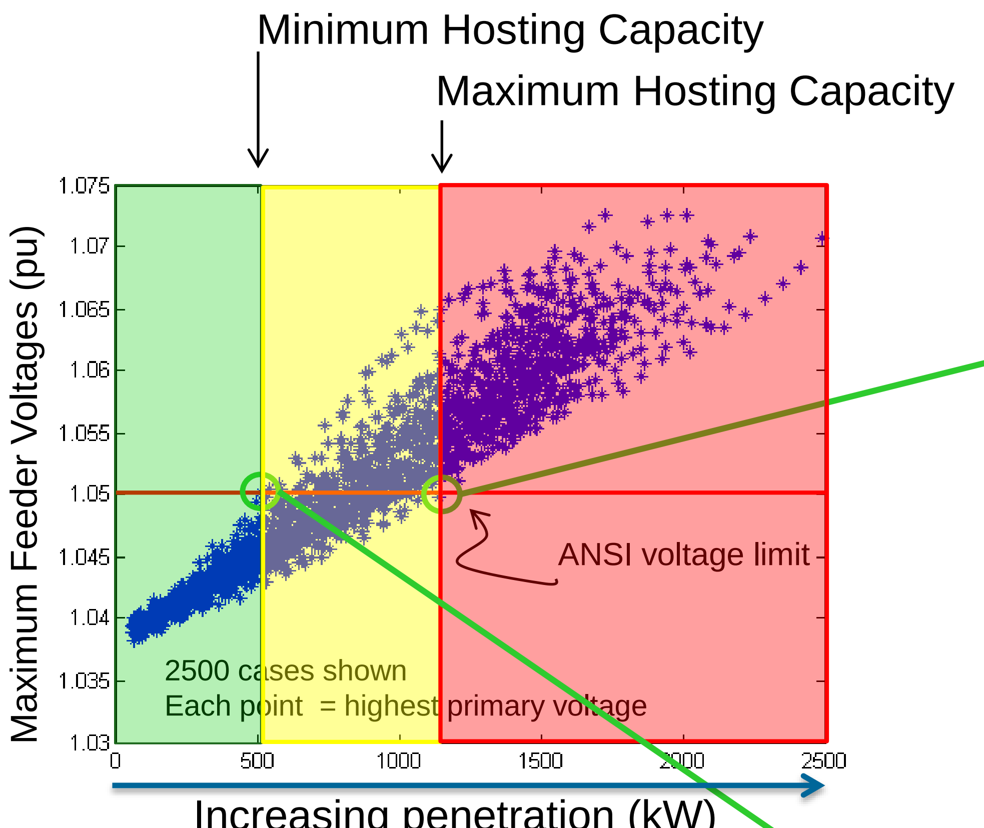
- Baseline – No PV
- PV Penetration 1
- PV Penetration 2
- PV Penetration 3
- Beyond…

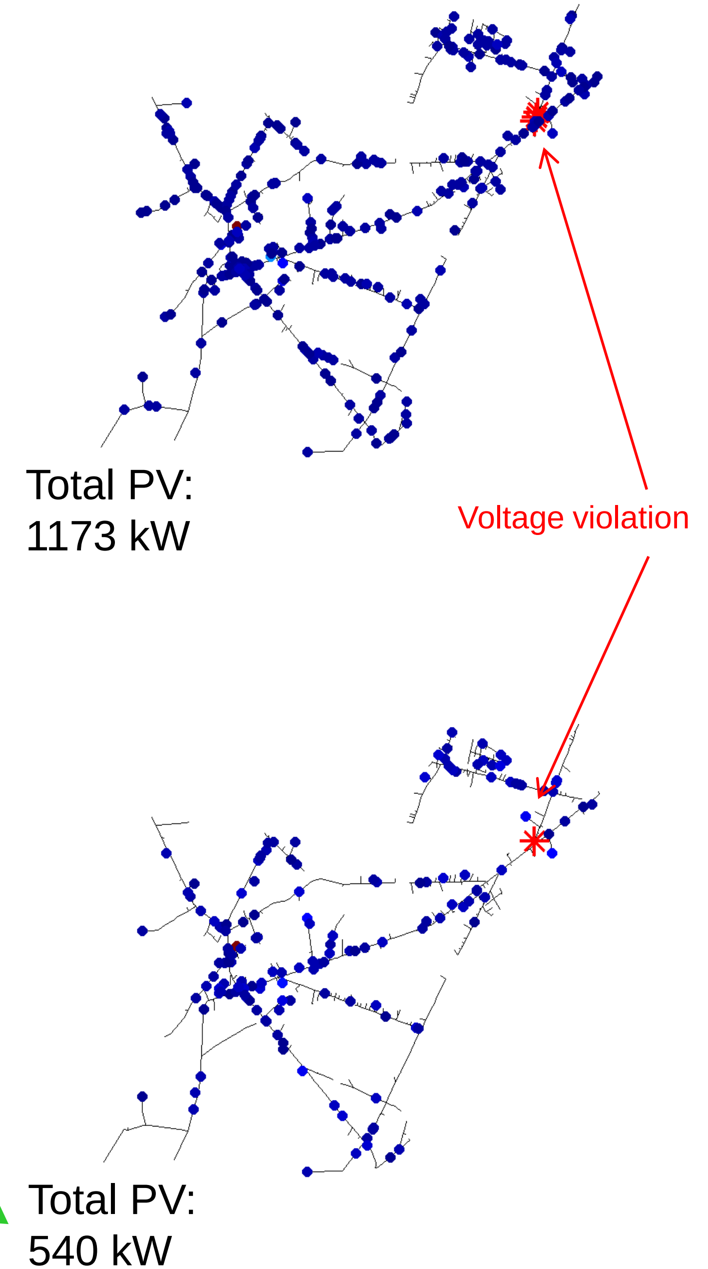
Process is repeated 100s of times to capture many possible scenarios

Increase Penetration Levels Until Violations Occur

Hosting Capacity

Overvoltage Results Shown for Feeder J1





No observable violations regardless of size/location

Possible violations based upon size/location

Observable violations occur regardless of size/location

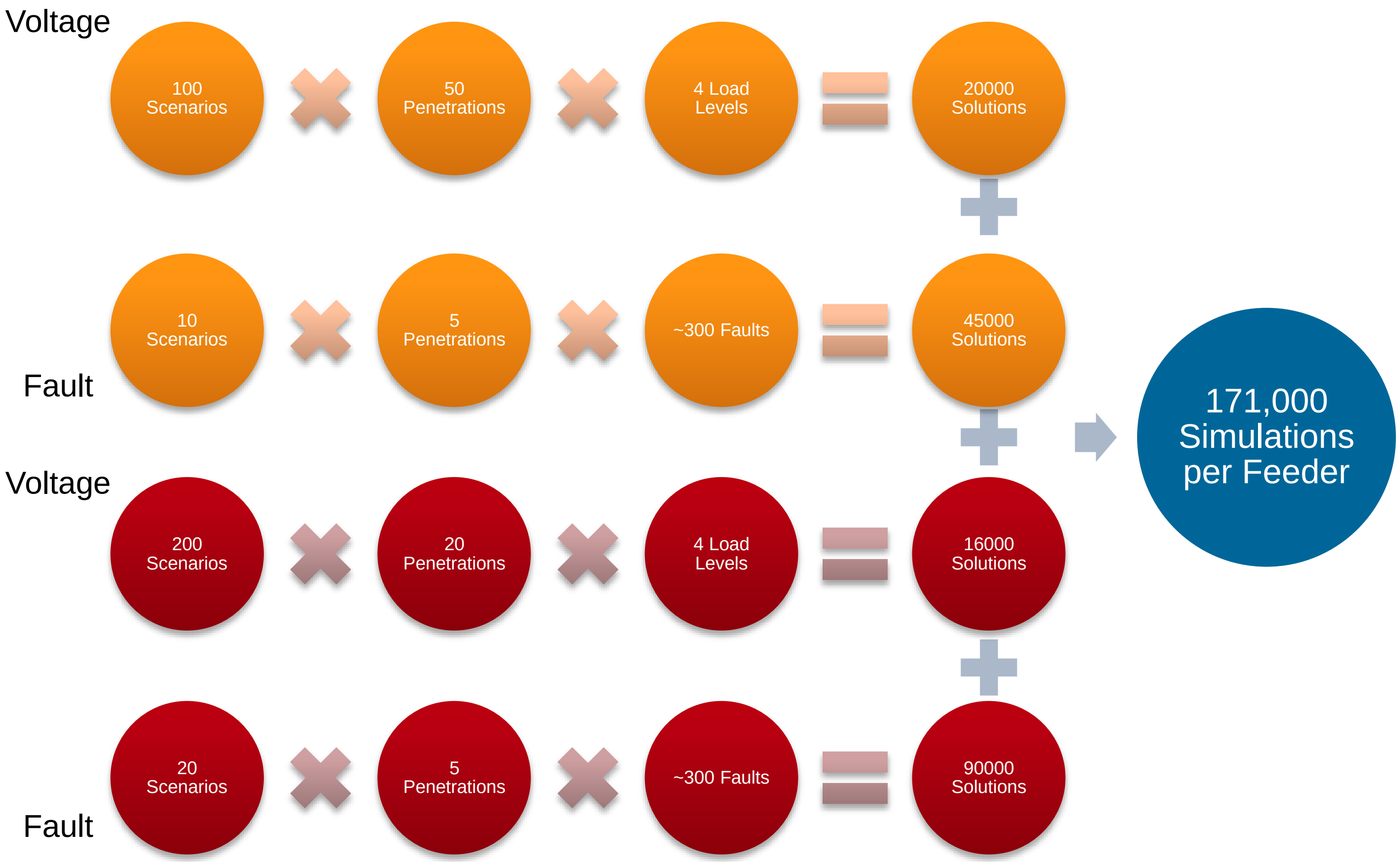
Voltage and Protection

Small Scale PV

Small, single and three-phase rooftop located @ customer loads

Large Scale PV

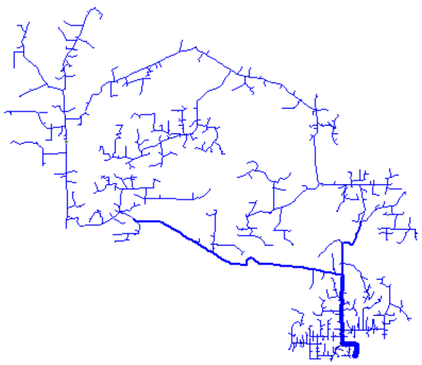
Large, stand-alone three-phase systems located on any three-phase point



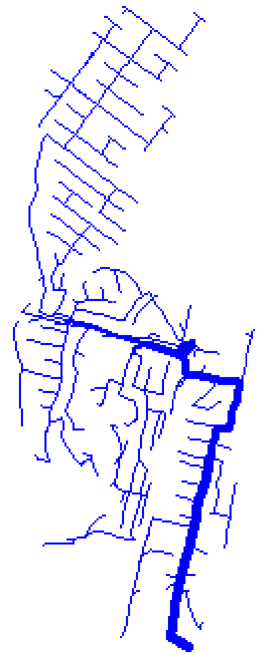
Study Feeders

Topology

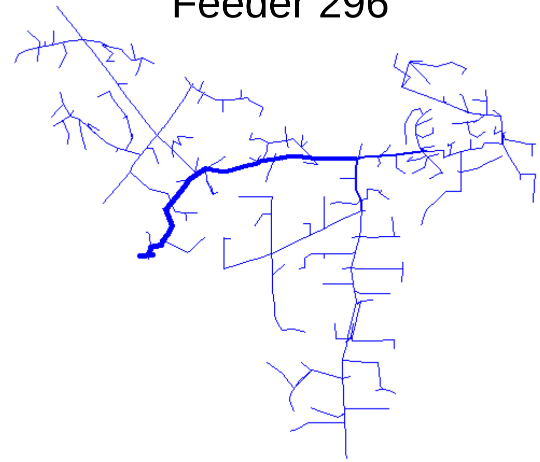
Feeder 440



Feeder 404

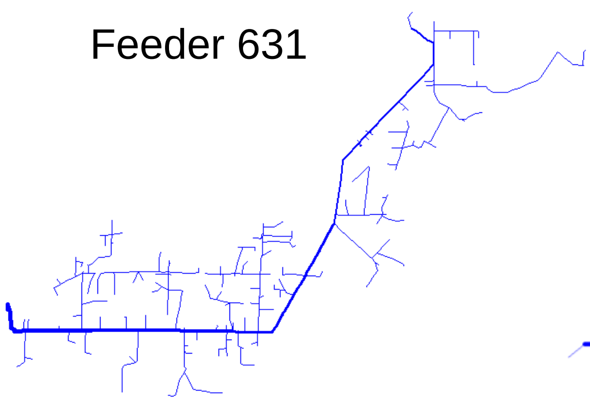


Feeder 296

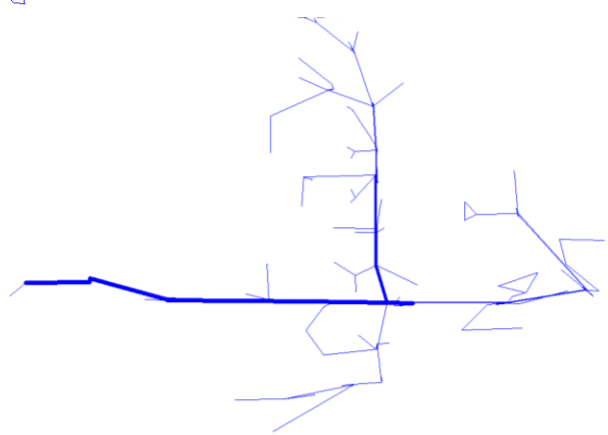


Feeder 683

Feeder 631



Feeder 525

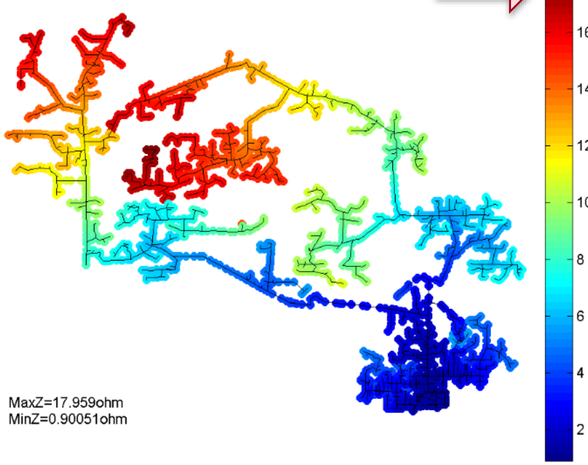


Impedance

Note scale

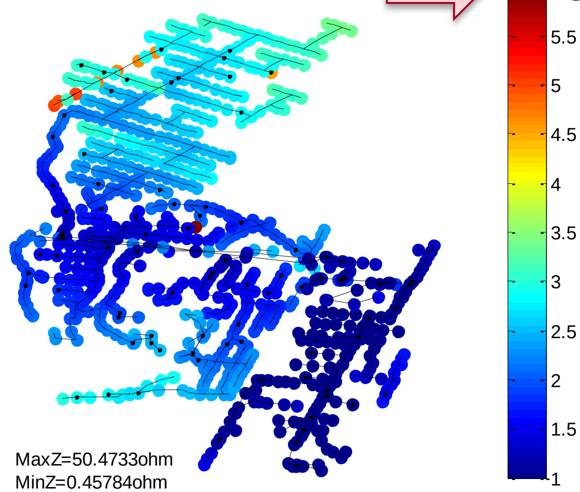
Feeder 440

18



Feeder 404

5



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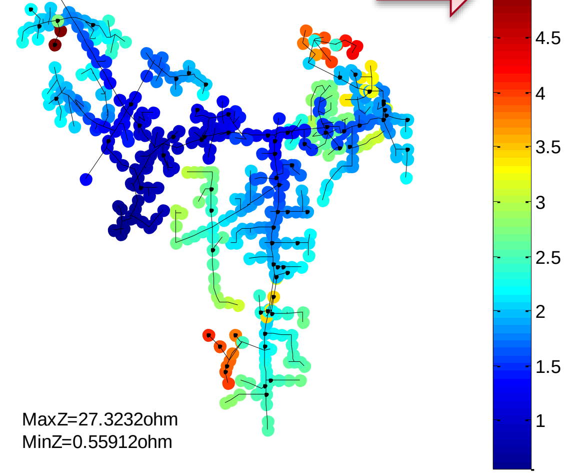
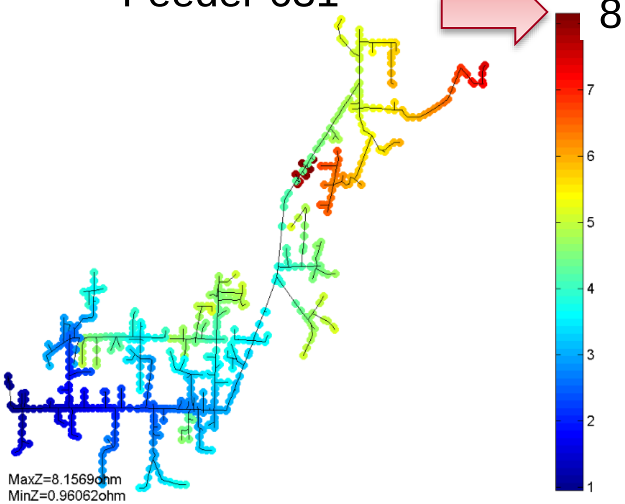


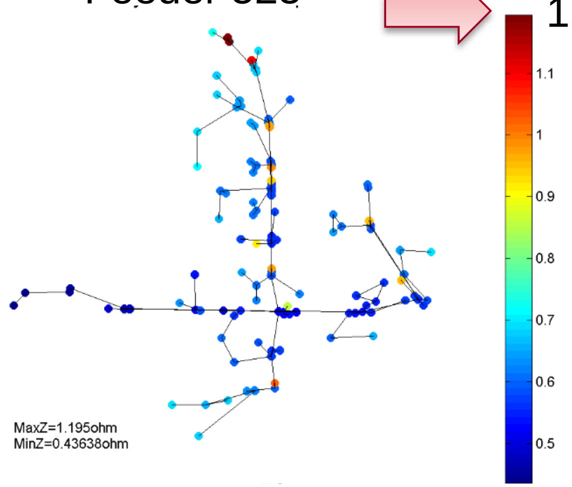
Feeder 631

8



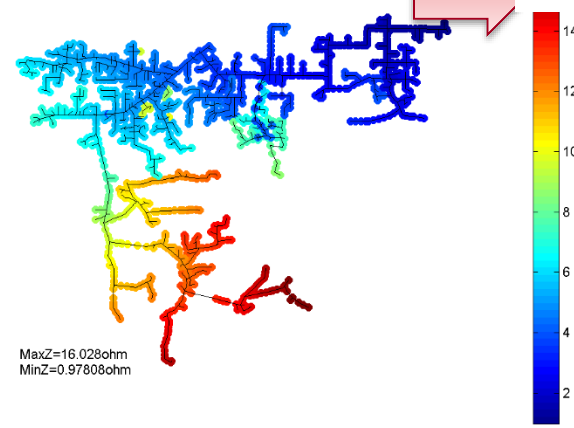
Feeder 525

1.2



Feeder 683

14



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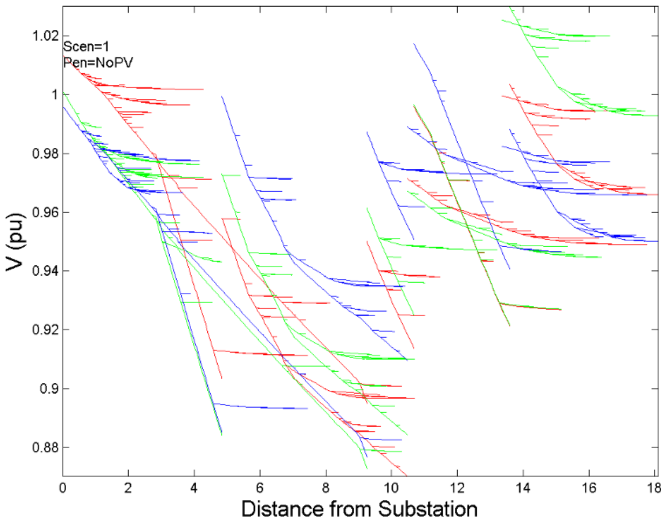
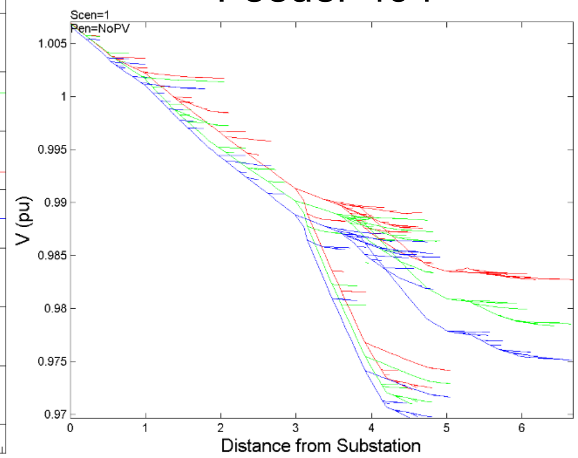
Peak Load Voltage Profiles

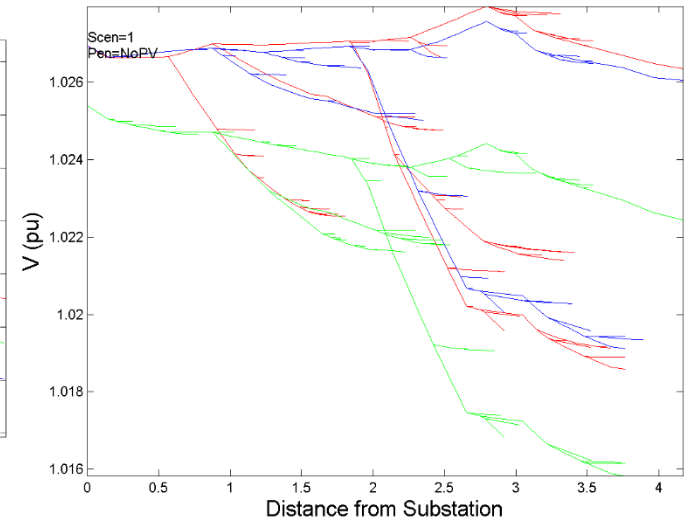
Feeder 440



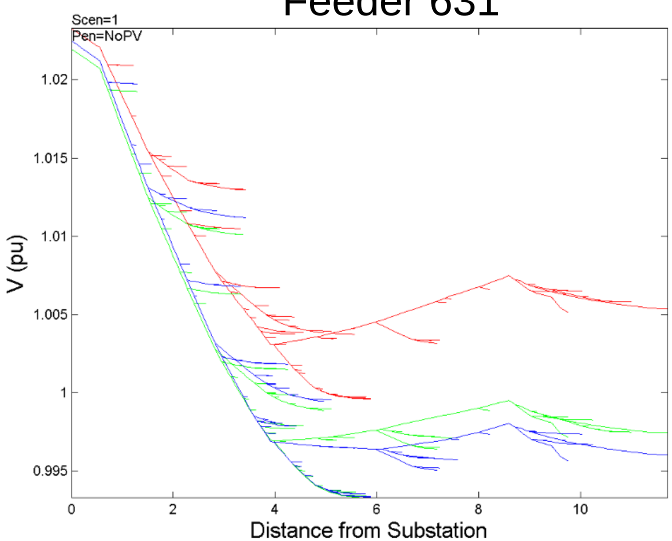
Feeder 404



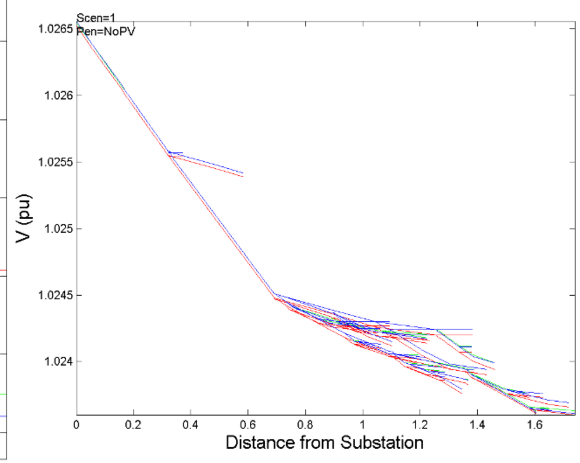
Feeder 296



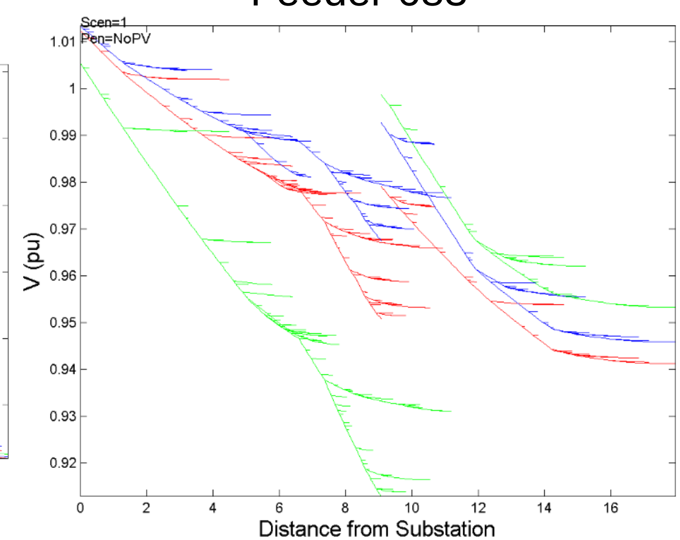
Feeder 631



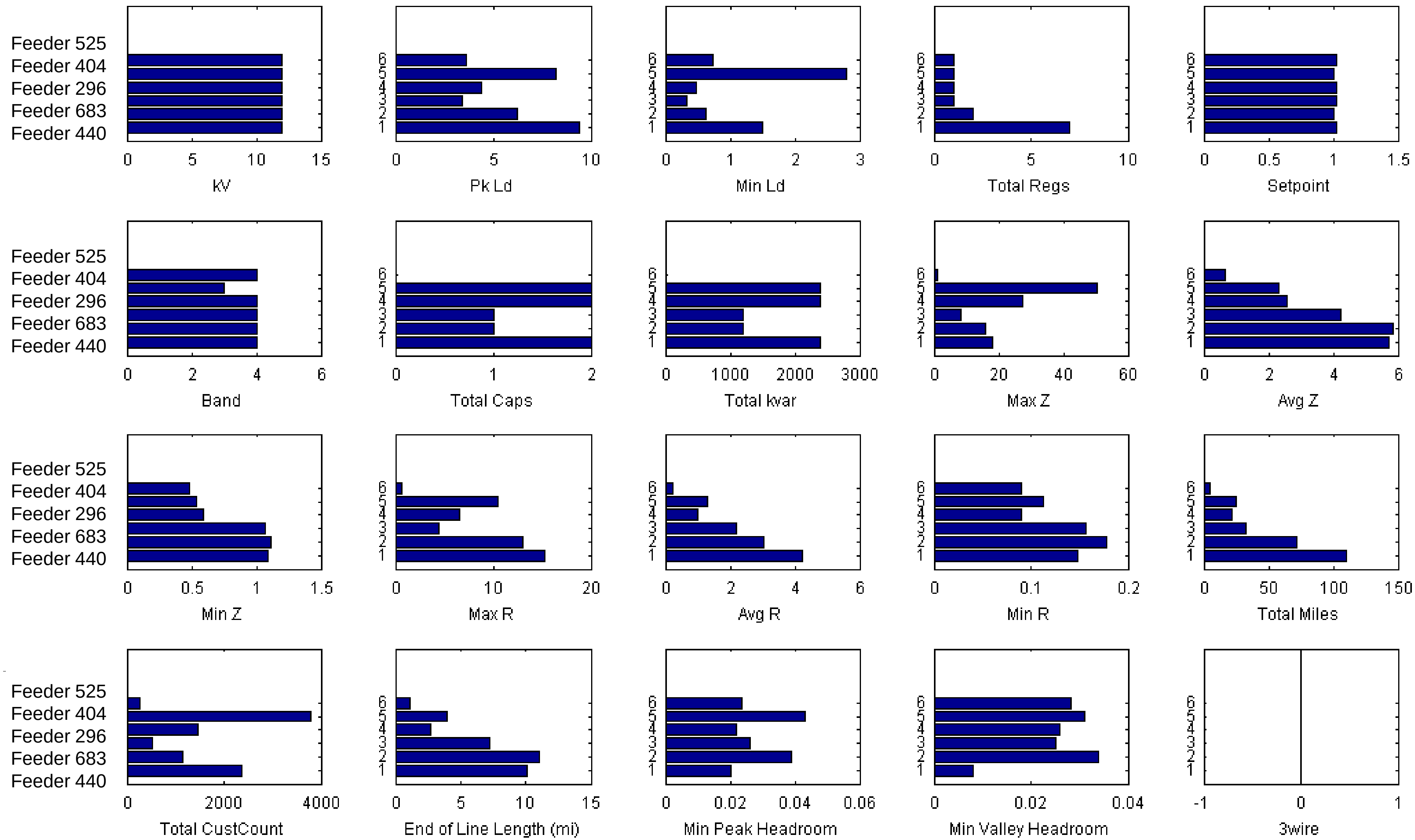
Feeder 525



Feeder 683



Characteristics



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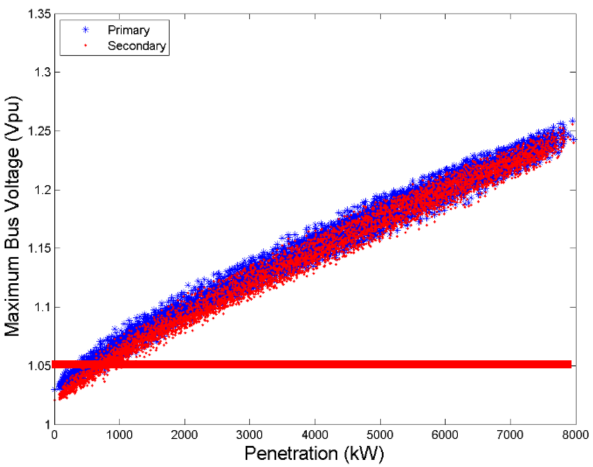
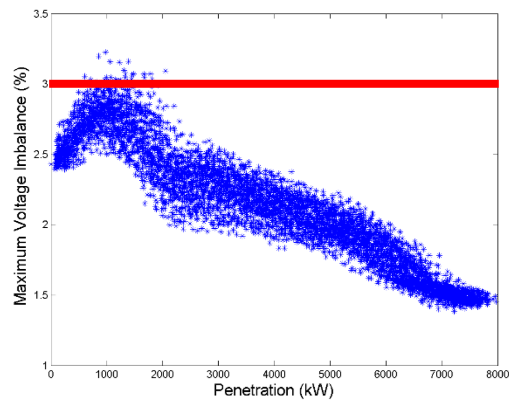
Small Scale PV

Feeder 440 Trends

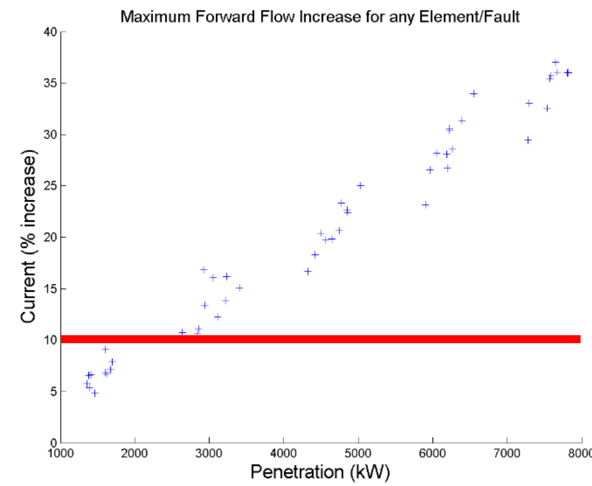
Voltage Magnitude



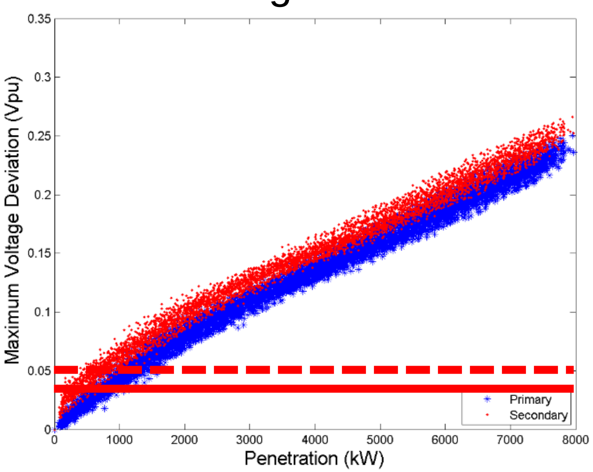
Voltage Imbalance



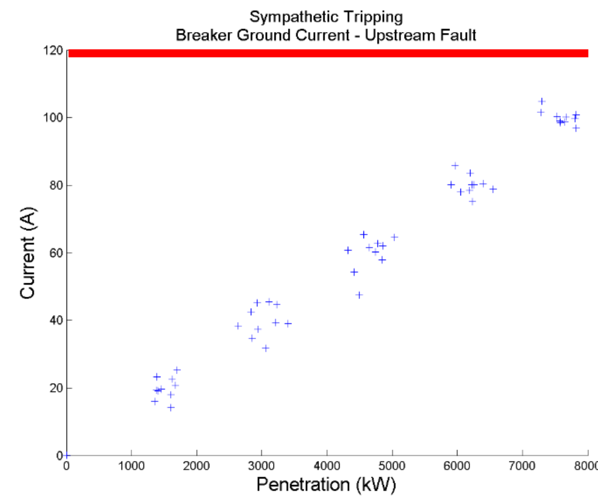
Element Fault Current



Voltage Deviation



Breaker Ground Current



- Trends evident with increased PV penetration
- Not all issues have adverse impacts

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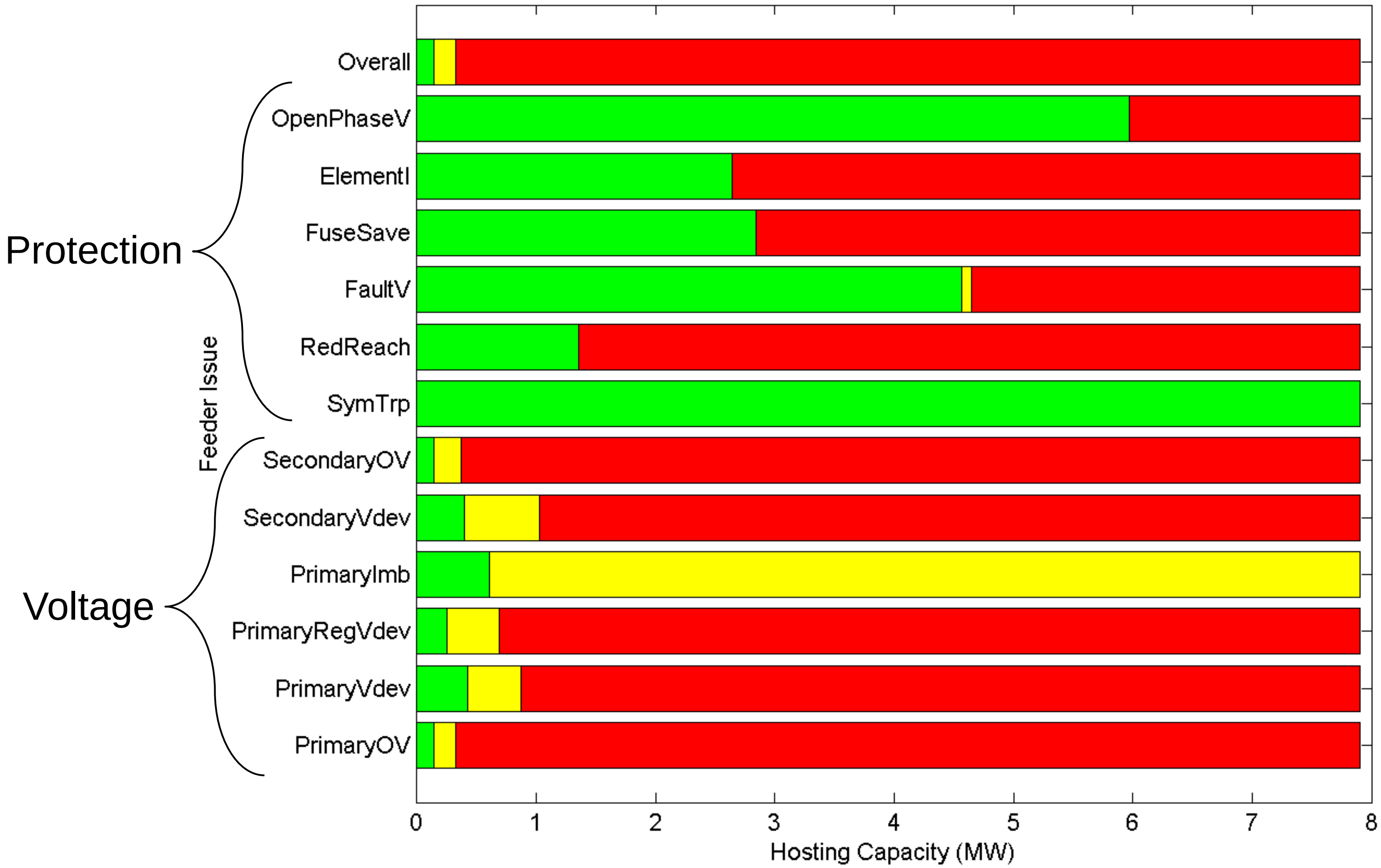
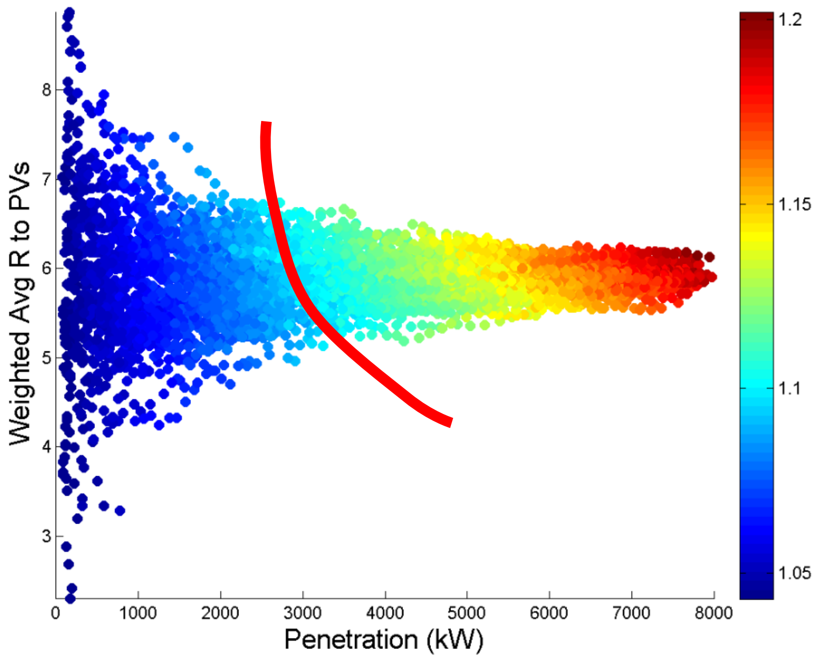
Feeder 440 PV Hosting Capacities



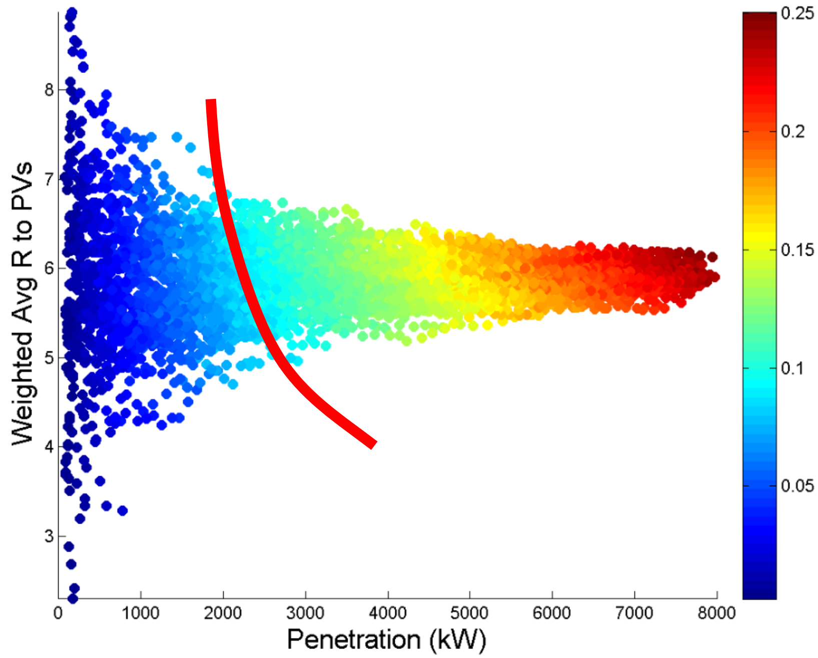
Yellow region identifies PV locational impact to feeder hosting capacity is greater for voltage issues

Feeder 440 PV Locational Impact

Voltage Magnitude

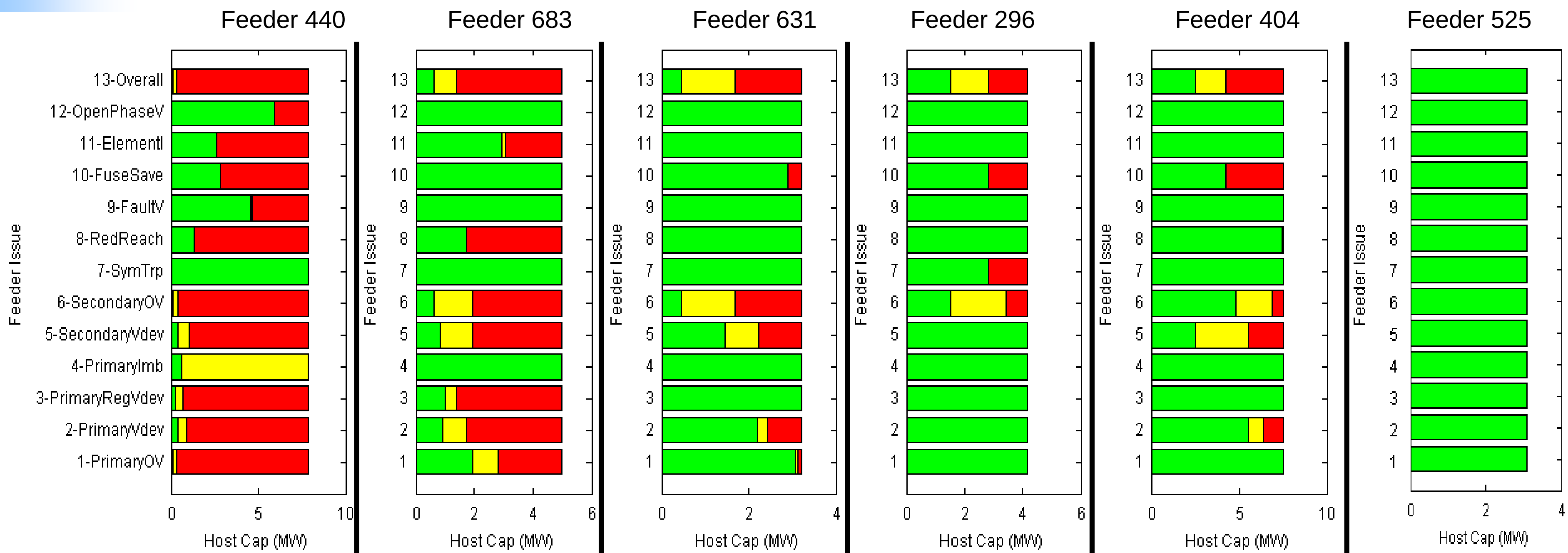


Voltage Deviation



- PV location approximated by "Weighted Average Resistance"
- Trends evident with PV location

Issue Specific Results



High Impact	High Impact	Medium Impact	Low Impact	Medium Impact	No Impact
• Protection • Voltage	• Protection • Voltage	• Voltage	• Voltage	• Voltage	• None

- Significant difference in hosting capacity based on feeder chosen from clustering

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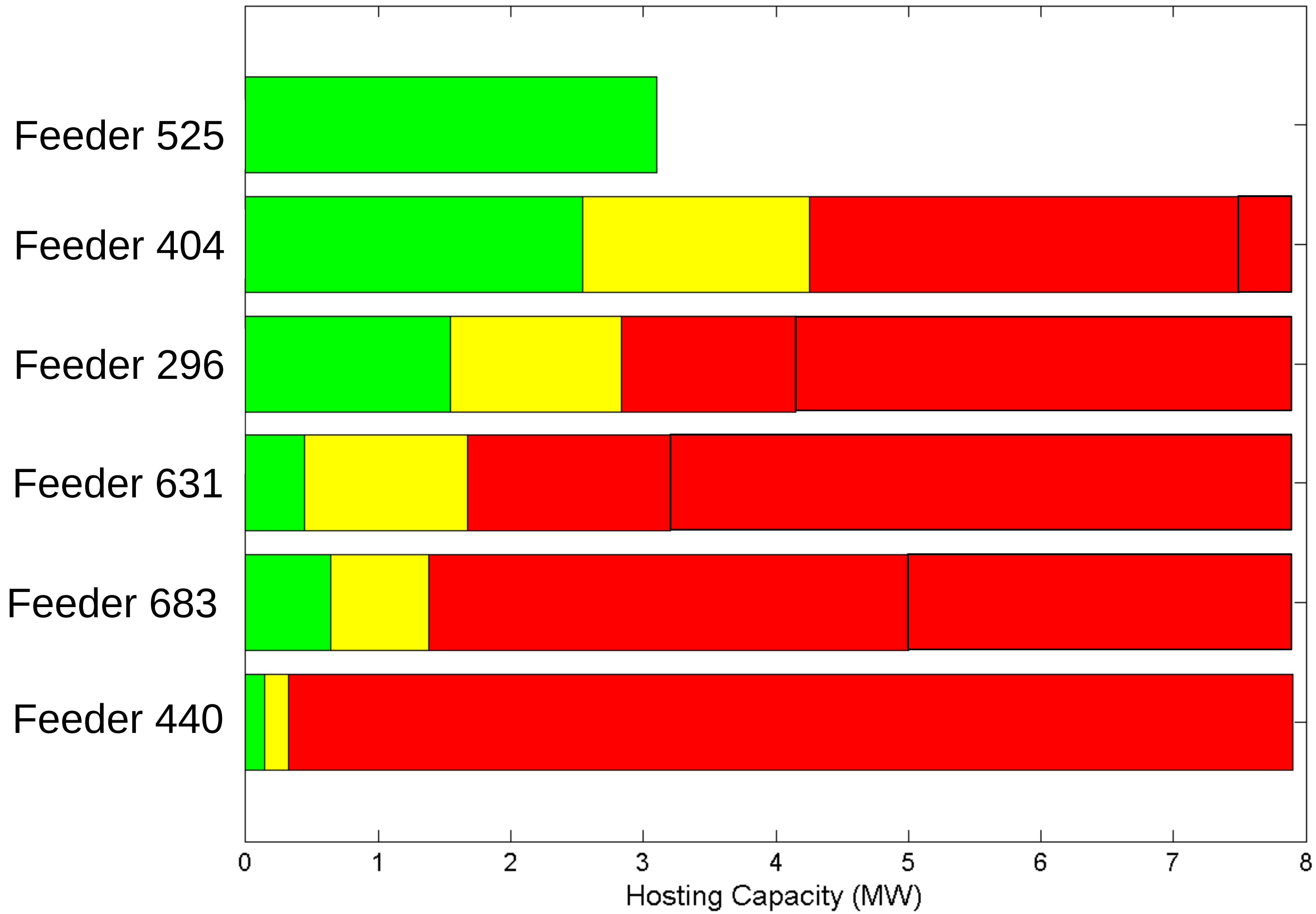
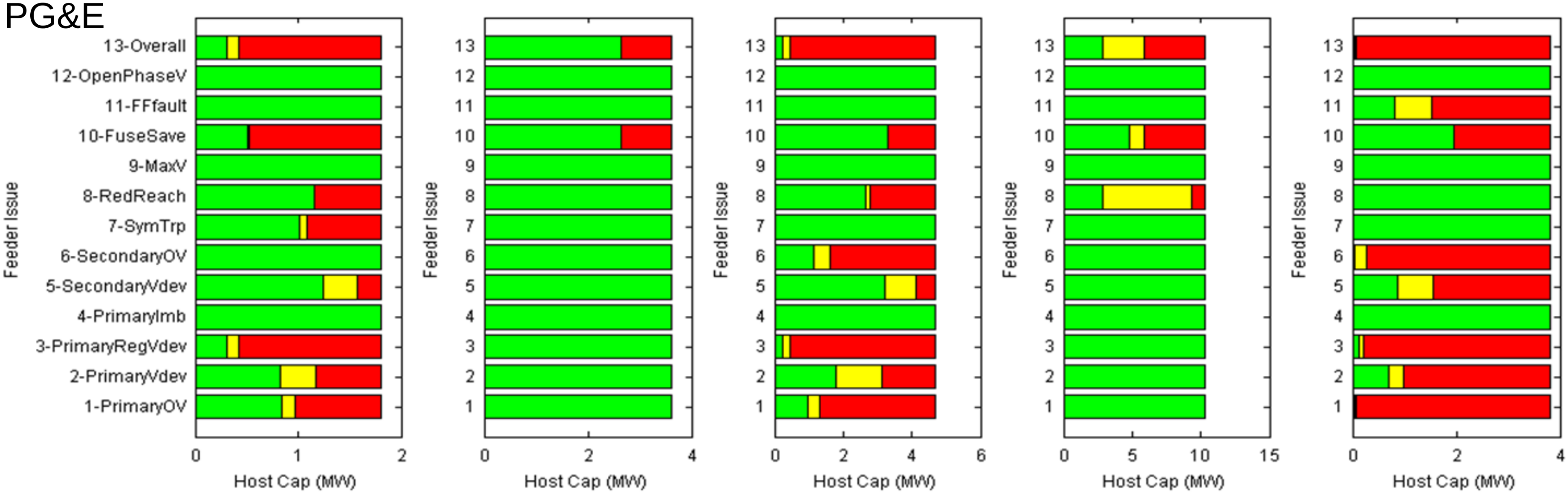
Overall Small Scale PV Results



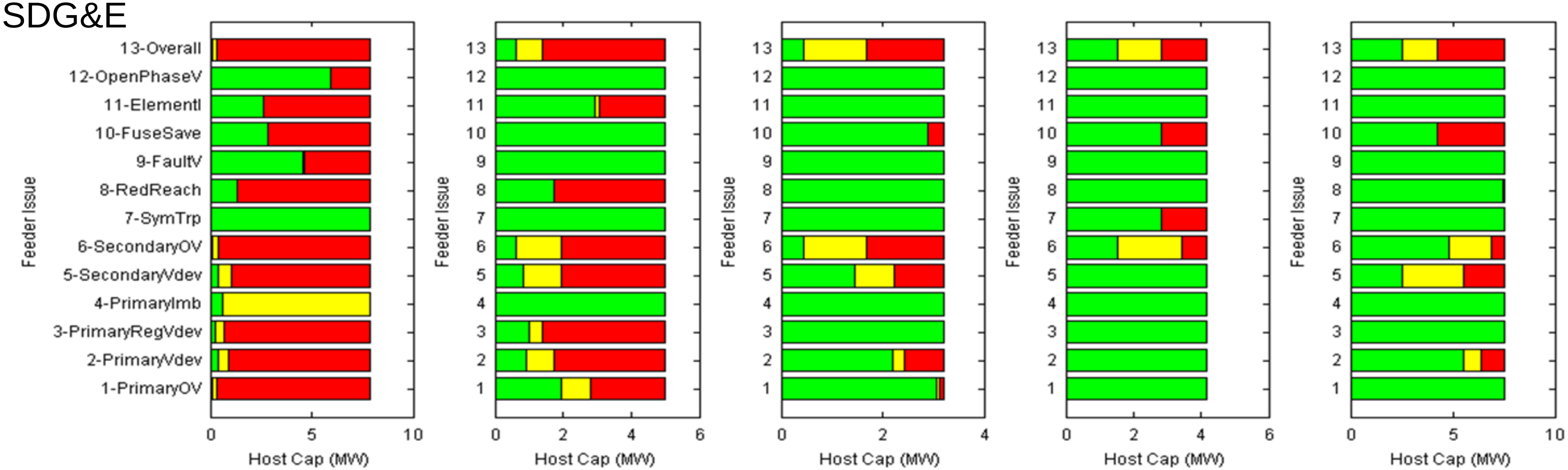
- Maximum small scale PV penetration dependent total feeder load
- Higher analyzed penetrations would show similar adverse issues

Small-Scale Issue Specific Results

PG&E



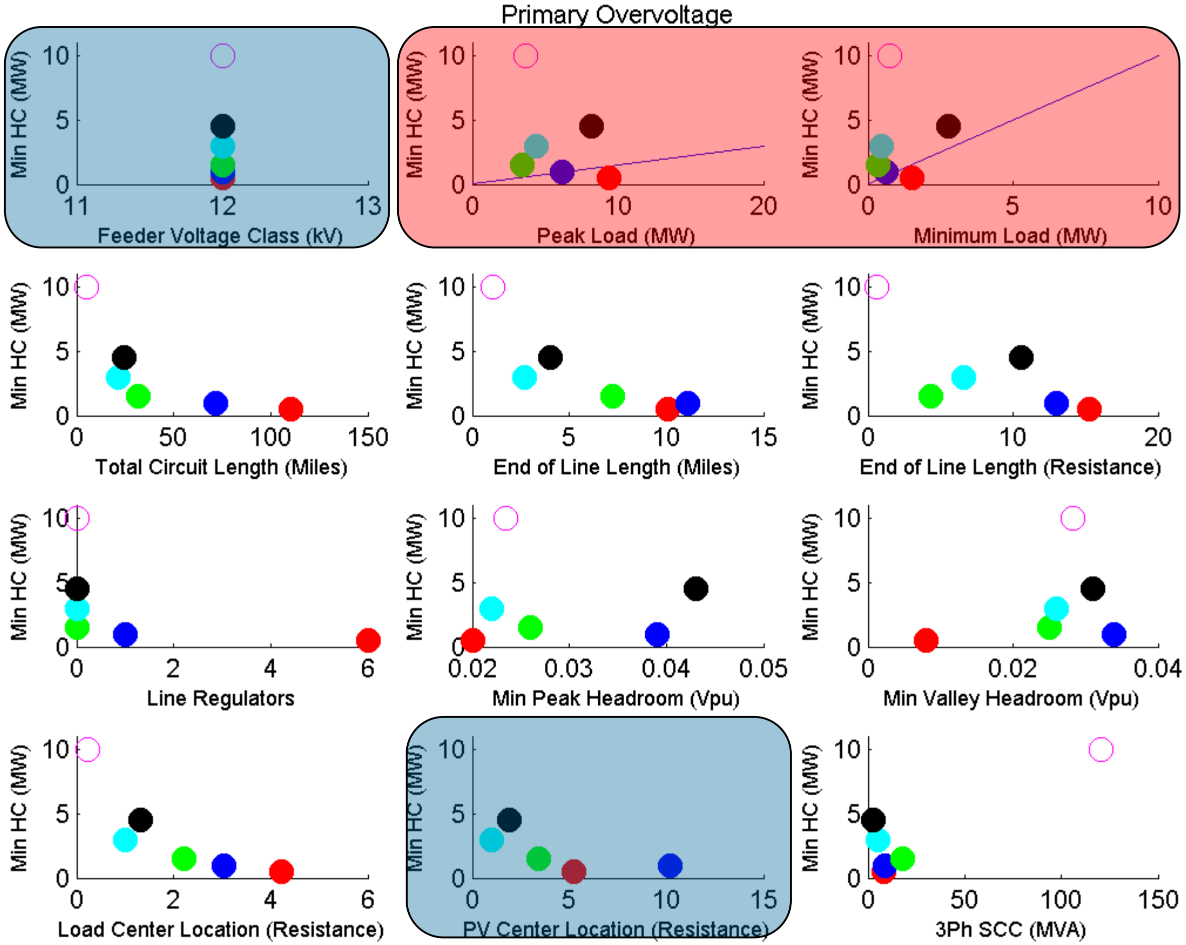
SDG&E



Characteristics Correlated to Minimum Hosting Capacity for Primary Overvoltage

Greater dependency on

- Voltage
  - Class
  - Regulation
  - Headroom
- Resistance to PV



Percent of load screens over/under estimate hosting capacity

- – 525
- – 404
- – 296
- – 631
- – 683
- – 440

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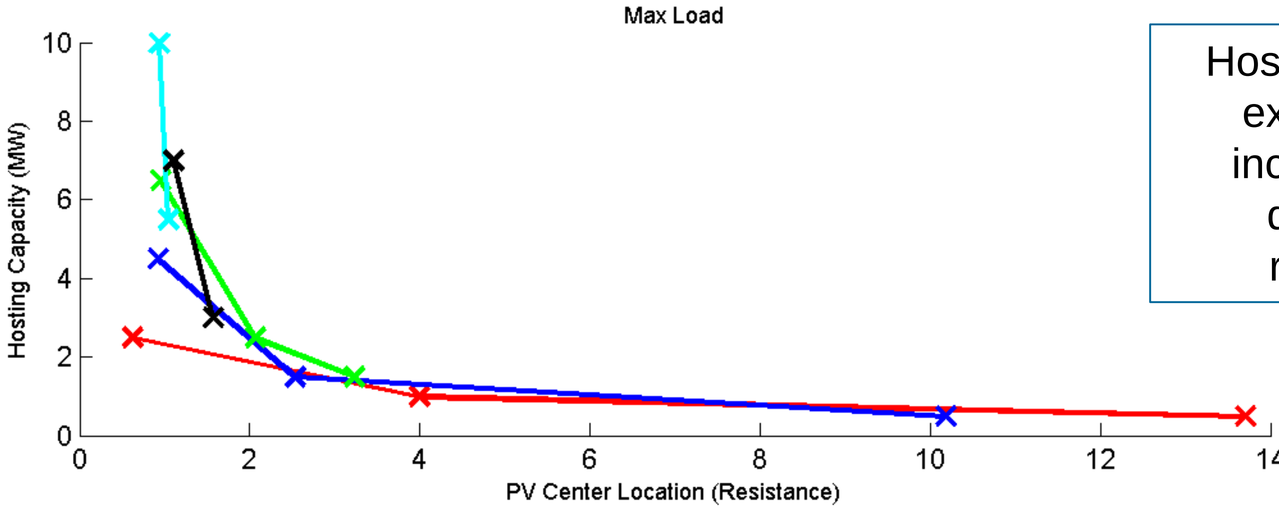
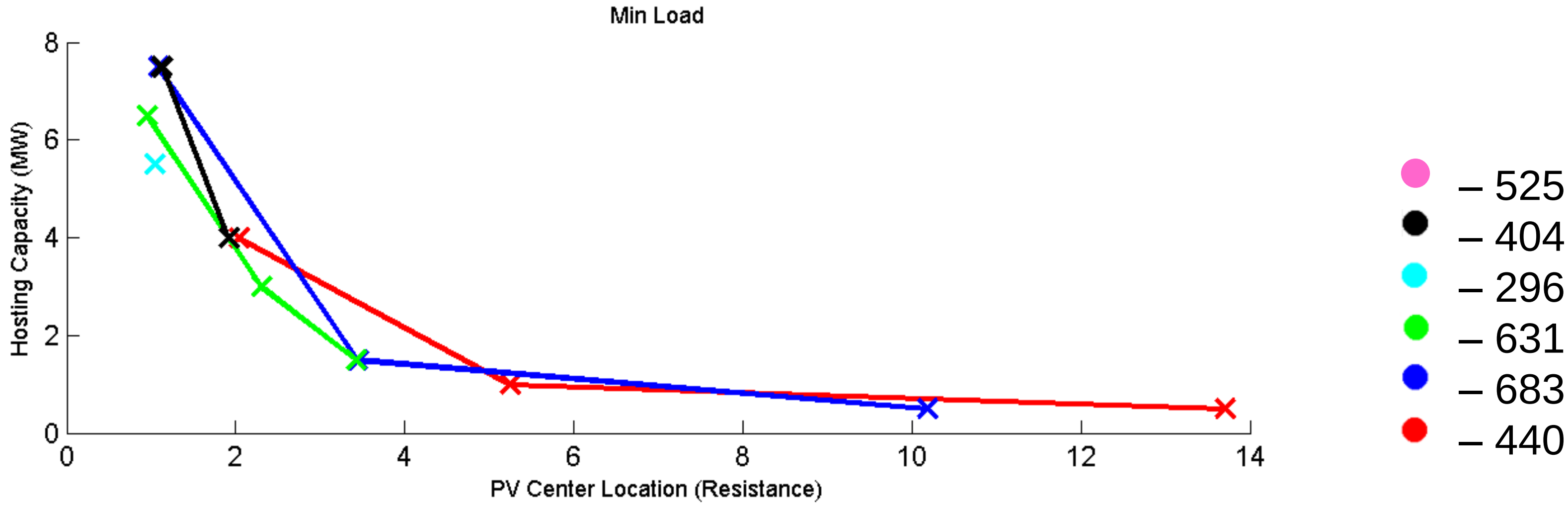
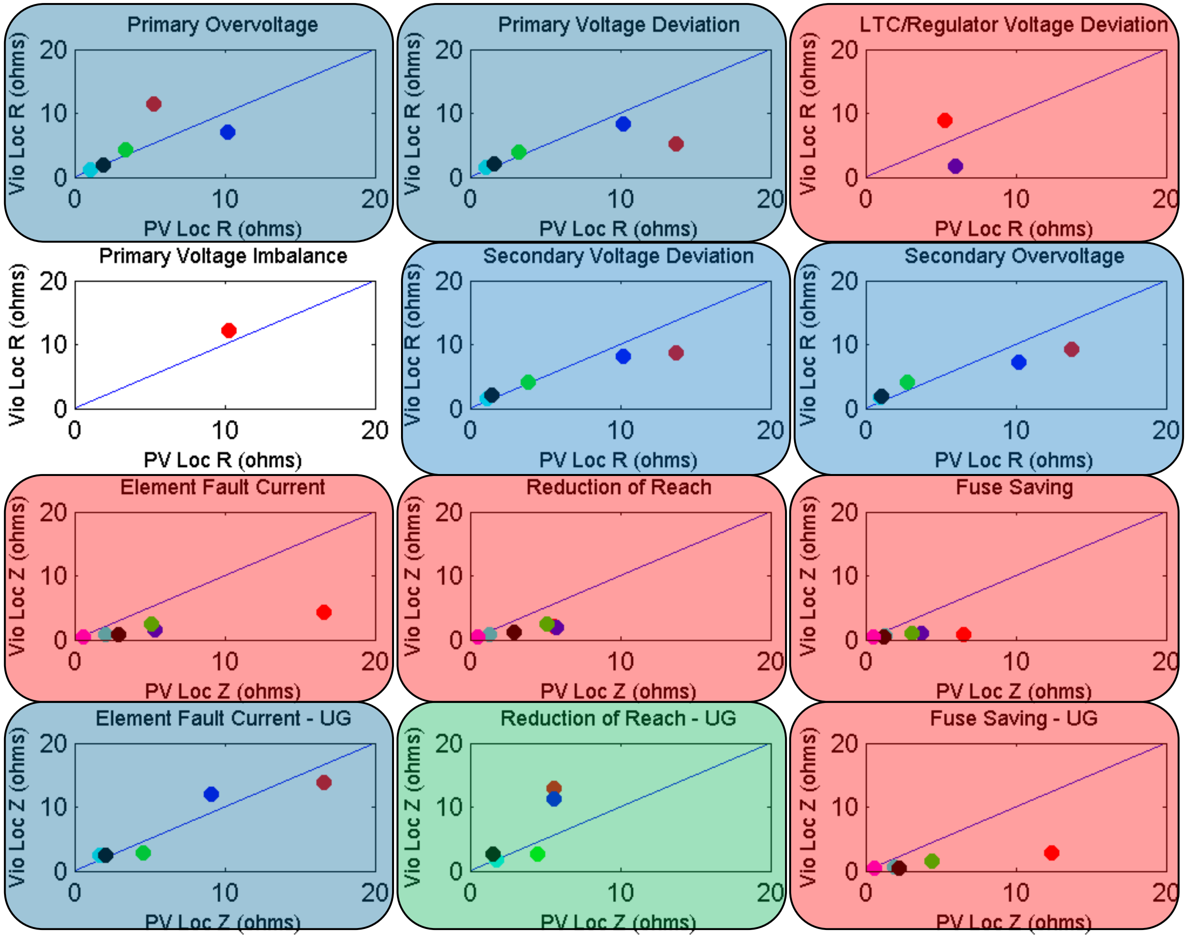
How does Primary Voltage Deviation Hosting Capacity Relate to PV Characteristic Location



Hosting Capacity exponentially increases with decreased resistance



Where are the Feeder Violations with Respect to the PV Characteristic Location



- – 525
- – 404
- – 296
- – 631
- – 683
- – 440

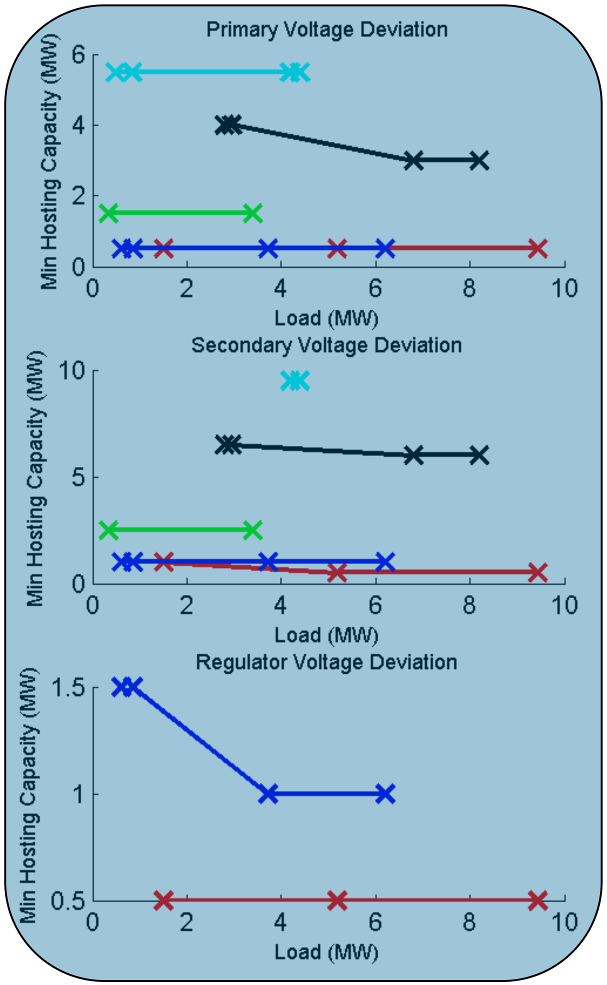
Violation electrically closer in than PV

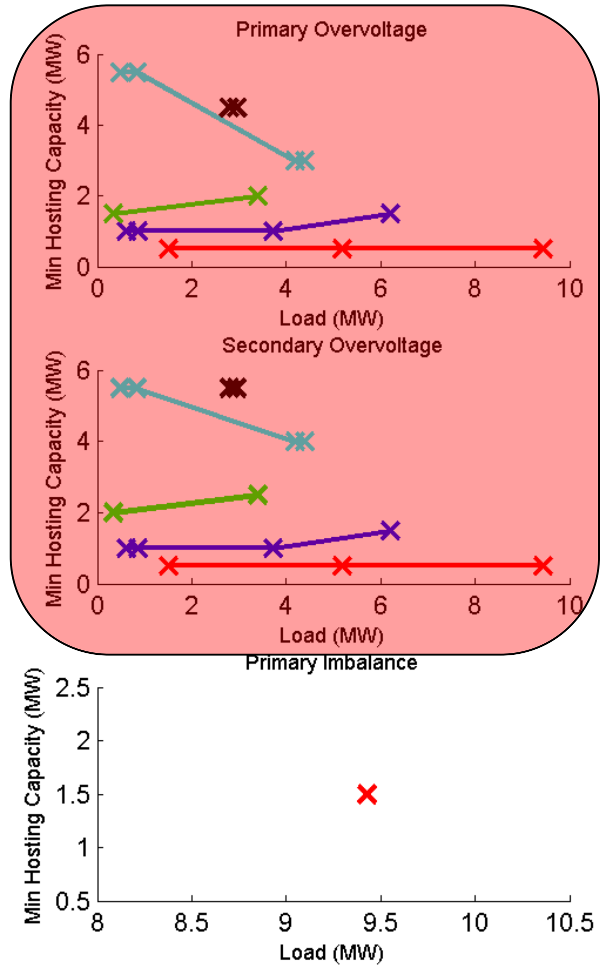
Violation electrically close to PV

Violation electrically further out than PV

Loading does not Dictate Hosting Capacity but does have an Influence

Hosting Capacity typically decreases with load.





Hosting Capacity typically increases with load.

With LDC the inverse is true

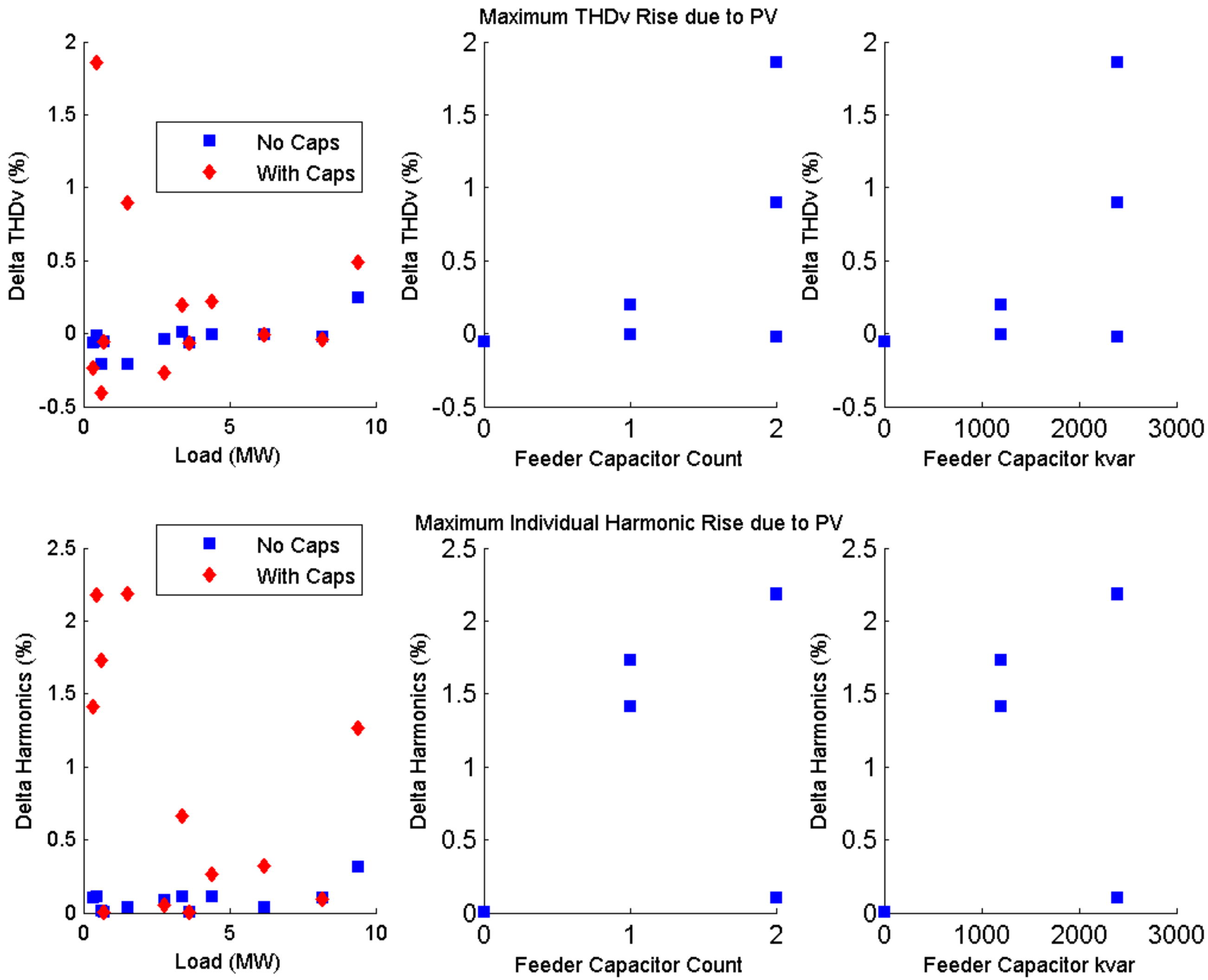
- – 525
- – 404
- – 296
- – 631
- – 683
- – 440

Harmonics with High Penetration PV

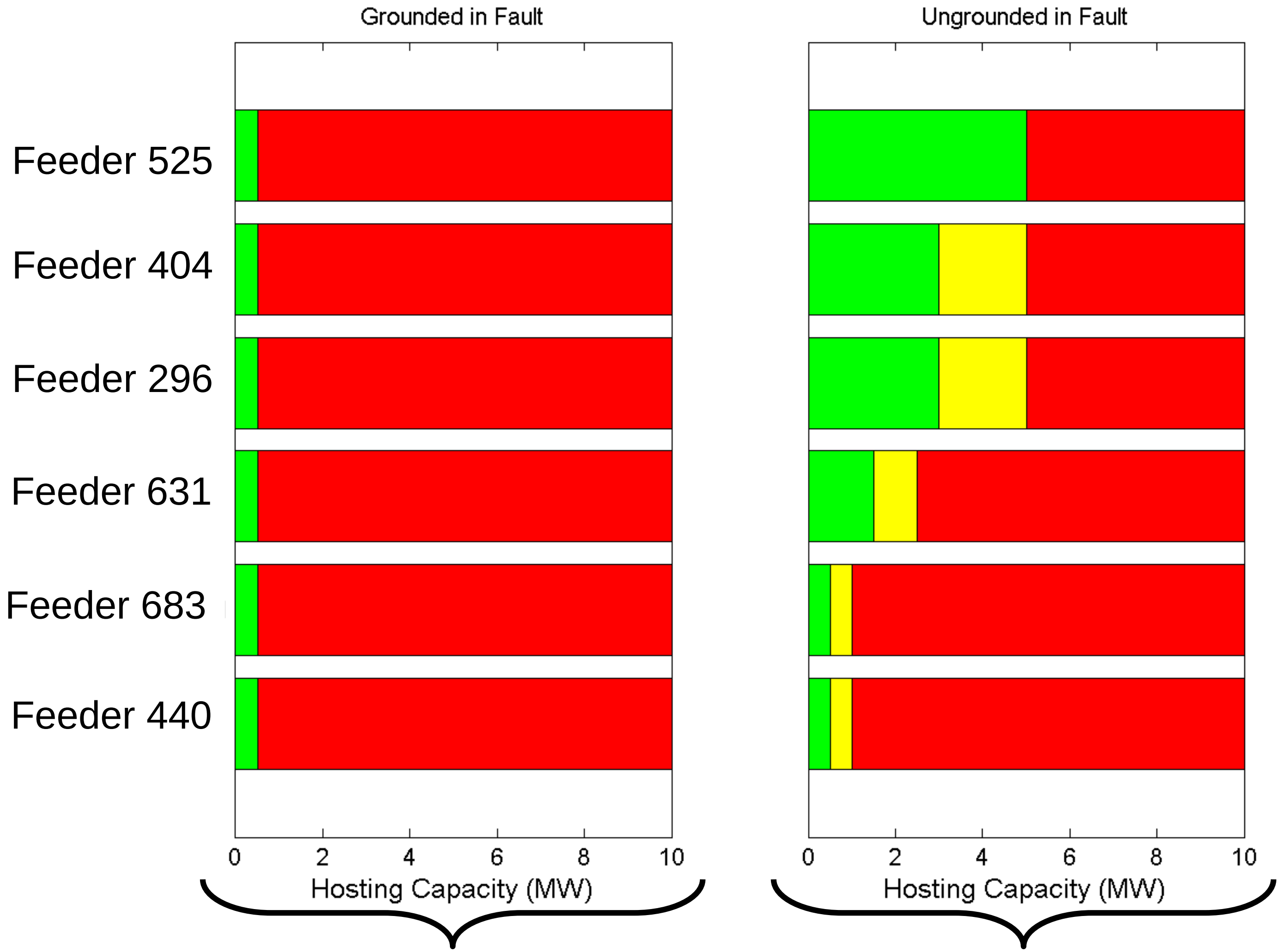
Impact of PV is examined as a change from base case without PV. Causes of high harmonic increases:

+ Low load

+ More capacitors



Overall Large Scale PV Results



Primarily influenced by protection issues (high ground fault contribution)

Primarily voltage-based issues

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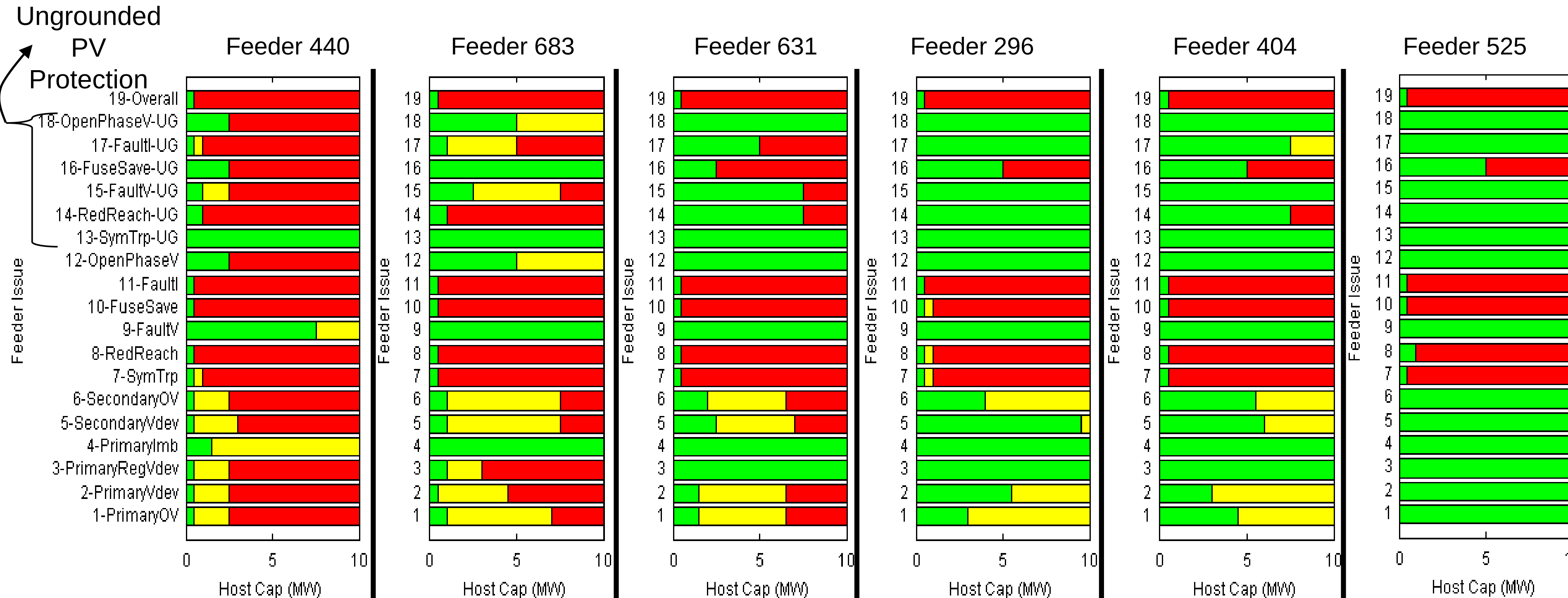
Large Scale PV

Issue Specific Results

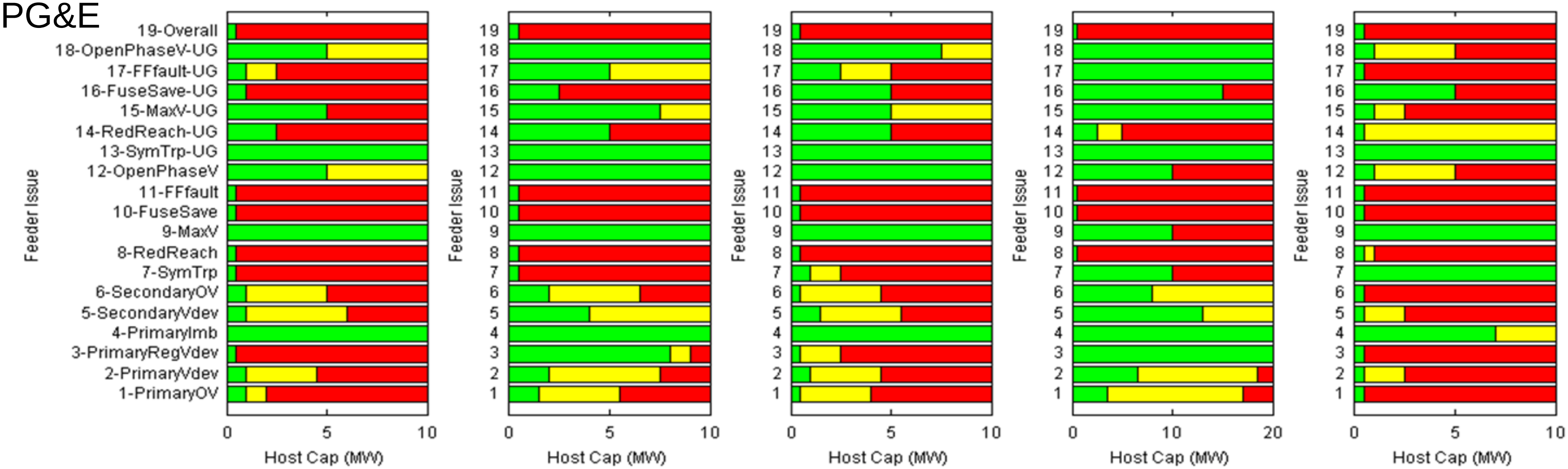


High Impact • Protection • Voltage	**High Impact** • Protection • Voltage	**High Impact** • Grounded PV Protection • Voltage	**Medium Impact** • Grounded PV Protection • Voltage	**Medium Impact** • Grounded PV Protection • Voltage	**Low Impact** • Grounded PV Protection

- Large scale analyzes to higher penetrations
- Can be in more non-optimal locations
- Low impact feeders in from SmallScale now show potential issues

Large-Scale Issue Specific Results

PG&E



SDG&E