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

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

10/07/2014

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**

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

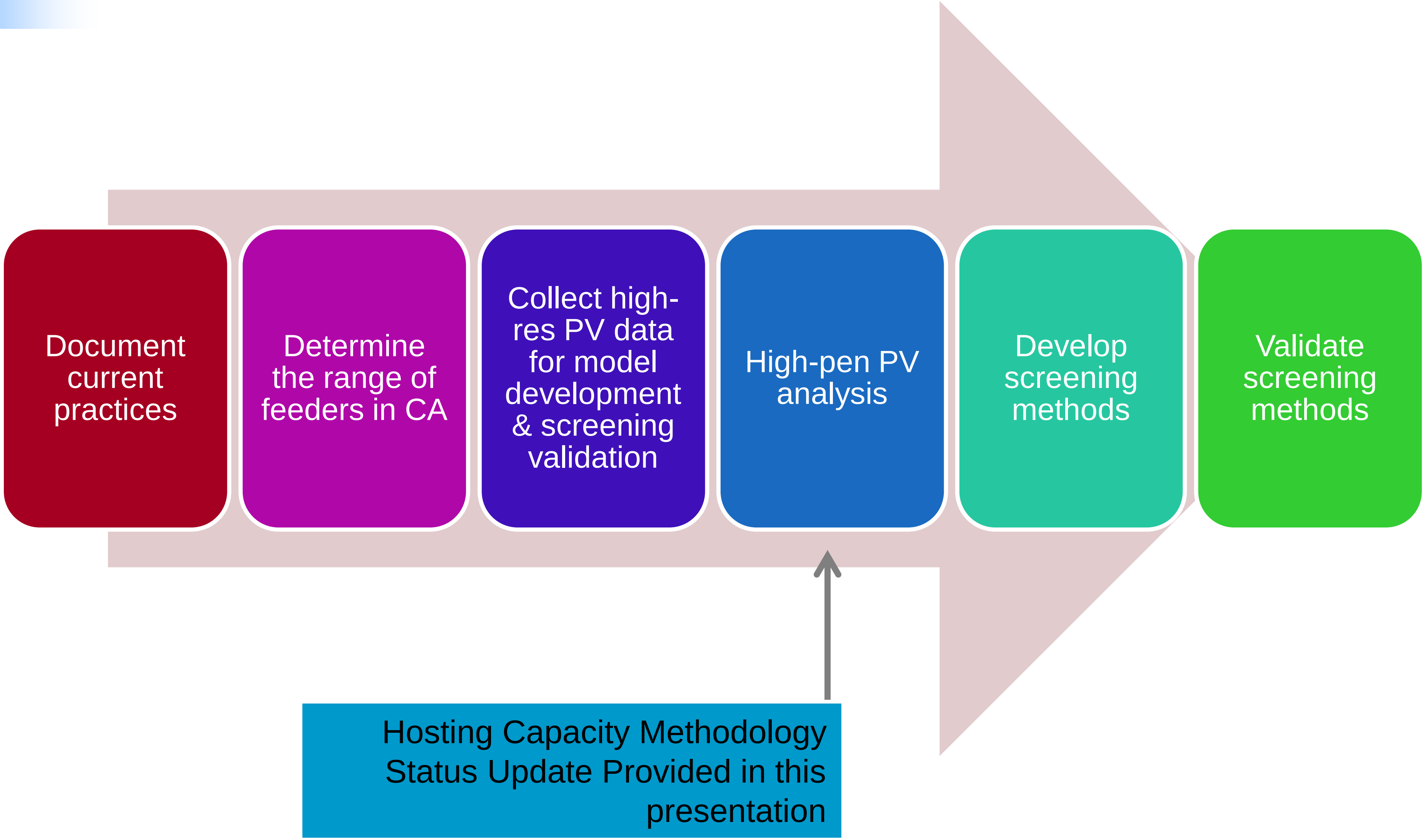
Sample feeders from DOE-funded VT/EPRI Hi-Pen Project

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

4% of Peak Load

Approach



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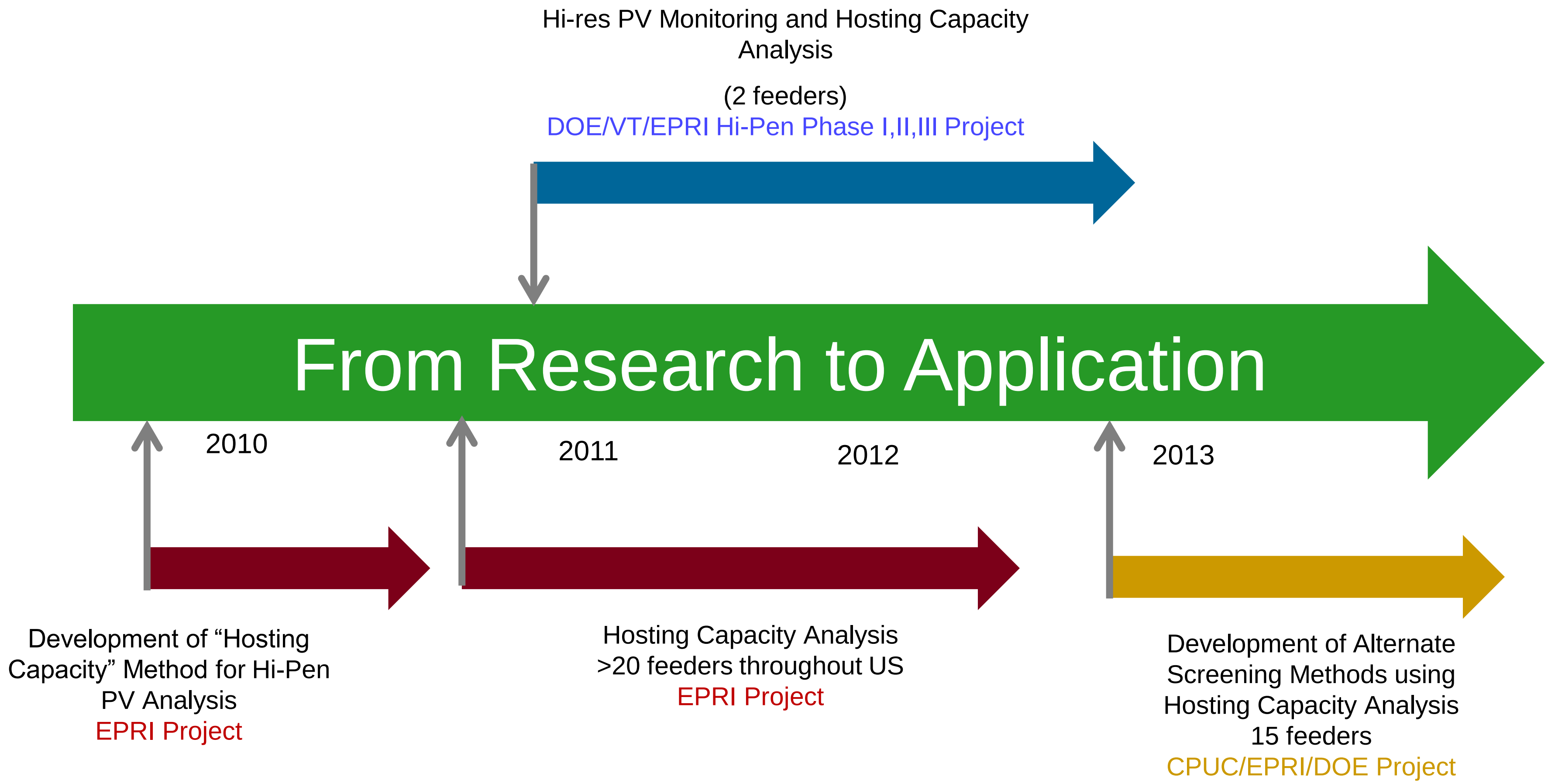
Leveraging Work Throughout Industry



Project Partners

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company
San Onofre Nuclear Generating Station

PG&E Pacific Gas and Electric Company®

SDG&E
A Sempra Energy utility℠

Sandia National Laboratories

NREL

SMUD
SACRAMENTO MUNICIPAL UTILITY DISTRICT
The Power To Do More.℠

PUBLIC UTILITIES COMMISSION
EUREKA
STATE OF CALIFORNIA

GO solar CALIFORNIA

Itron

SunShot
U.S. Department of Energy

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)

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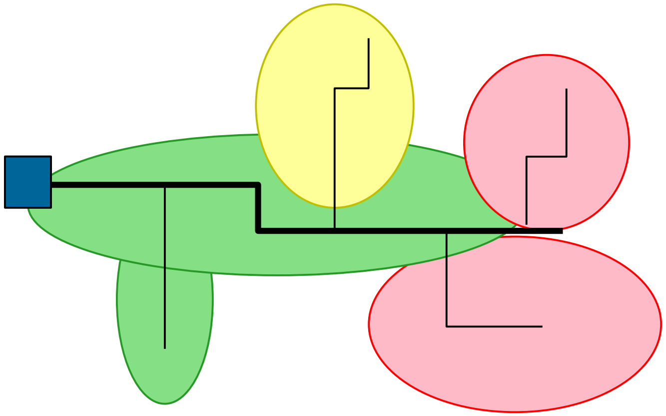
Detailed Feeder Study Overview

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
- …



Probable Issues

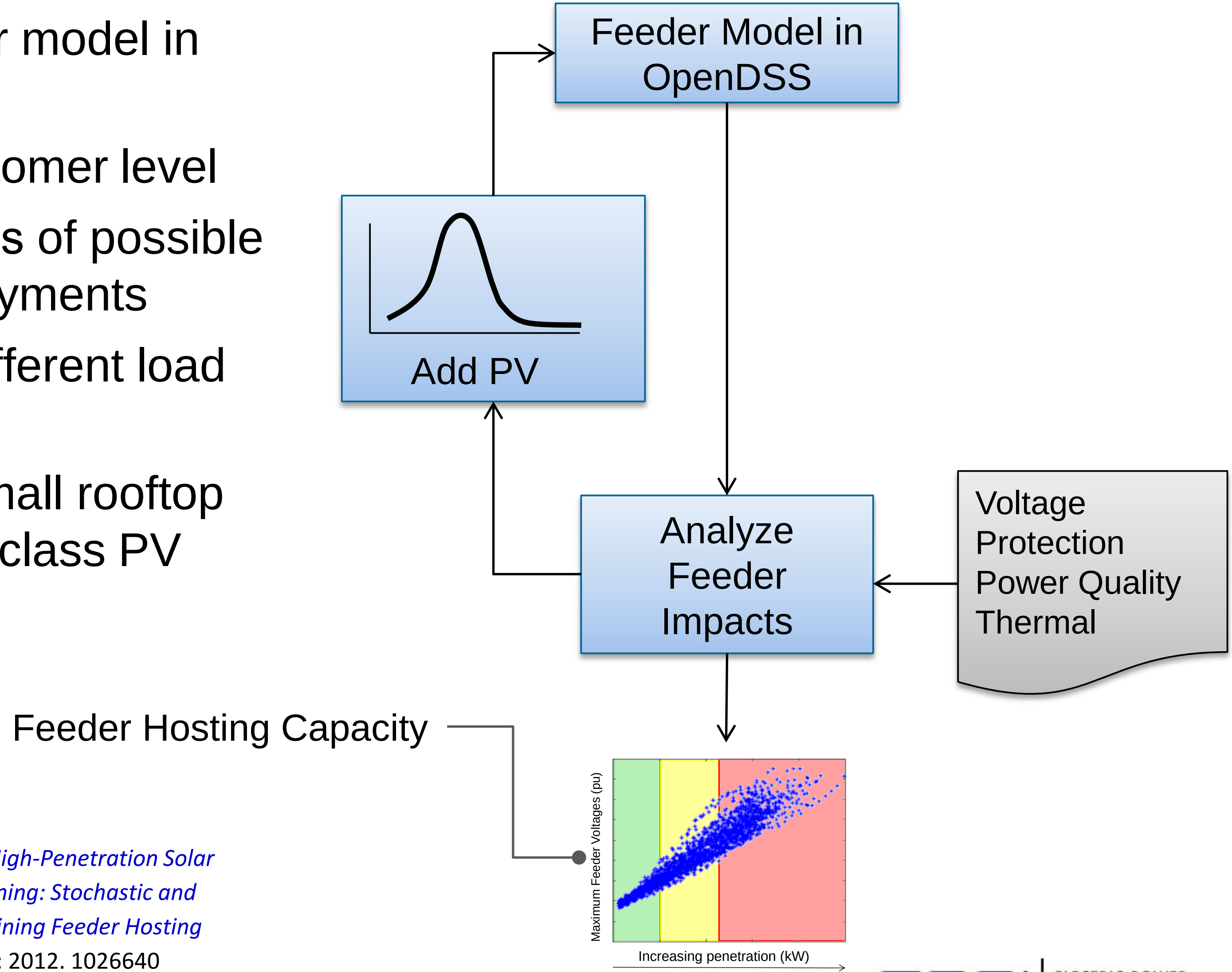
Possible Issues

No Issues

<u>What is Hosting Capacity?</u>
Amount of PV that can be accommodated on a given feeder without impacting reliability or power quality

Overall Approach

- Detailed feeder model in OpenDSS
- Add PV at customer level
- Evaluate 1000's of possible solar PV deployments
- Considering different load levels
- Considering small rooftop and large MW-class PV



Details on Approach: Analysis of High-Penetration Solar PV Impacts for Distribution Planning: Stochastic and Time-Series Methods for Determining Feeder Hosting Capacity. EPRI, Palo Alto, CA: 2012. 1026640

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Evaluation Criteria

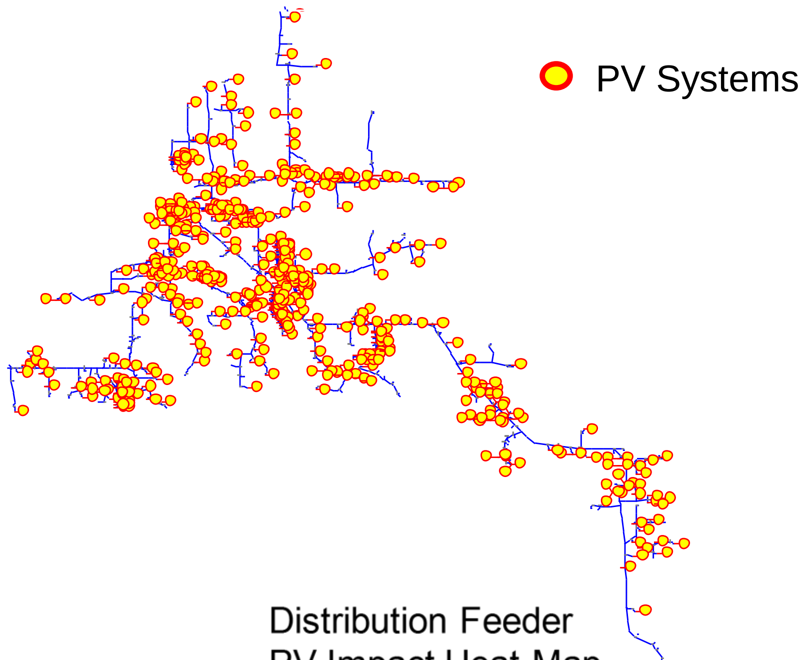
Voltage	• Overvoltage • Voltage deviations • Unbalance
Protection	• Increased fault current contribution • Sympathetic tripping • Reduction of reach • Unintentional islanding • Fuse saving
Power Quality	• Total harmonic distortion • Individual harmonics
Loading	• Thermal overloads

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%

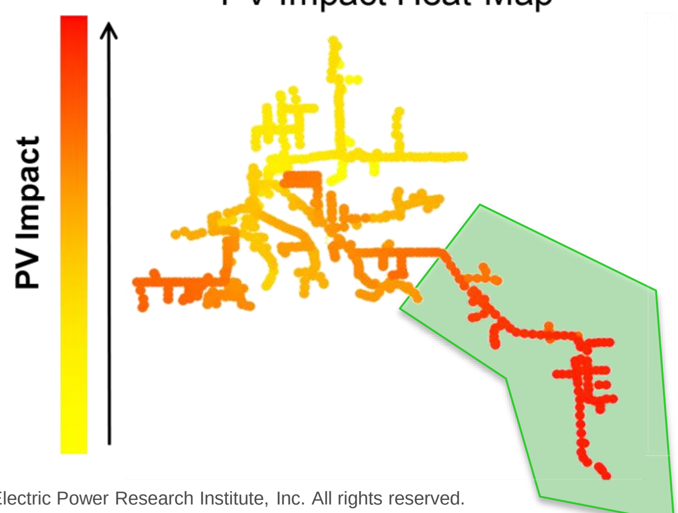
Stochastic PV Deployment



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

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

Distribution Feeder PV Impact Heat Map



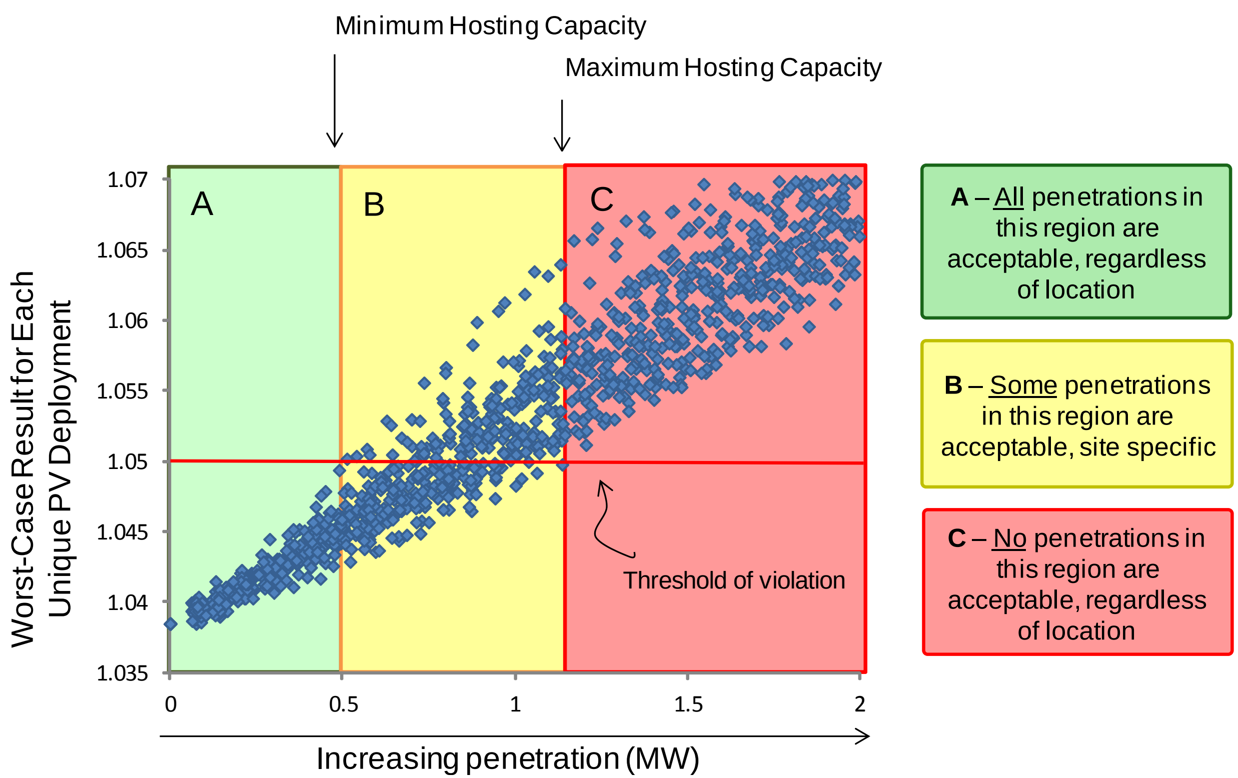
Increase Penetration Levels Until Violations Occur

Feeder Response

- Feeder-wide impact analyzed for each potential PV deployment
- Range in hosting capacity reported for each issue

Evaluation Criteria

- Voltage
- Protection
- Power Quality
- Loading



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

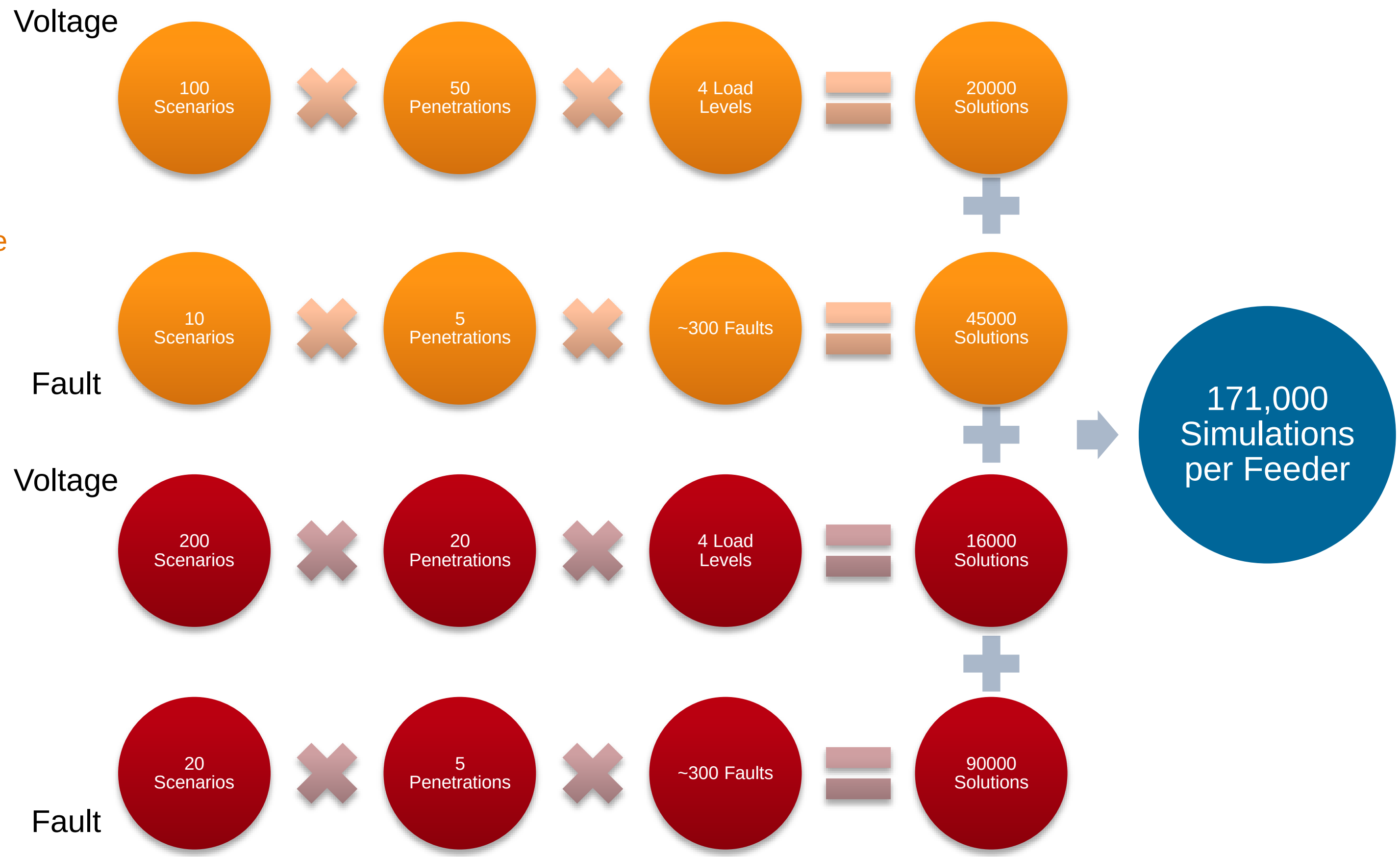
Voltage and Protection

Small Scale PV

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

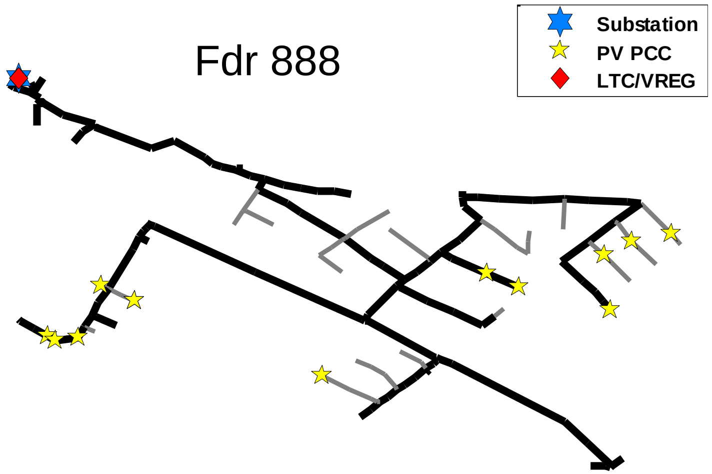
Large Scale PV

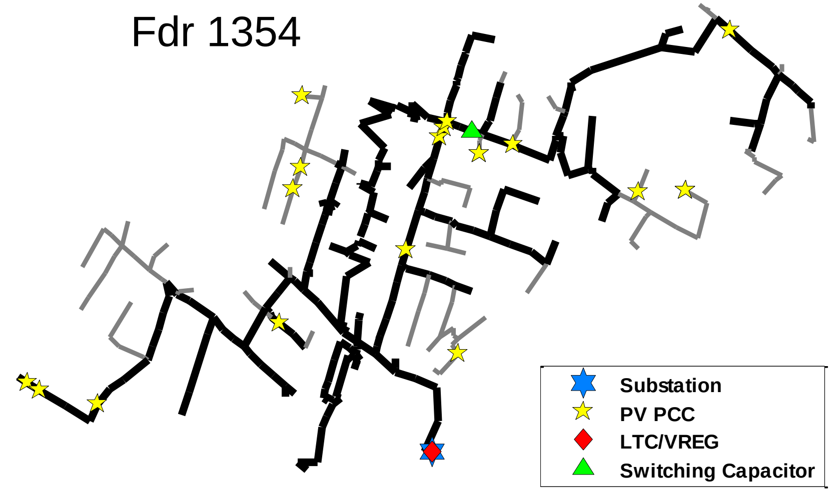
Large, stand-alone three-phase systems located on any three-phase point

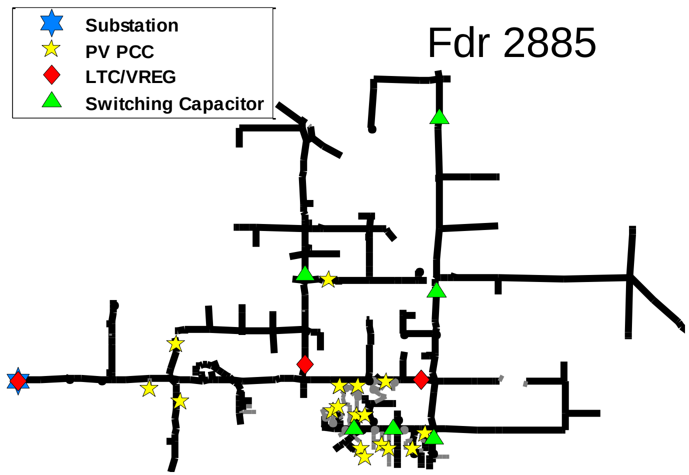


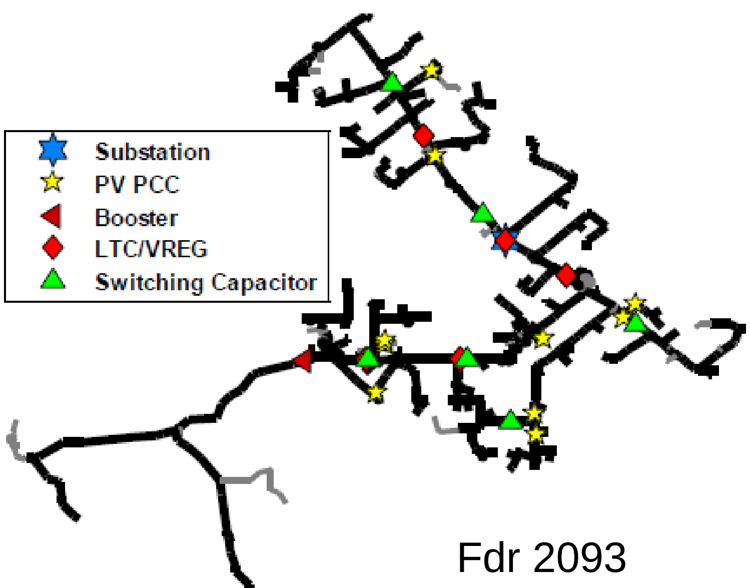
Study Feeders

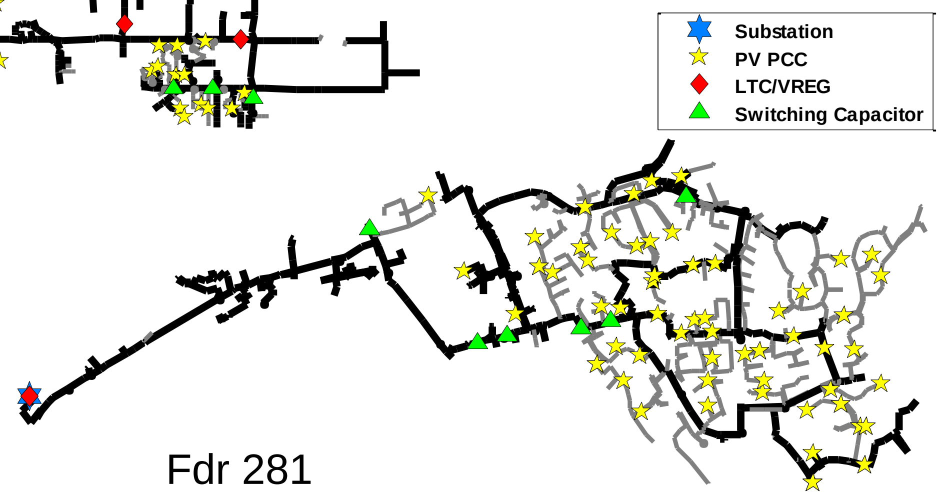
Topology


Fdr 888
Substation
PV PCC
LTC/VREG


Fdr 1354
Substation
PV PCC
LTC/VREG
Switching Capacitor

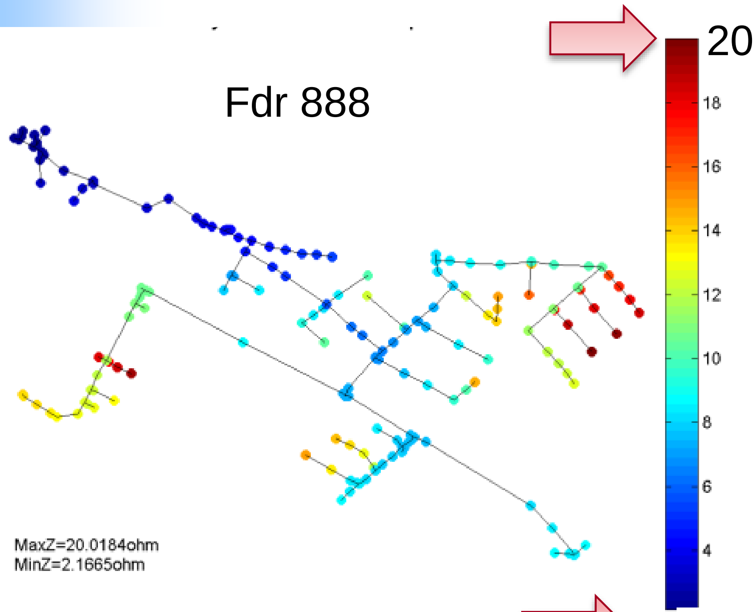

Fdr 2885
Substation
PV PCC
LTC/VREG
Switching Capacitor

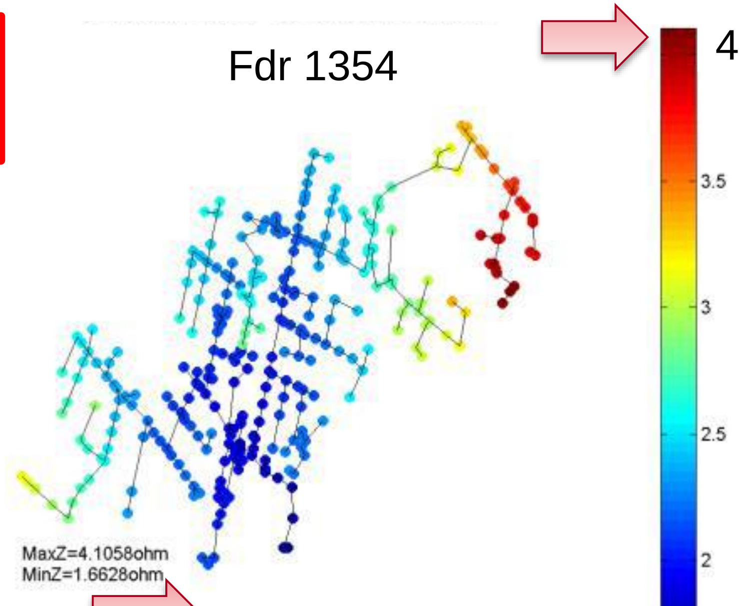

Substation
PV PCC
Booster
LTC/VREG
Switching Capacitor
Fdr 2093

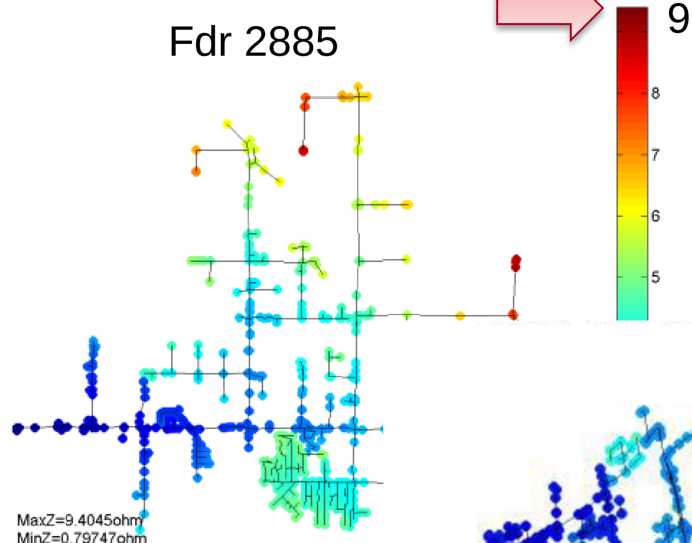

Substation
PV PCC
LTC/VREG
Switching Capacitor
Fdr 281

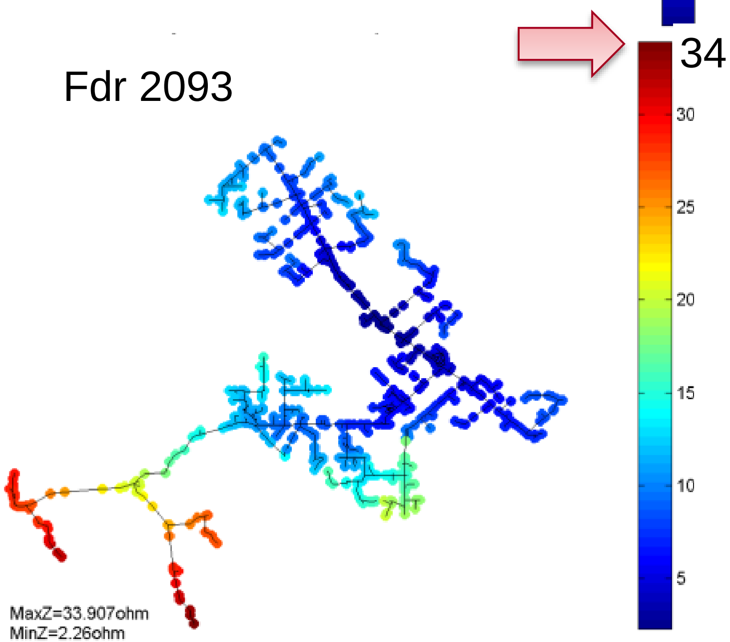
Impedance

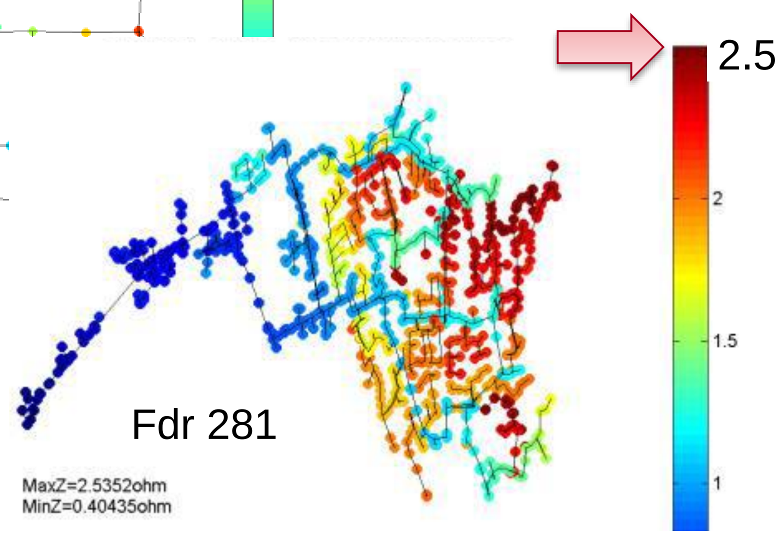
Note scale





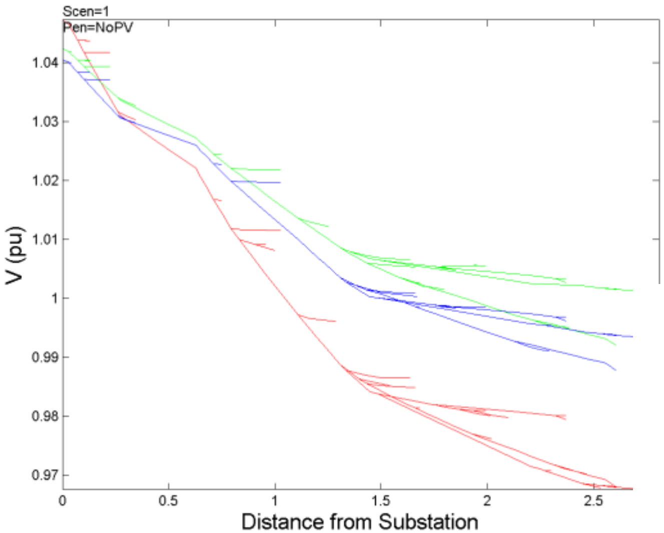




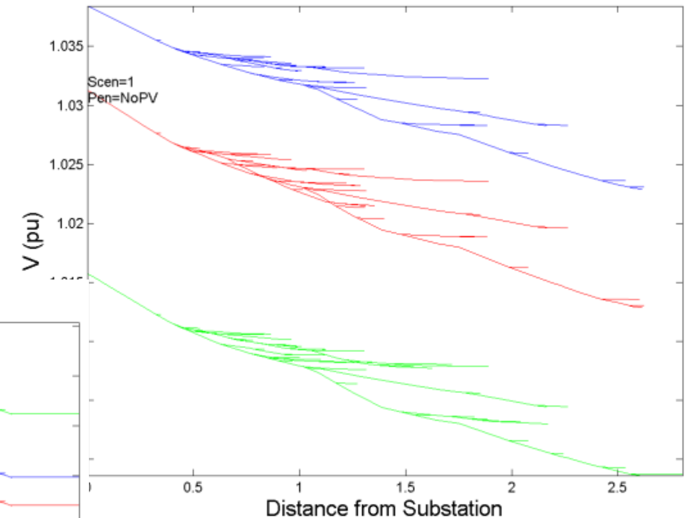


Peak Load Voltage Profiles

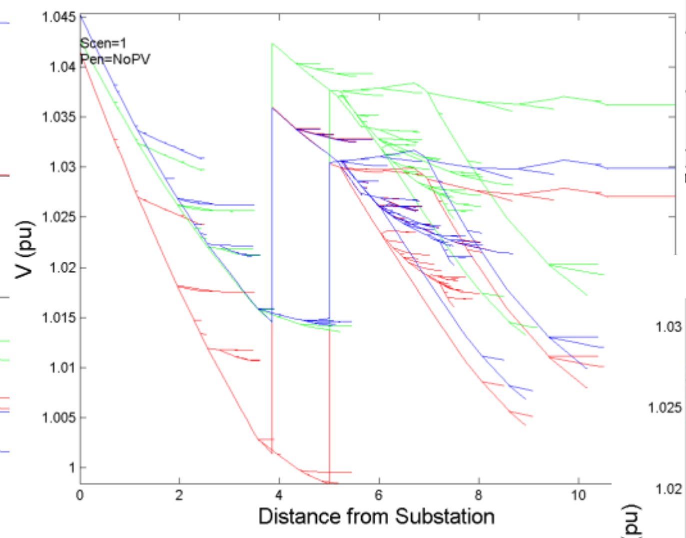
Fdr 888



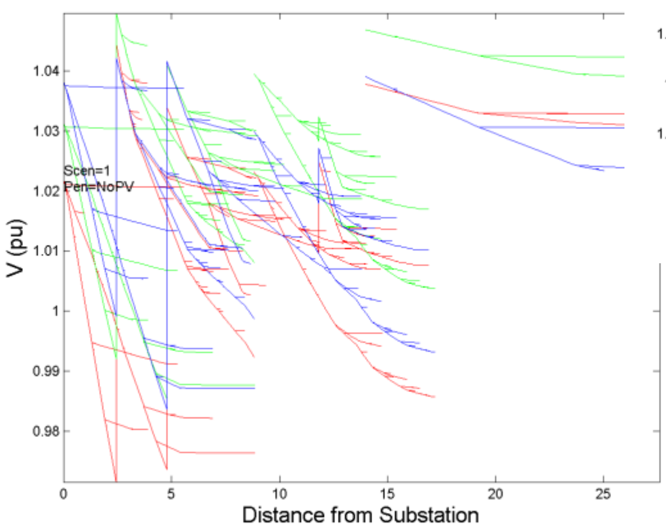
Fdr 1354



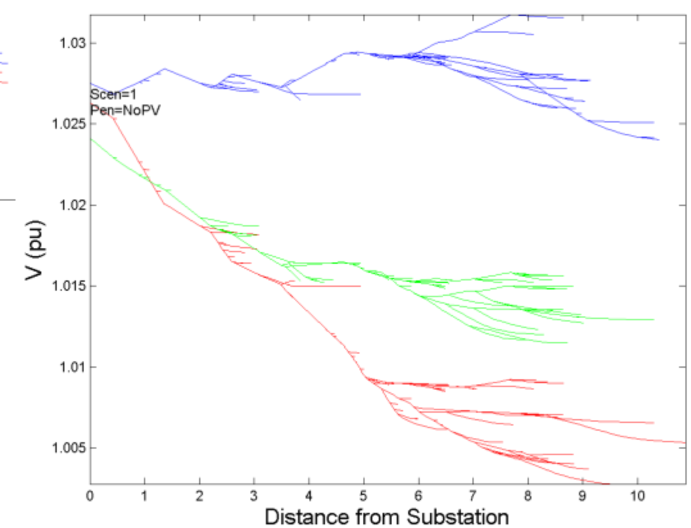
Fdr 2885



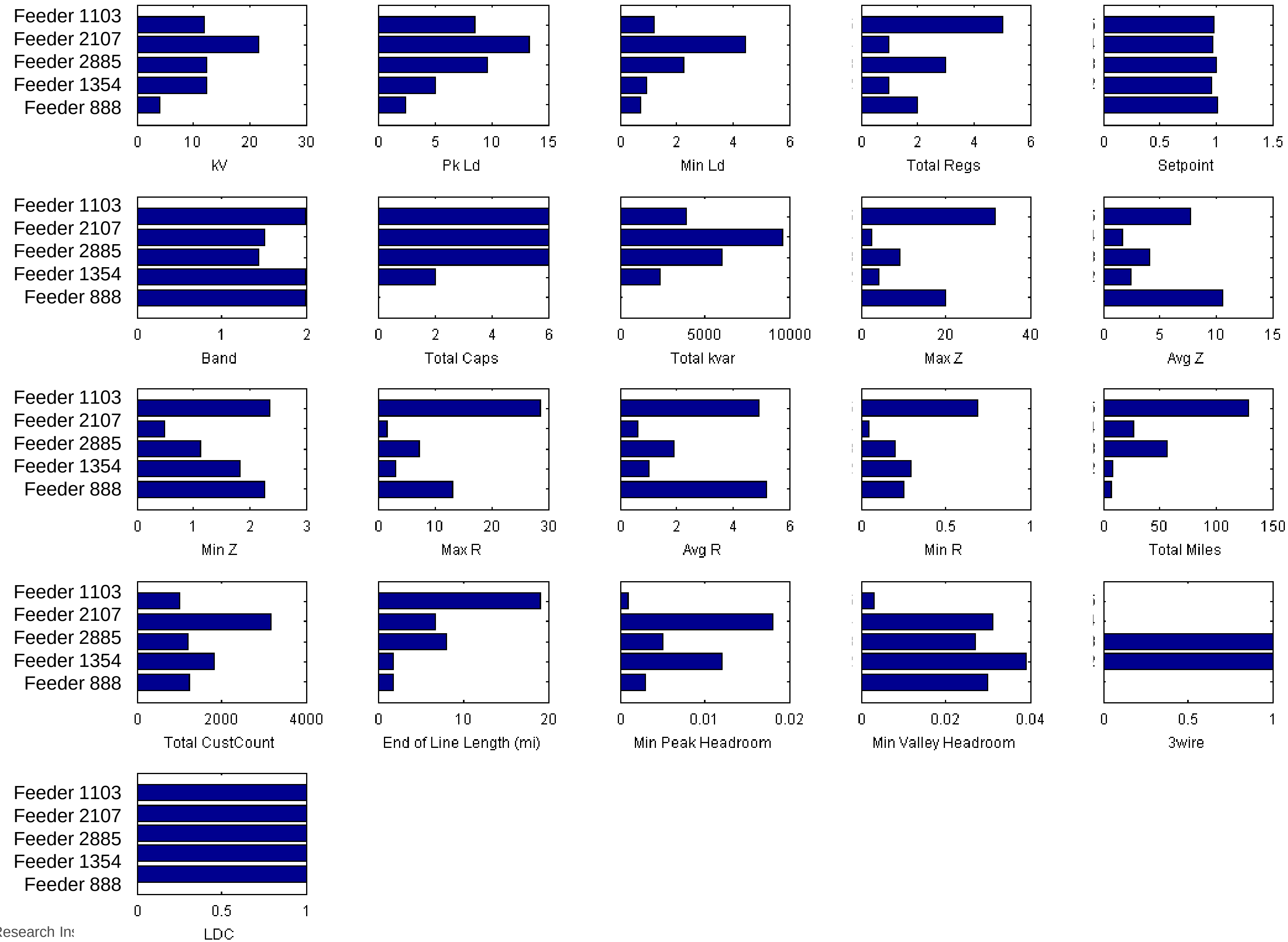
Fdr 2093



Fdr 281

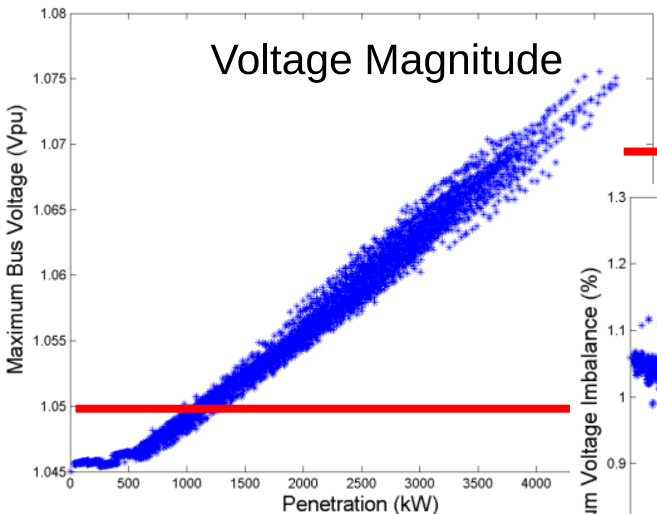


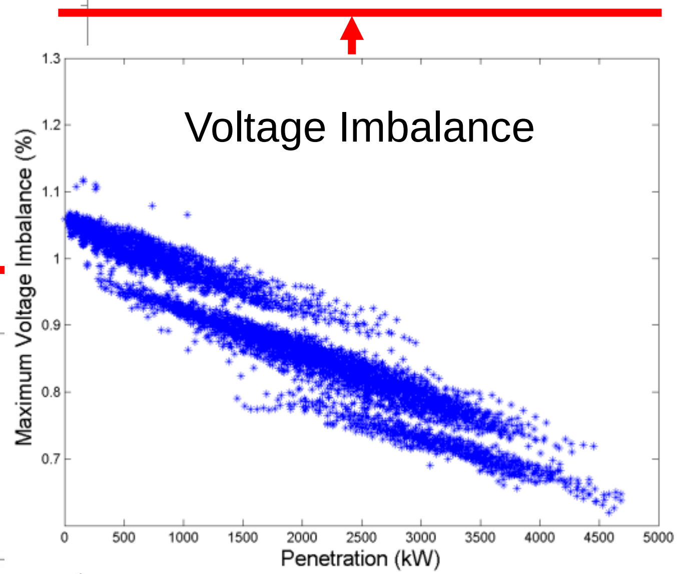
Characteristics

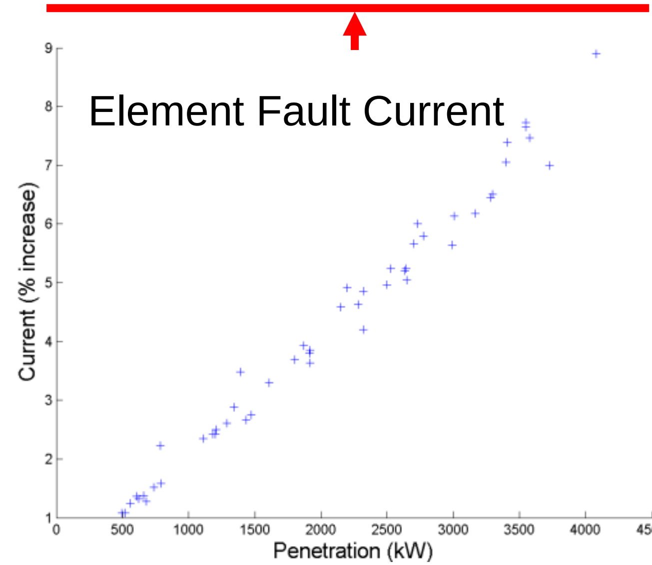


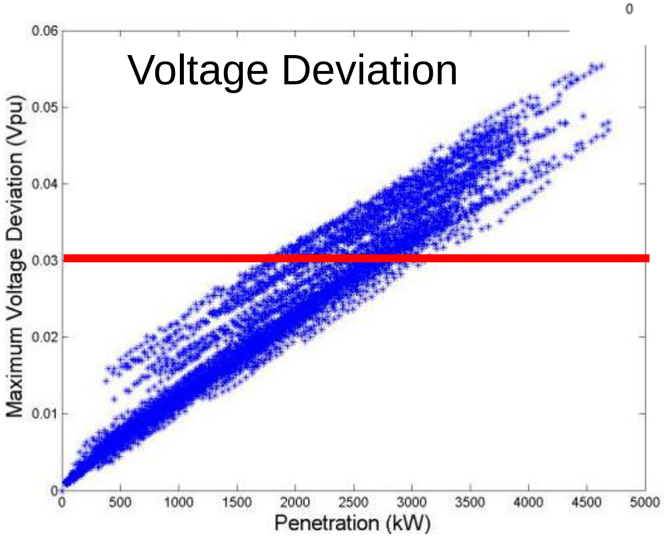
Small Scale PV

Feeder 2885 Trends

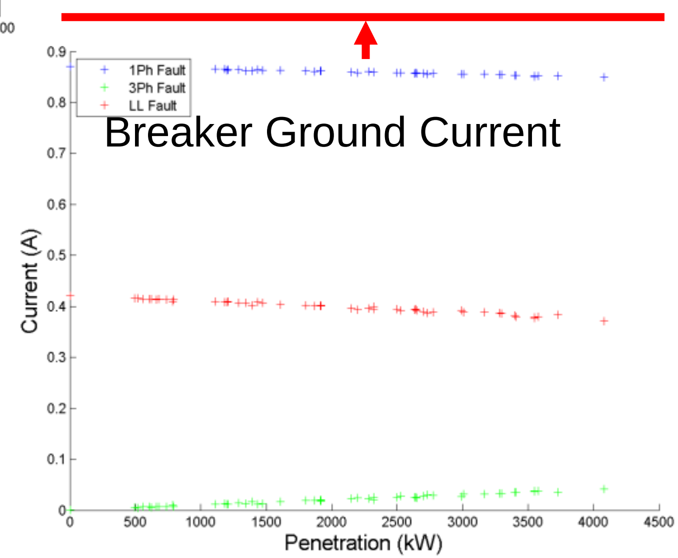




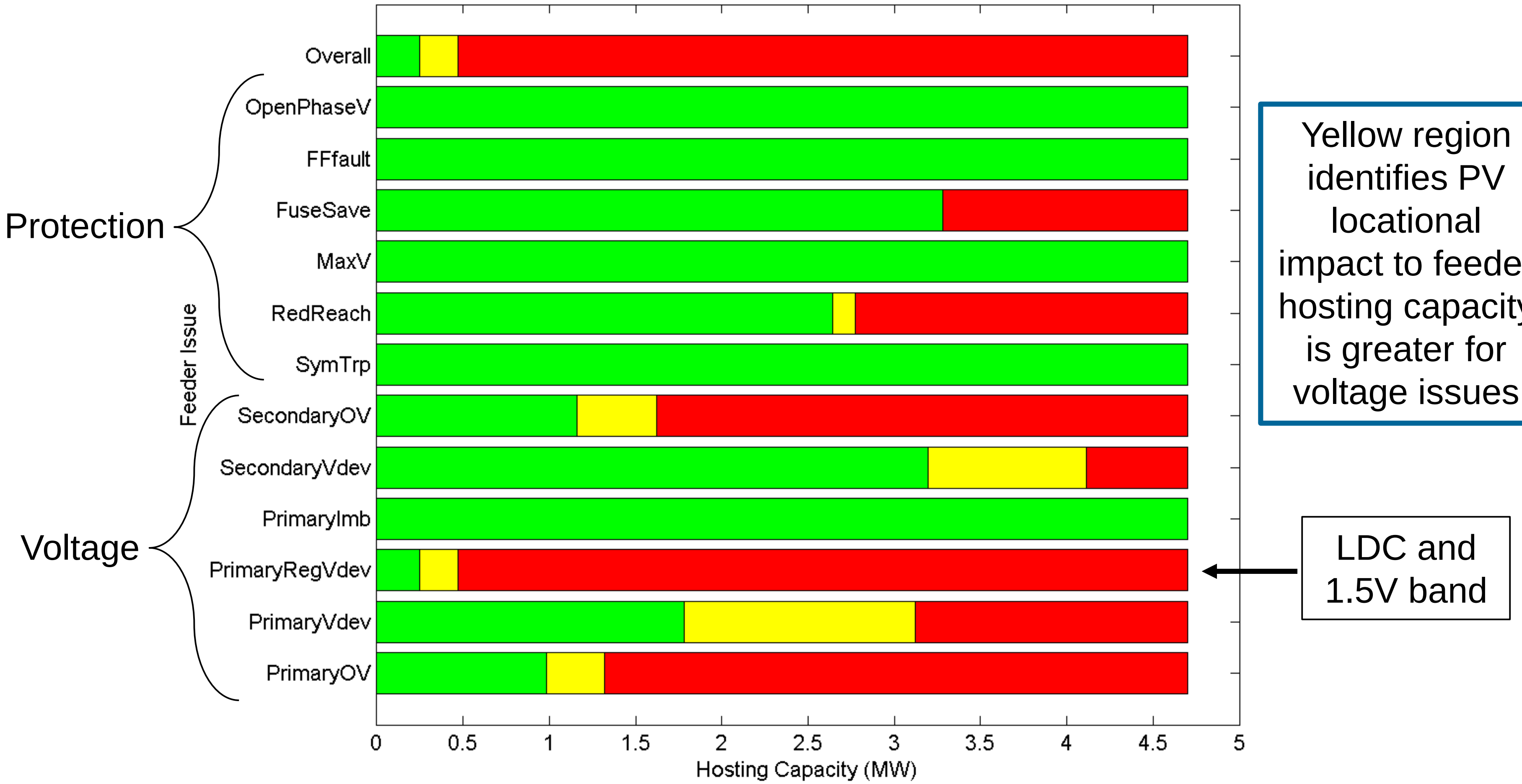




- Trends evident with increased PV penetration
- Not all issues have adverse impacts



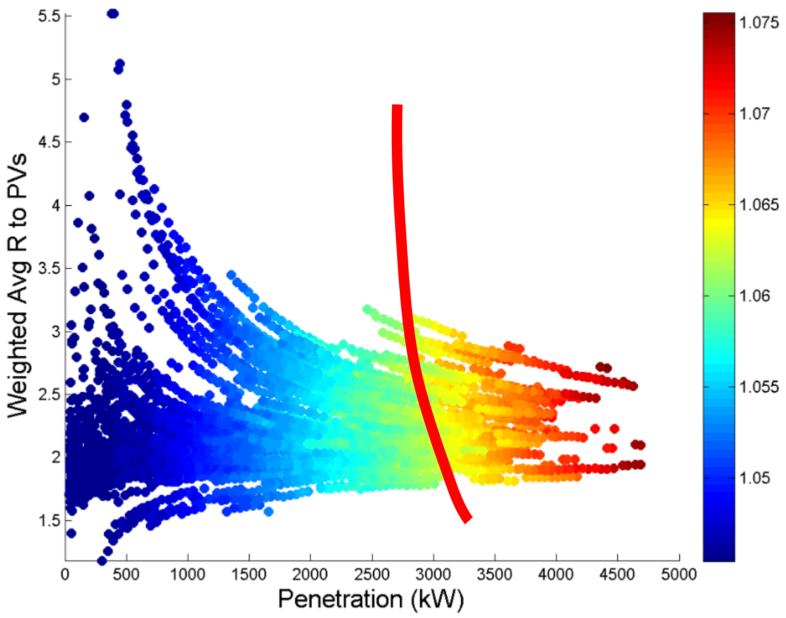
Feeder 2885 PV Hosting Capacities



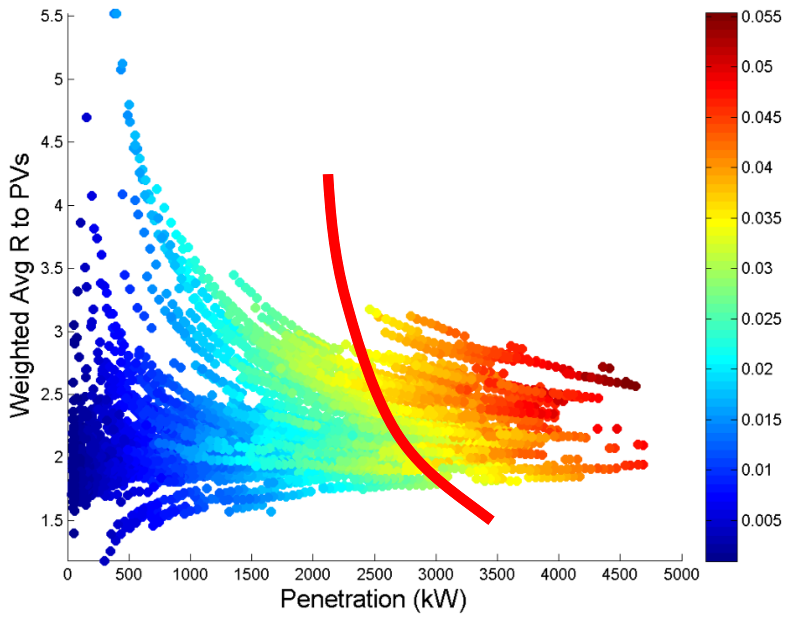
Yellow region identifies PV locational impact to feeder hosting capacity is greater for voltage issues

Feeder 2885 PV Locational Impact

Voltage Magnitude

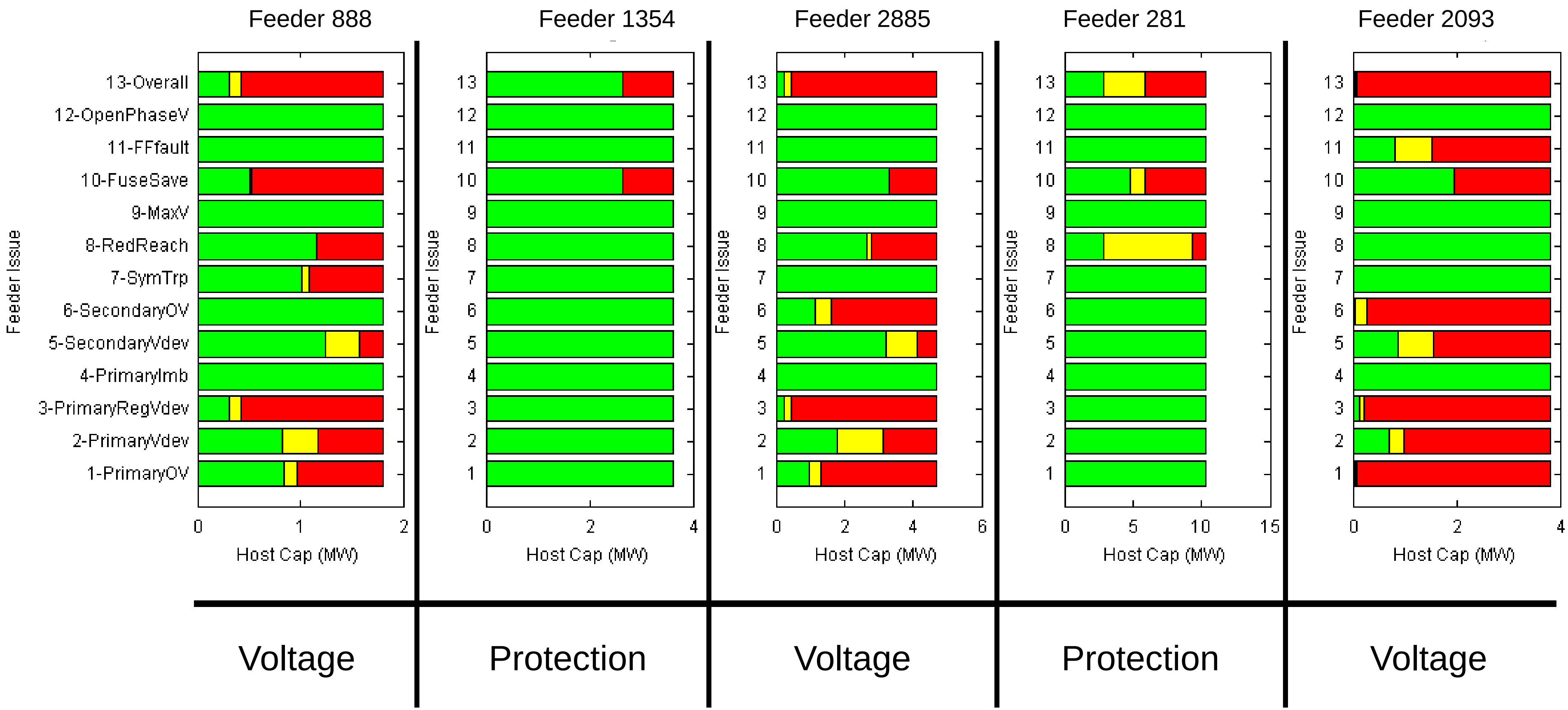


Voltage Deviation



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

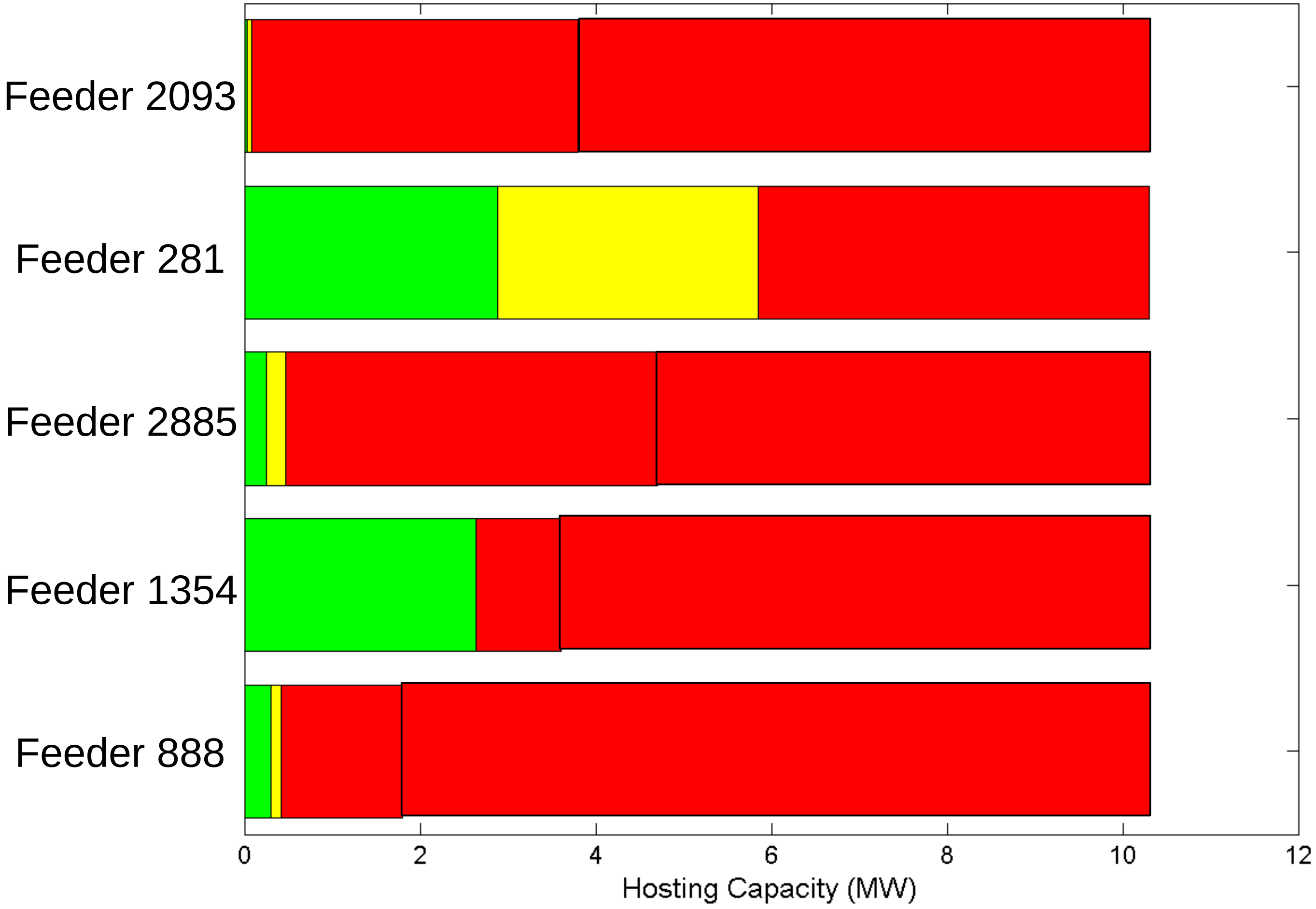
Issue Specific Results



First Issue

- Significant difference in hosting capacity based on feeder cluster

Overall Small Scale PV Results



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

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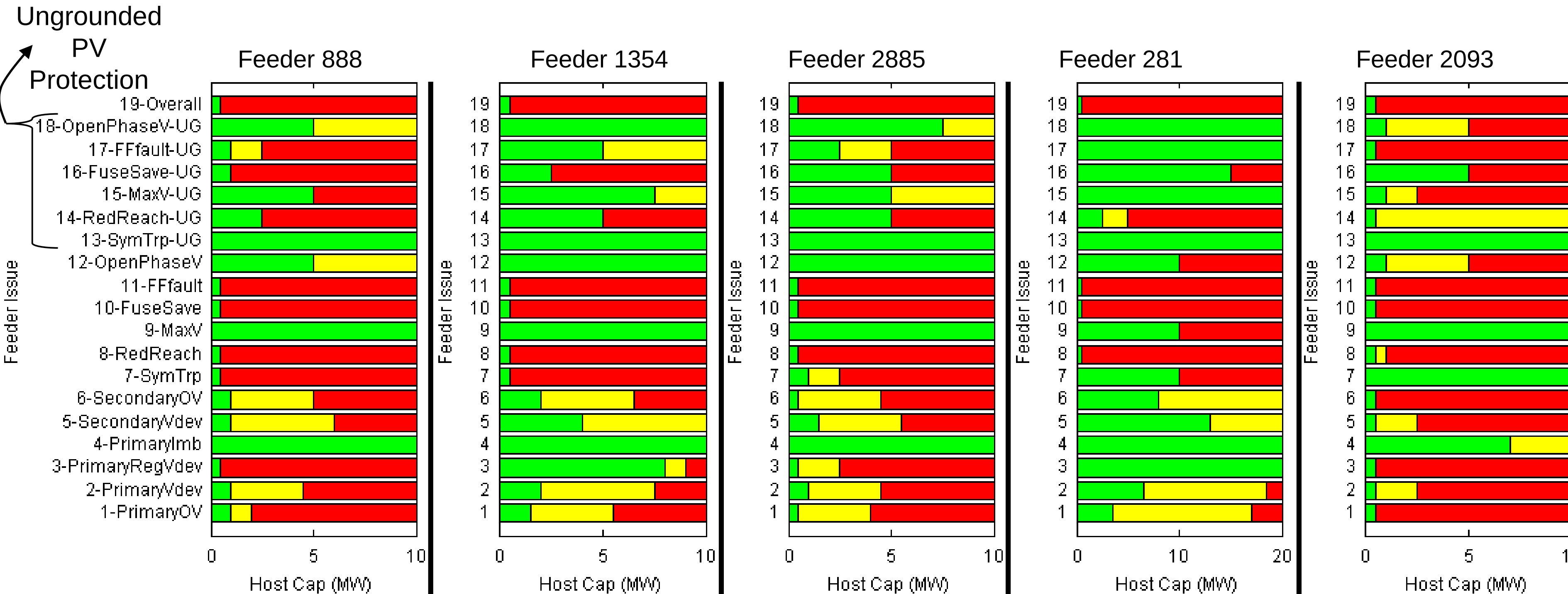
Large Scale PV

Issue Specific Results



- Grounded PV Protection
- Voltage

- Grounded PV Protection

- Grounded PV Protection
- Voltage

- Grounded PV Protection

- Grounded PV Protection
- Voltage

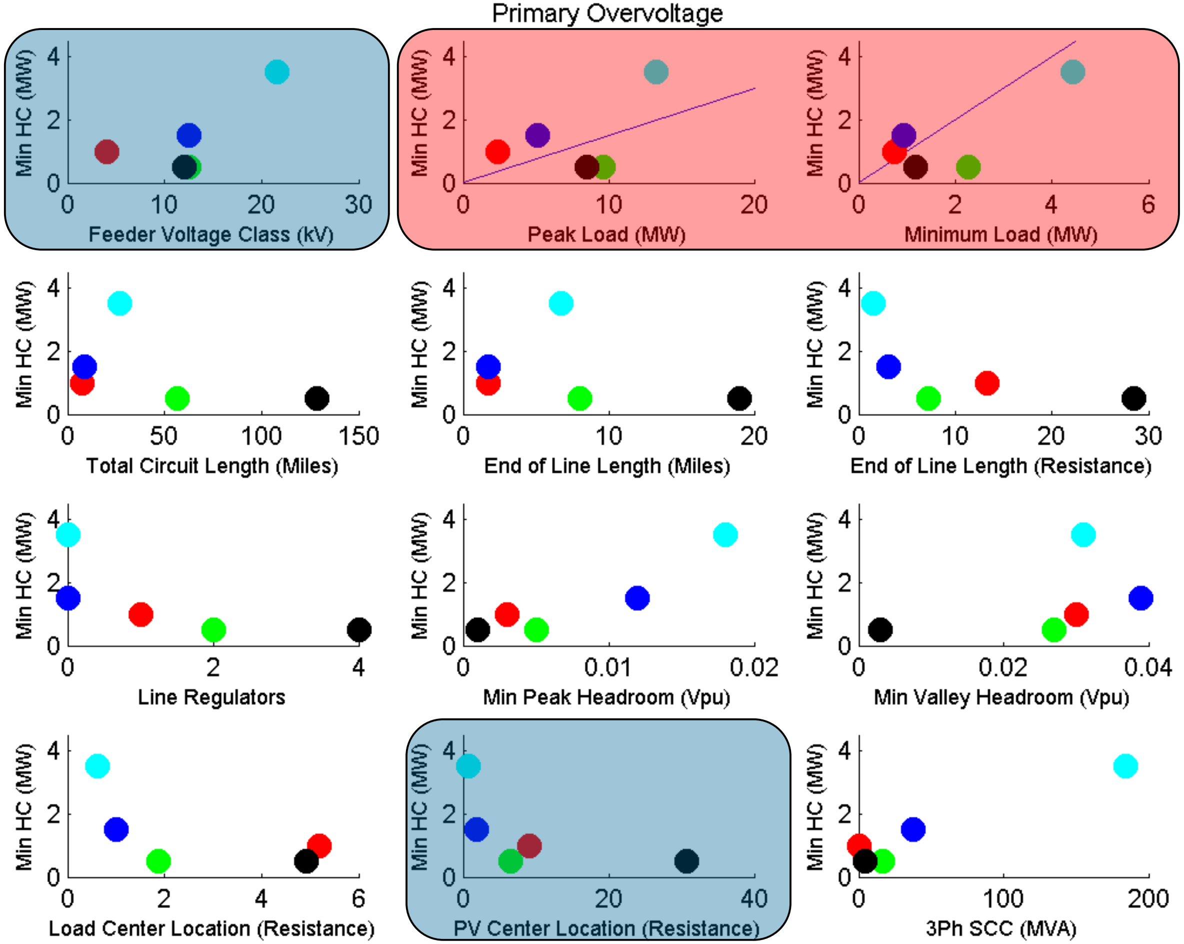
- Can go to higher penetrations
- Can be in more non-optimal locations
- Los Gatos and Newark now show potential issues

<u>First Issue</u>

Characteristics Correlated to Minimum Hosting Capacity for Primary Overvoltage

Greater dependency on

- Voltage
- Resistance to PV



Percent of load screens over/under estimate hosting capacity

- ● – 2093
- ● – 281
- ● – 2885
- ● – 1354
- ● – 888

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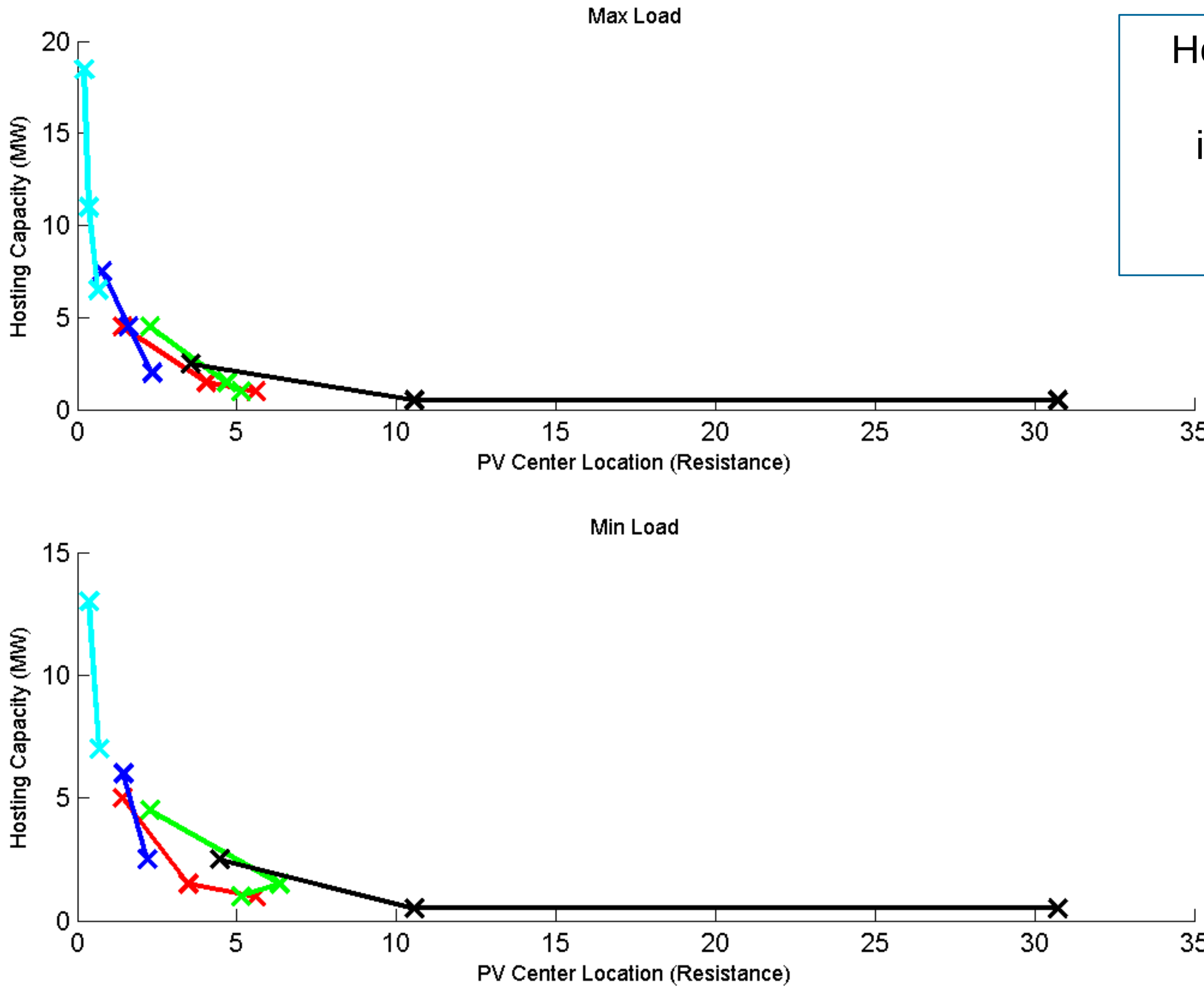
How does Primary Voltage Deviation Hosting Capacity Relate to PV Characteristic Location



Hosting Capacity exponentially increases with decreased resistance

● – 2093
● – 281
● – 2885
● – 1354
● – 888

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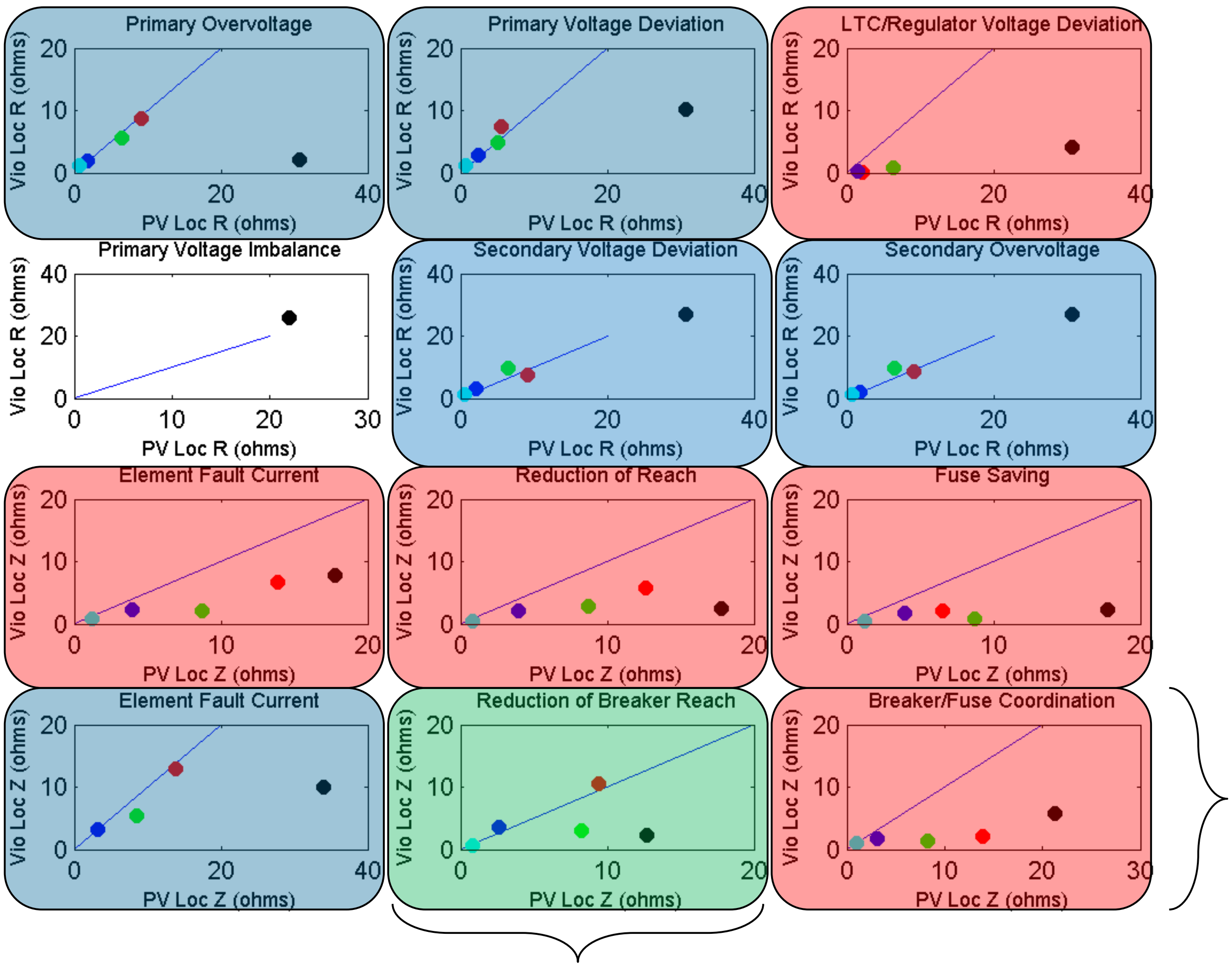
Where are the Feeder Violations with Respect to the PV Characteristic Location



Skewed due to PV/fault locations

- ● – 2093
- ● – 281
- ● – 2885
- ● – 1354
- ● – 888

Violation electrically closer in than PV

Violation electrically close to PV

Violation electrically further out than PV

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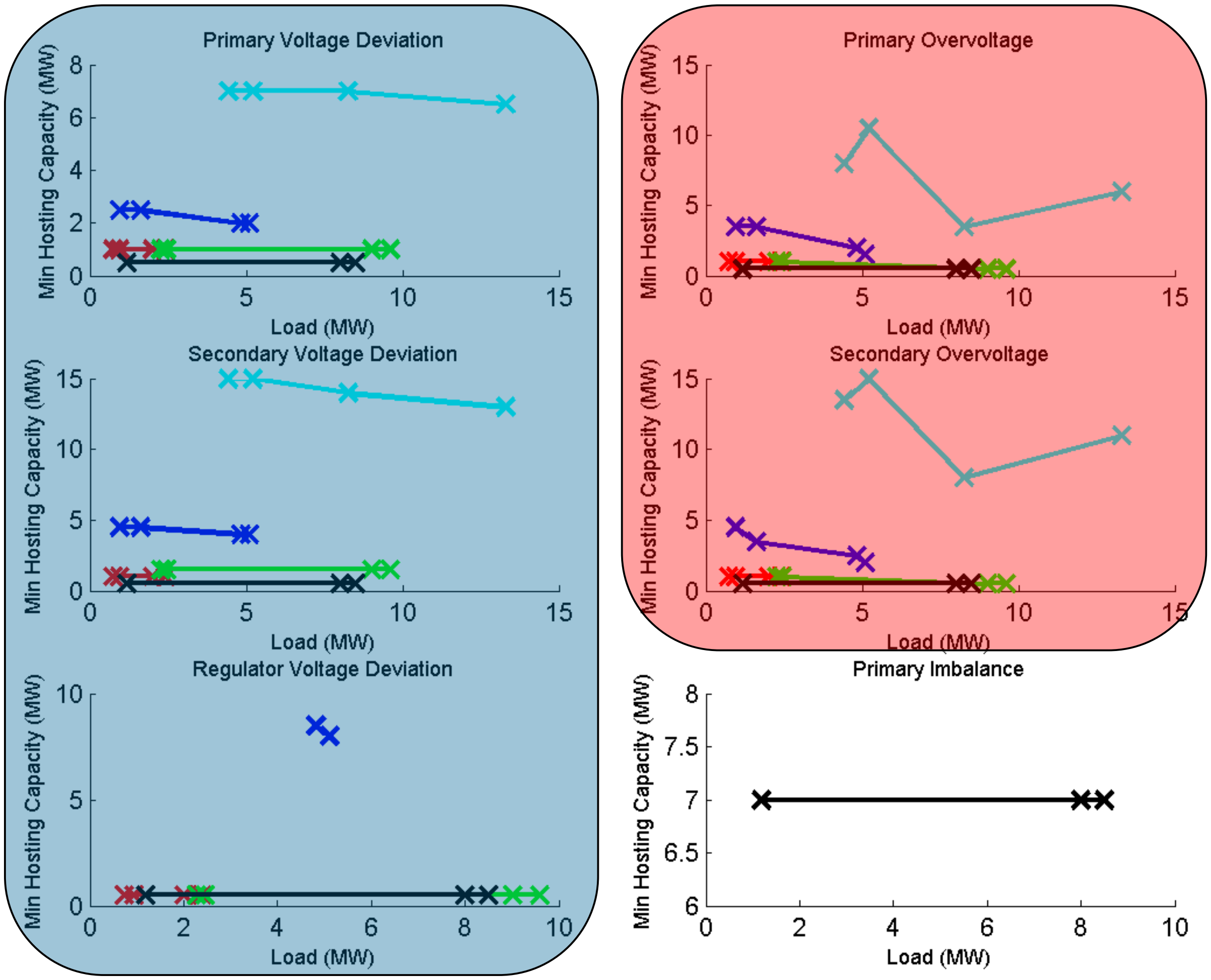
Loading does not Dictate Hosting Capacity but does have an Influence

Hosting Capacity typically decreases with load



Hosting Capacity typically increases with load, but with LDC the inverse is true

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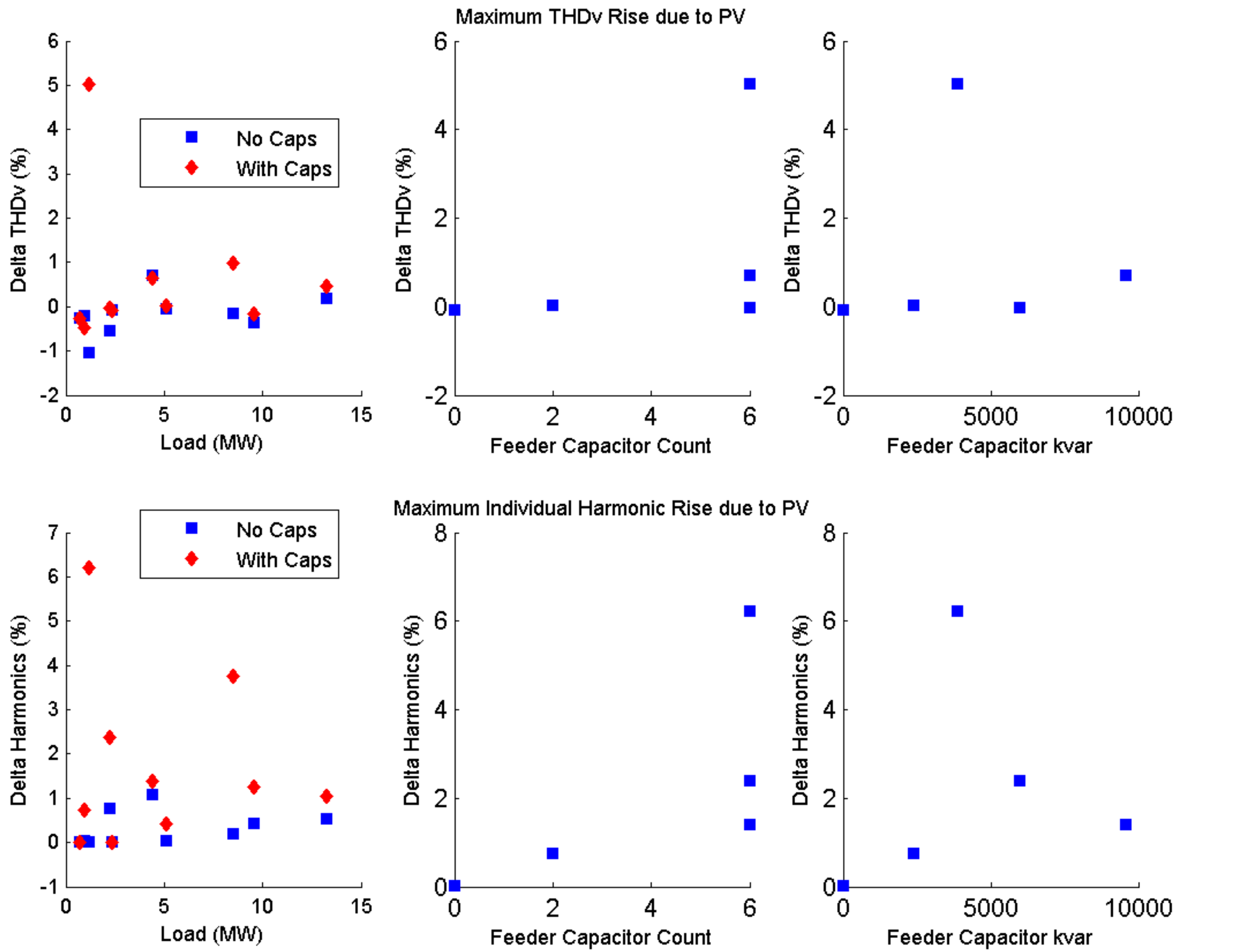
Harmonics with High Penetration PV

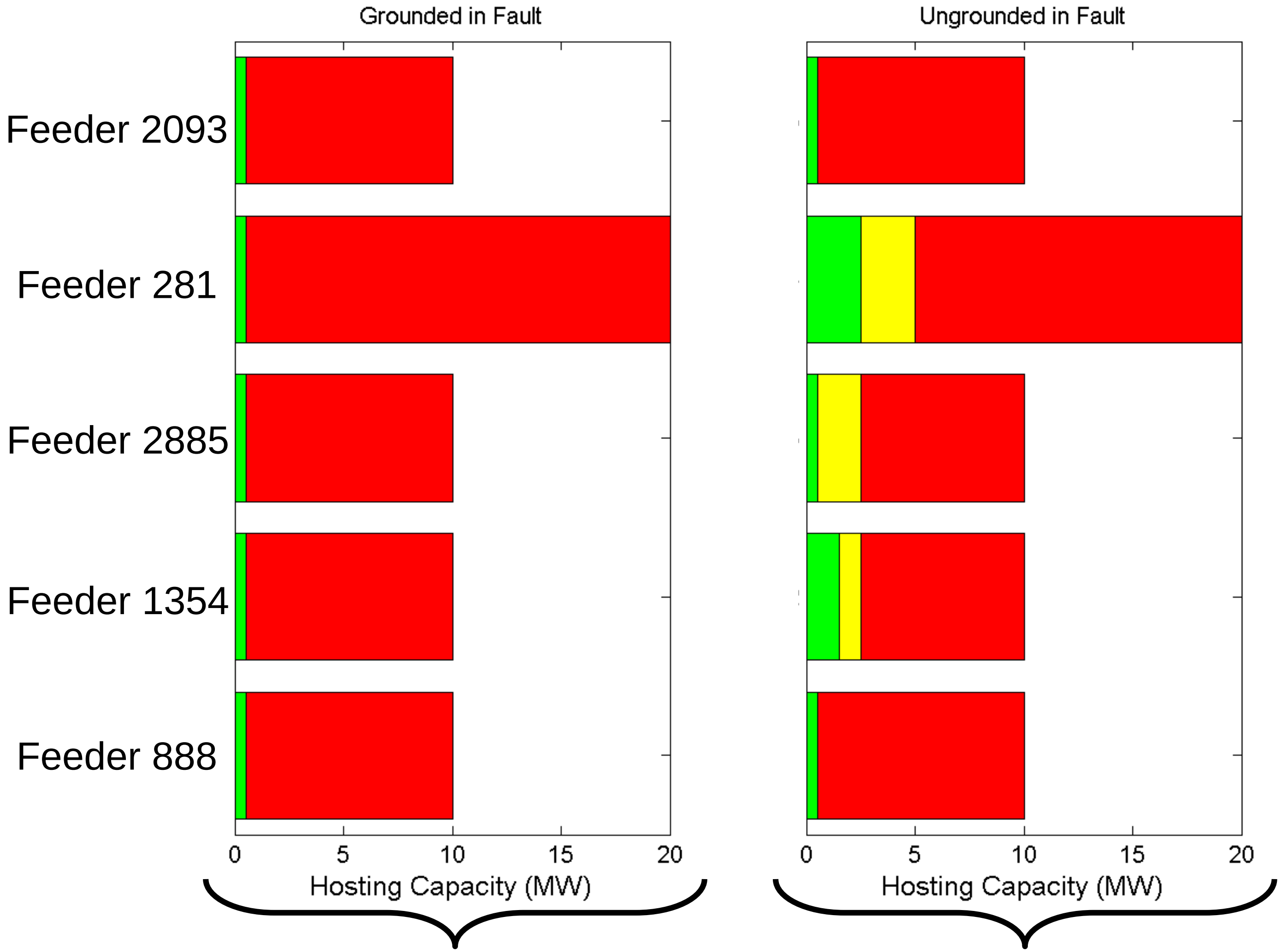
Impact of PV is examined as a change from base case without PV. Causes of high harmonic increases:

+ Low load

+ More capacitors



Overall Large Scale PV Results

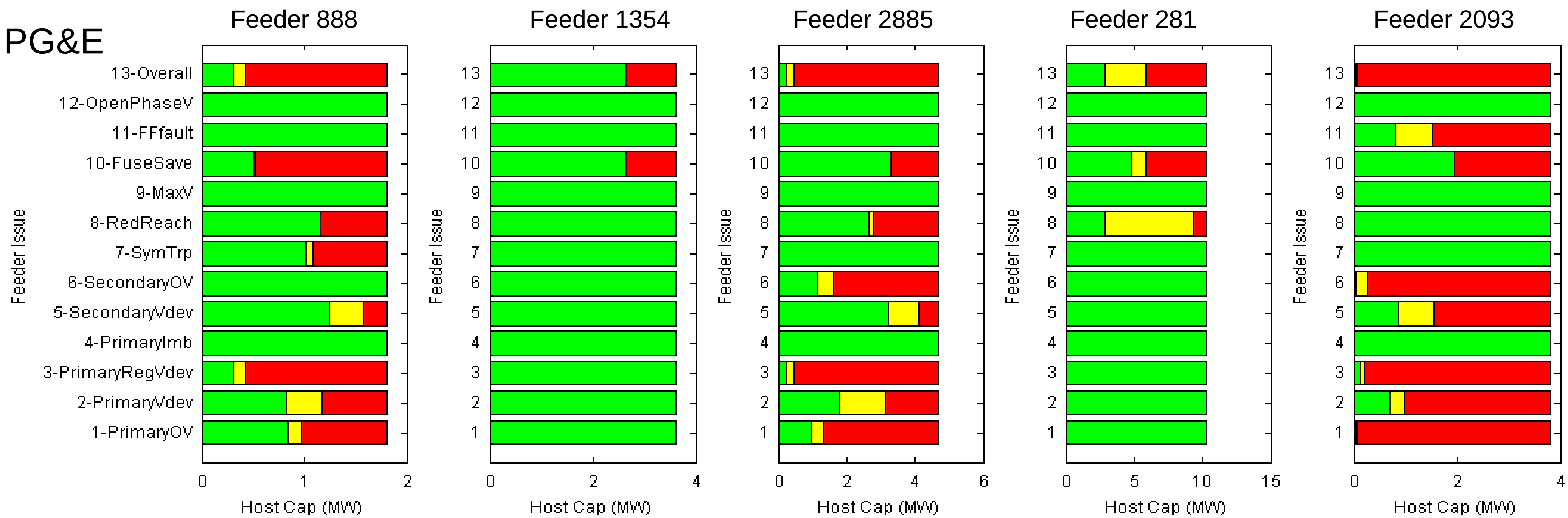


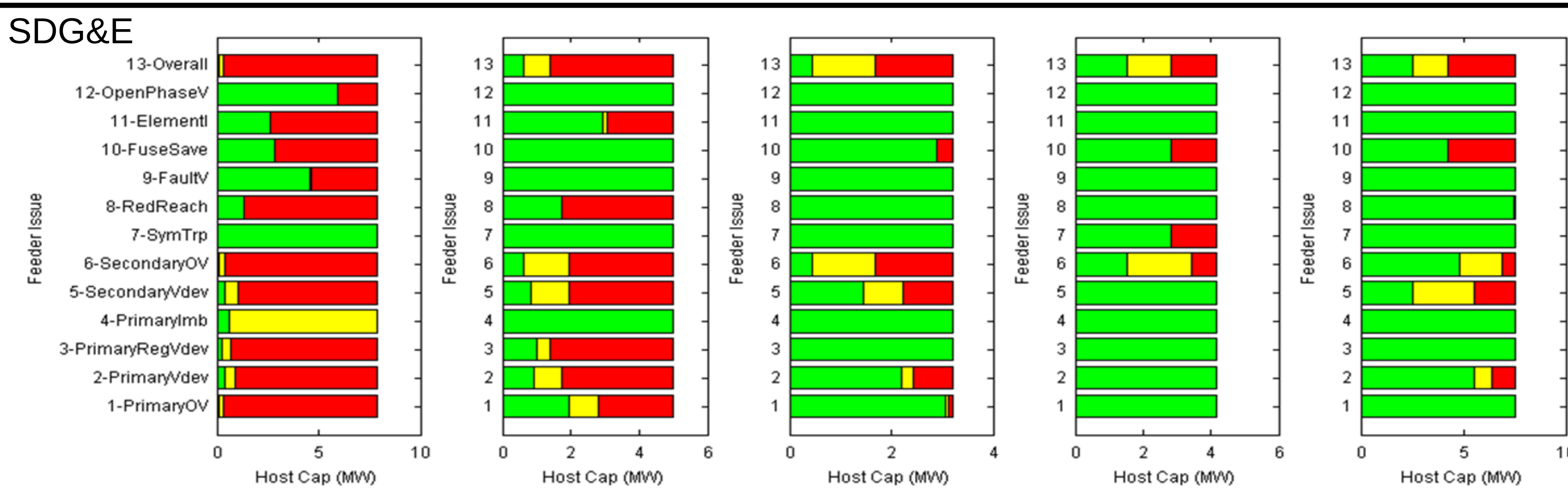
Primarily influenced by protection issues (high ground fault contribution)

Primarily voltage-based issues

- Maximum large scale PV penetration dependent on kV class
- Higher analyzed penetrations would show similar adverse issues

Small-Scale Issue Specific Results





Large-Scale Issue Specific Results