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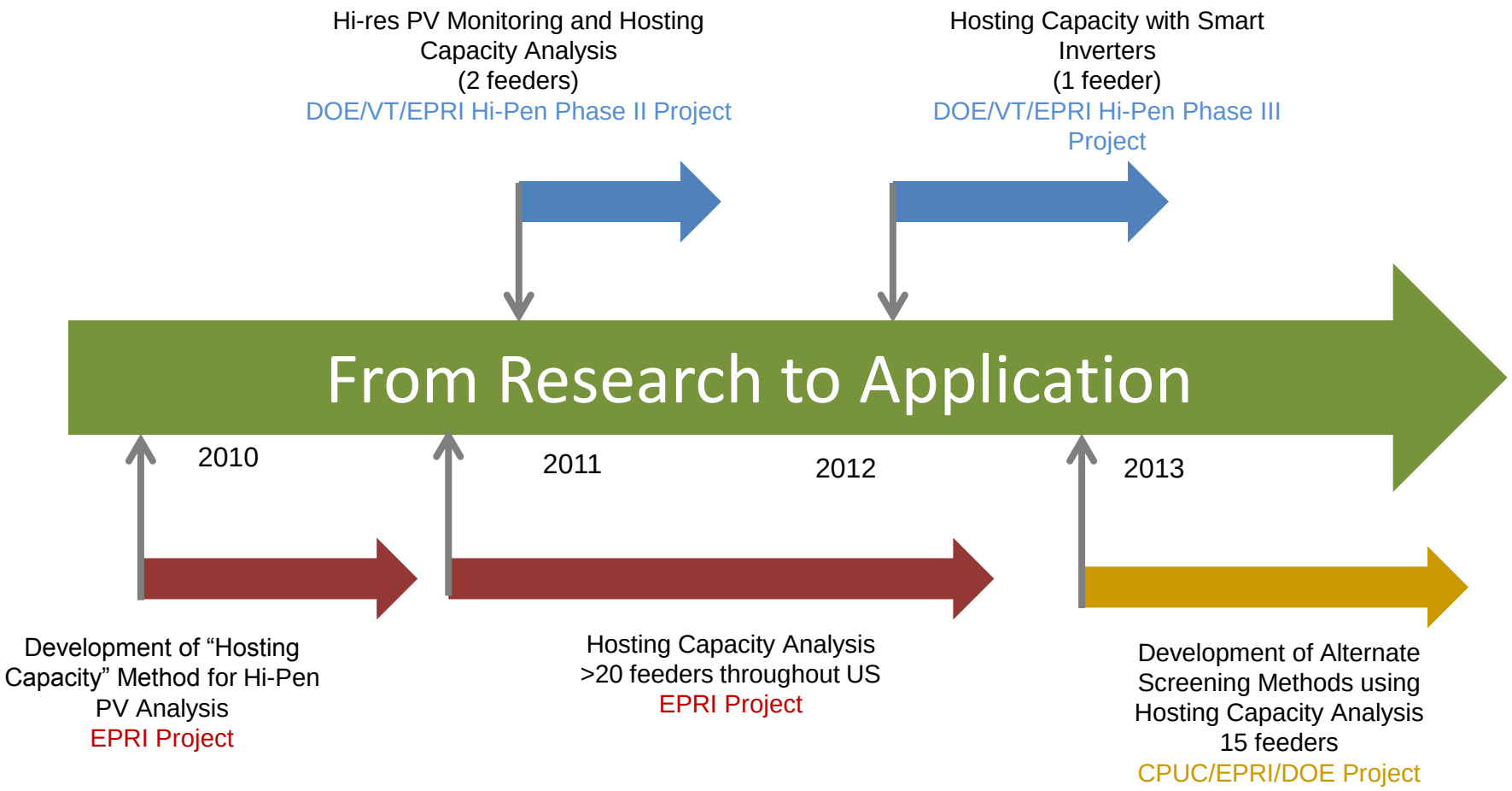
ALTERNATIVE SCREENING METHODS

PV HOSTING CAPACITY IN DISTRIBUTION SYSTEMS

Leveraging Work Throughout Industry



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

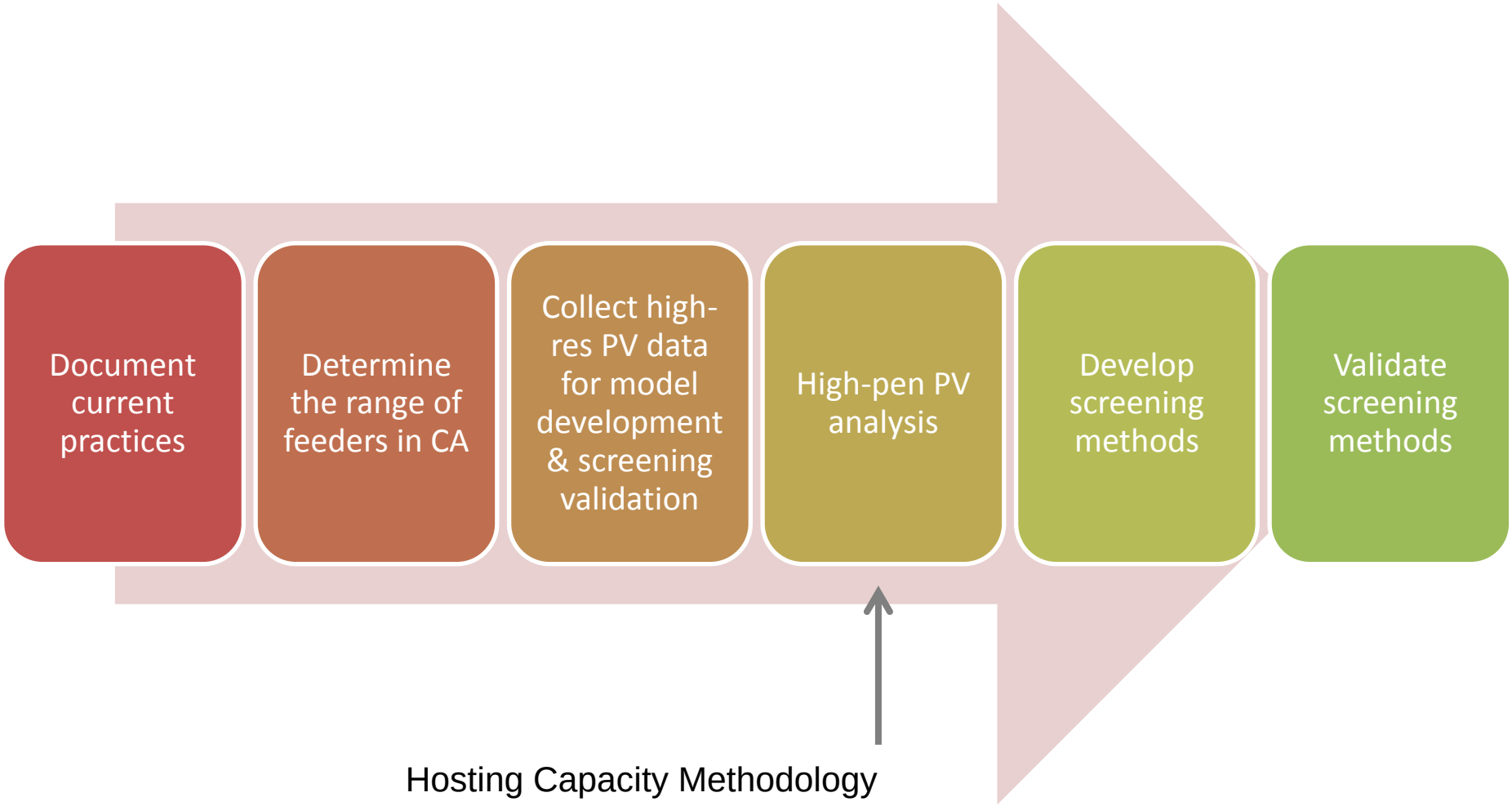
Sample feeders from DOE-funded VT/EPRI Hi-Pen Project

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**

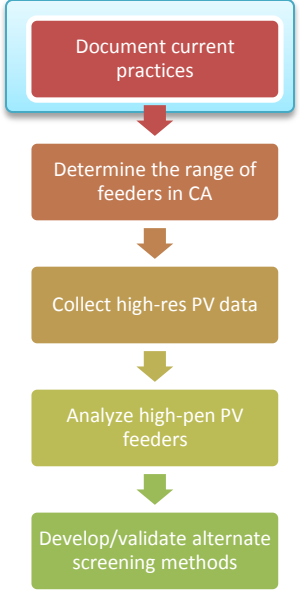
70% of Peak Load

4% of Peak Load

Approach


Document current practices
Determine the range of feeders in CA
Collect high-res PV data for model development & screening validation
High-pen PV analysis
Develop screening methods
Validate screening methods
Hosting Capacity Methodology

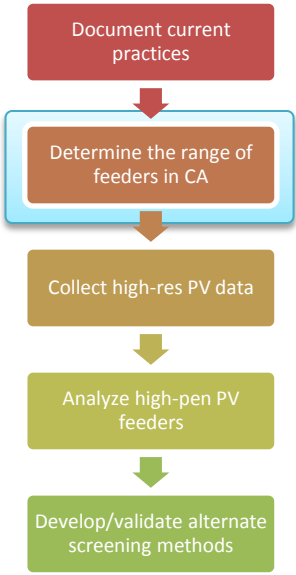
Step 1: Current Screening Practices

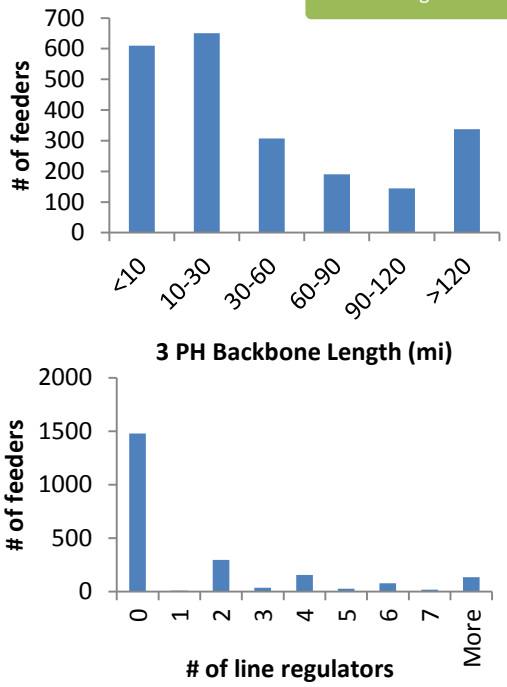


- Task Purpose
  - > Investigate and document current practices for screening PV interconnection requests among California utilities and from other sources outside California.
- Approach
  - > Consider federal, state, and local interconnection procedures pertaining to CA (Rule 21, WDAT, SGIP)
  - > Consider non-CA and European utility screening practices as well

Step 2: Define Feeder Configurations in CA

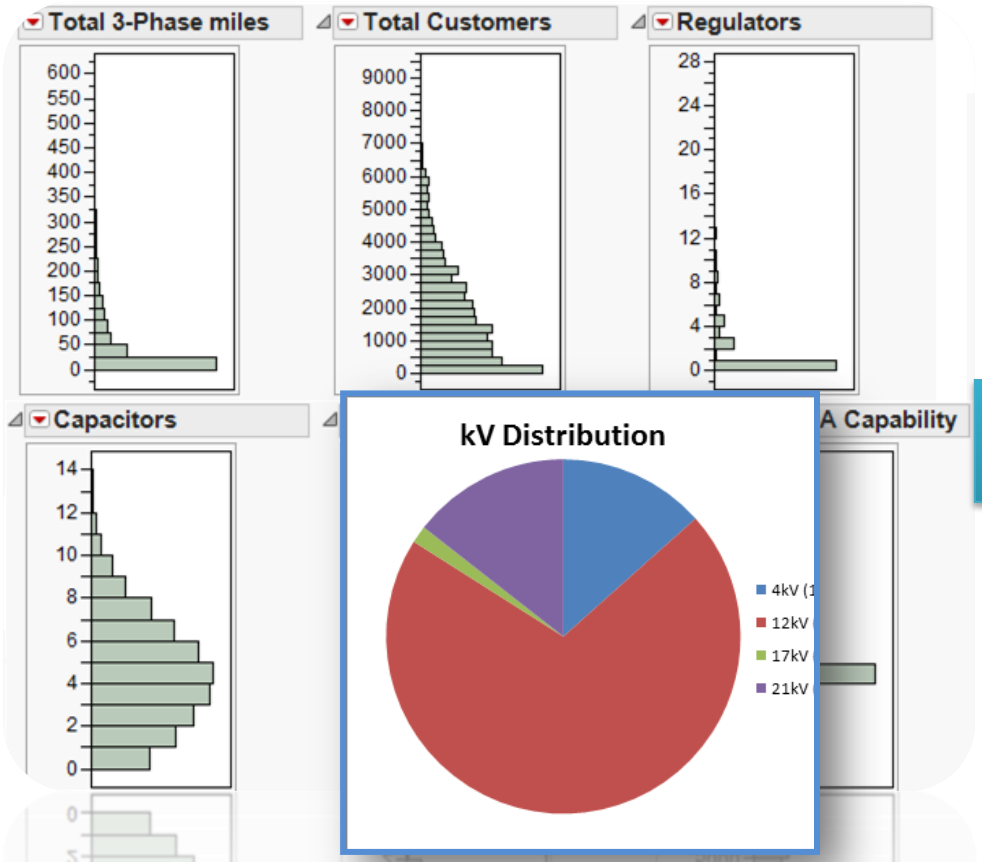
- Purpose of task
  - > Determine the range of feeder configurations and characteristics for CA utilities
  - > The representative feeders selected will be used in developing and validating the proposed screening methodology
- Approach
  - > Develop database of feeder characteristics for statistical processing
  - > Identify 20 feeders representative of range of distribution feeder types for the grid in CA
    - 15 Test Feeders for methodology development
    - 5 Control Feeders for methodology validation



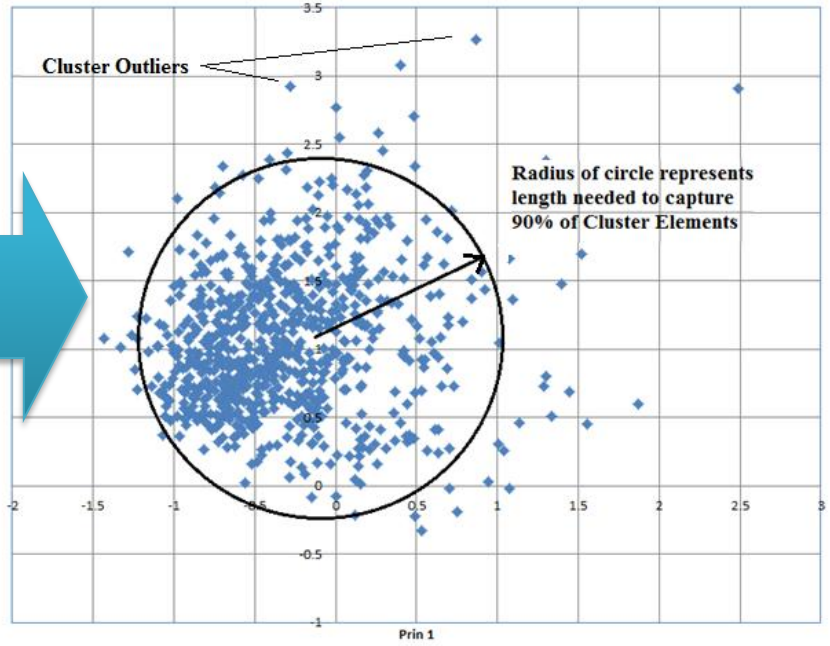


Evaluate Distribution Feeder Characteristics

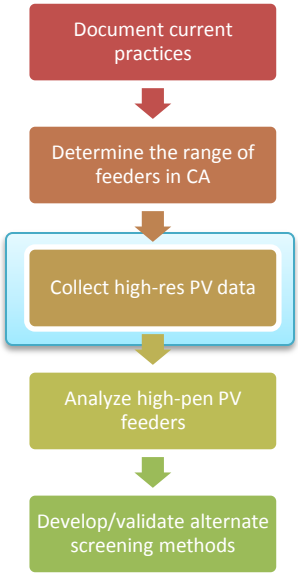
Clustering of data to select feeders



- 1000's of feeders
- Clustering of feeder data characteristics
- Select 20 feeders for analysis



Step 3: Collect High-Resolution Solar Data



- Purpose of Task
  - > Collect high-resolution, time-series solar output data that can be used for
    - Validation of feeder models
    - Definition of scenarios for high-penetration PV output
    - Verification of screening method with empirical data
- Approach
  - > Install monitoring equipment via pole-mount and at existing PV facilities (provided by EPRI, installed by utilities)
  - > From selected feeders ID'd in previous task, obtain high-resolution (1-sec) PV production data via field monitoring

Distributed PV Monitoring

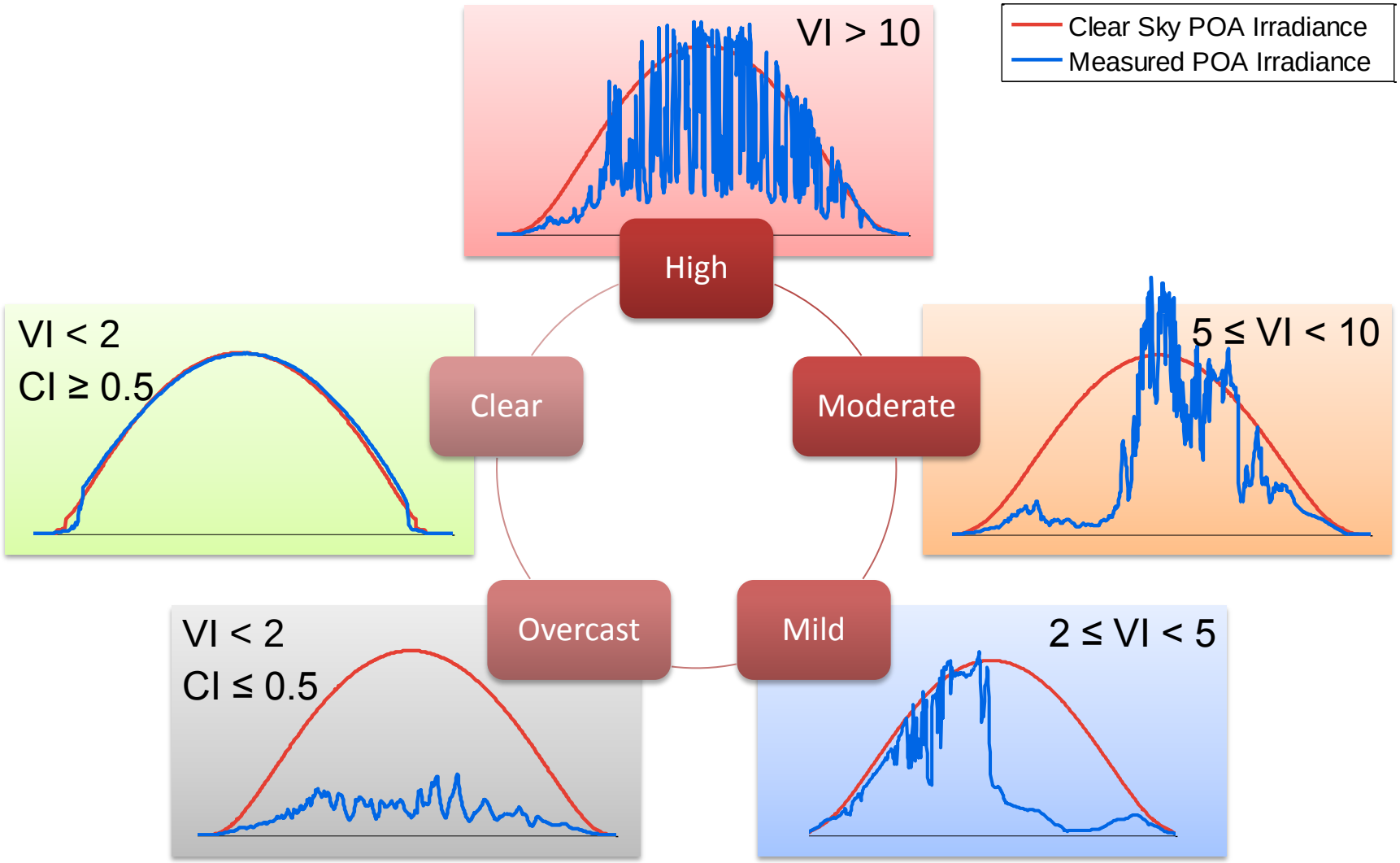
Leveraging a Utility Research Project

Field monitoring to characterize PV system performance & variability

- **Utility interactive PV systems**
  - ✓ Single modules on poles
  - ✓ 1MW plants
  - ✓ 200+ sites committed nationwide
- **Field measurements for 1+ years**
  - ✓ AC power meter
  - ✓ Plane-of-array pyranometer
  - ✓ Module surface temperature
  - ✓ …More sensors on select sites
- **Data acquisition**
  - ✓ 1-second resolution
  - ✓ Time synchronized
  - ✓ Automated uploads to EPRI
  - ✓ Structured data storage at EPRI

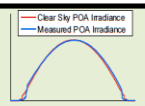
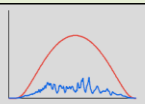
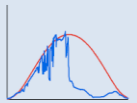
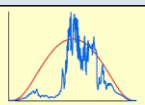
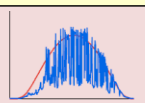
Classifying Solar Days

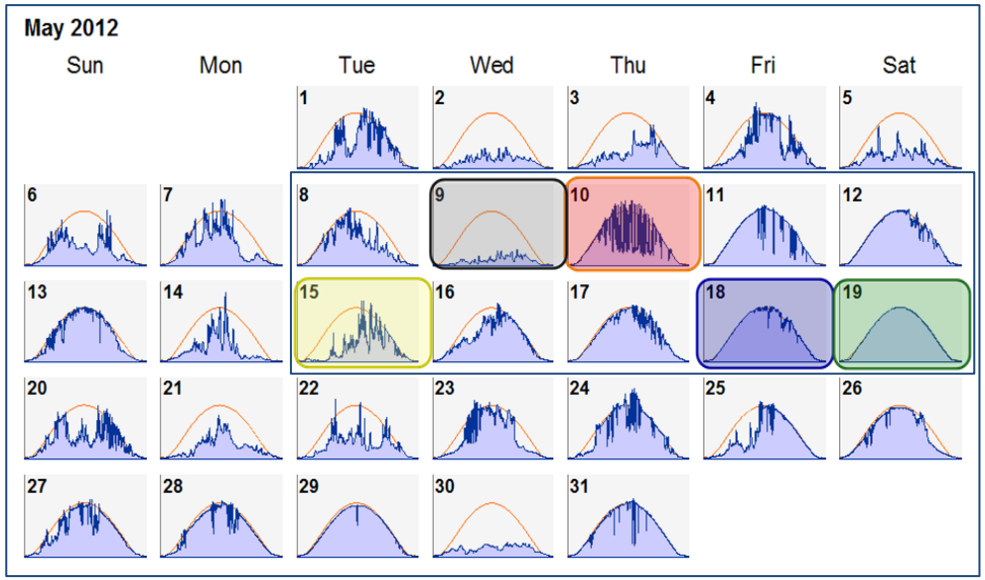
Applied Sandia's variability index (VI) with clearness index (CI) to classify days

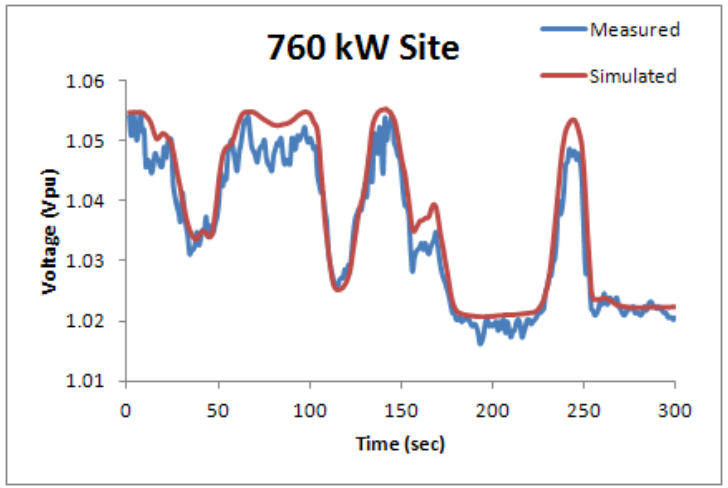


Solar PV Measurements for Modeling

- Solar Resource Classification-

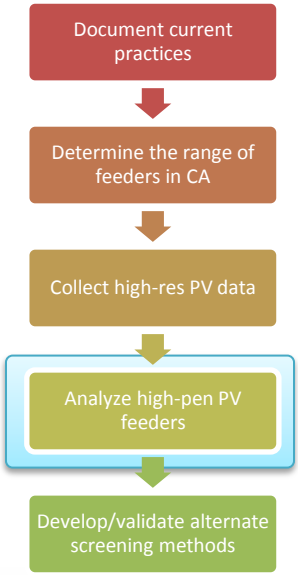
Classification	Example Day	Variability Index (VI)	Clearness Index (CI)
Clear VI < 2 CI >= 0.5		VI = 1.0	CI = 1.09
Overcast VI < 2 CI < 0.5		VI = 1.6	CI = 0.20
Mild 2 <= VI < 5		VI = 4.0	CI = 0.51
Moderate 5 <= VI < 10		VI = 8.1	CI = 0.59
High VI >= 10		VI = 21.3	CI = 0.64



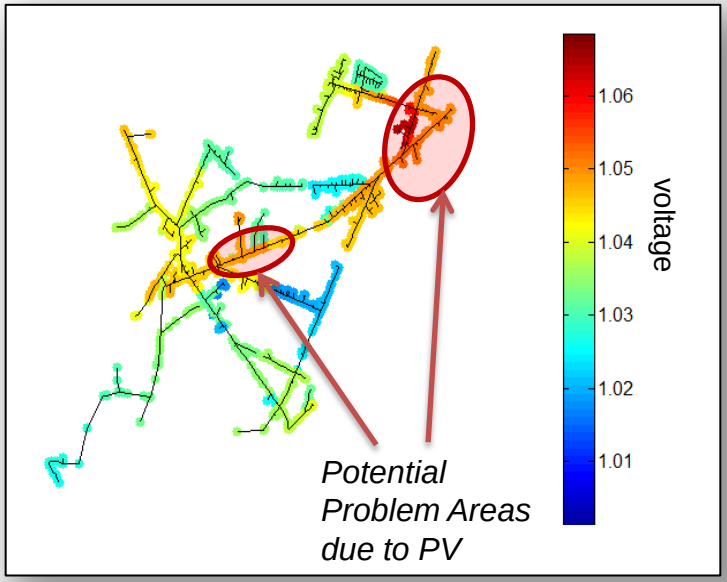


- Input to solar model
- Validation of feeder response to PV in OpenDSS

Step 4: Modeling and Hi-Pen Analysis

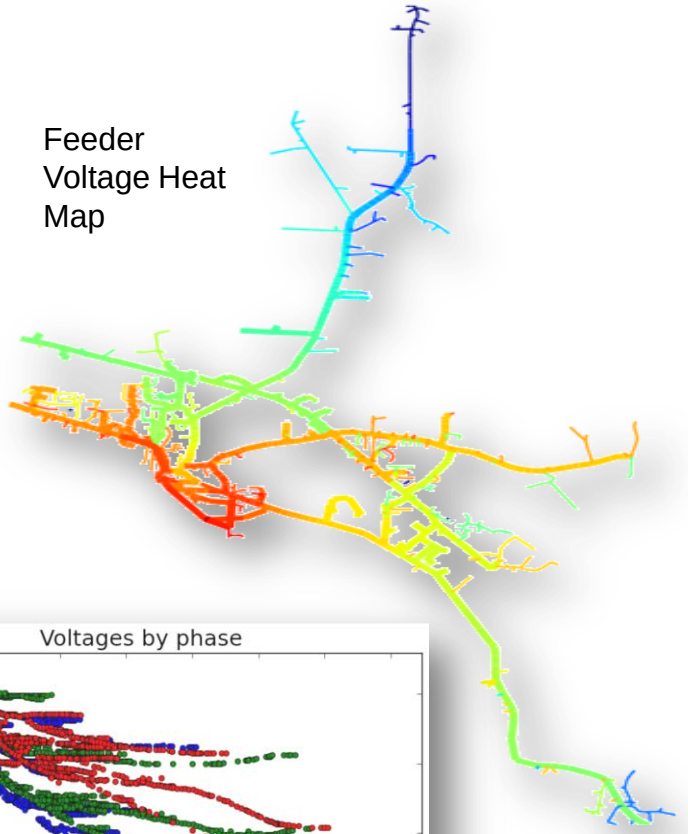


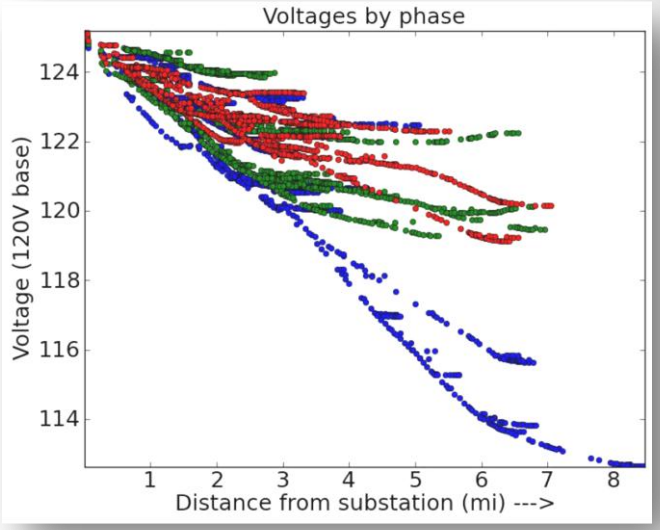
- Purpose of Task
  - > Perform high-penetration assessment of the test feeders to determine each specific feeder's hosting capacity for solar PV
- Approach
  - > Utilize EPRI's Distributed PV (DPV) Feeder Analysis Method for determining feeder impacts and hosting capacity
  - > Simulate a wide range of PV deployment scenarios and penetration levels on each feeder



Feeder Modeling

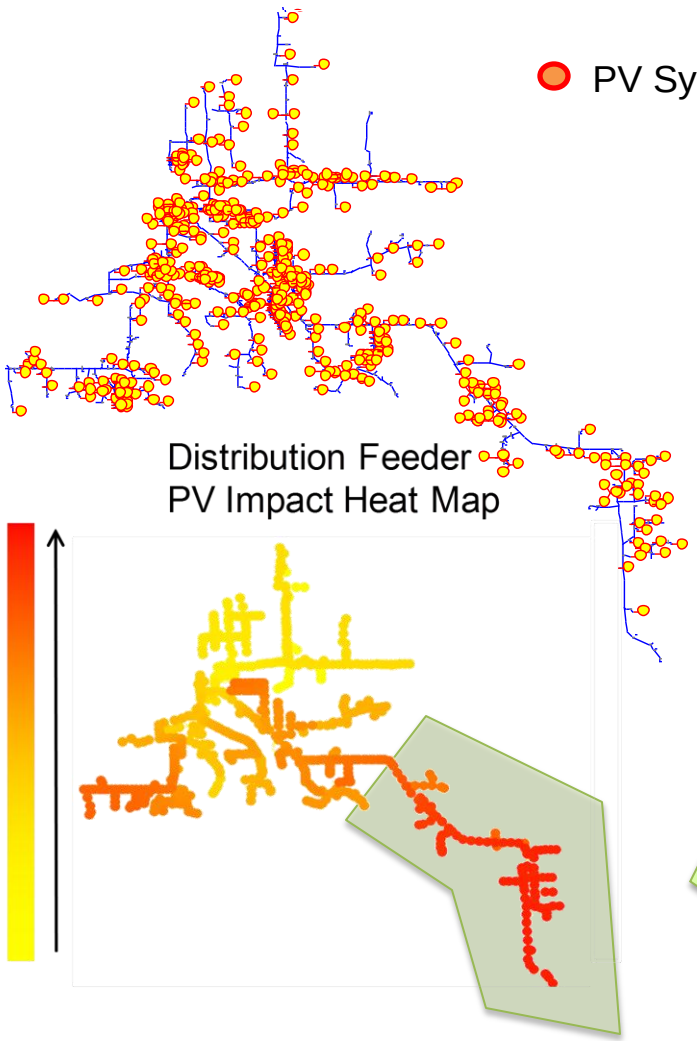
- Detailed distribution models
  - > Full three-phase
  - > Test and control feeders
- Work with participating utility to obtain base feeder data
  - > Add secondary transformers and service drops
  - > Incorporate time-series load data
- Convert model to OpenDSS (open source)
- Validate/verify model with measurement data





PV Analysis: Determining Feeder Hosting Capacity

Leveraging an EPRI Research Project



Baseline – No PV

PV Penetration 1

PV Penetration 2

PV Penetration 3

Beyond…

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

Increase Penetration Levels Until Violations Occur

High-Pen PV Analysis

Evaluation Criteria for Determining Hosting Capacity

Voltage	• Overvoltage • Voltage deviations @ regulation equipment • 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 • Demand masking • Consumption/Loss change
Control	• Load tap changers • Regulators • Capacitor banks

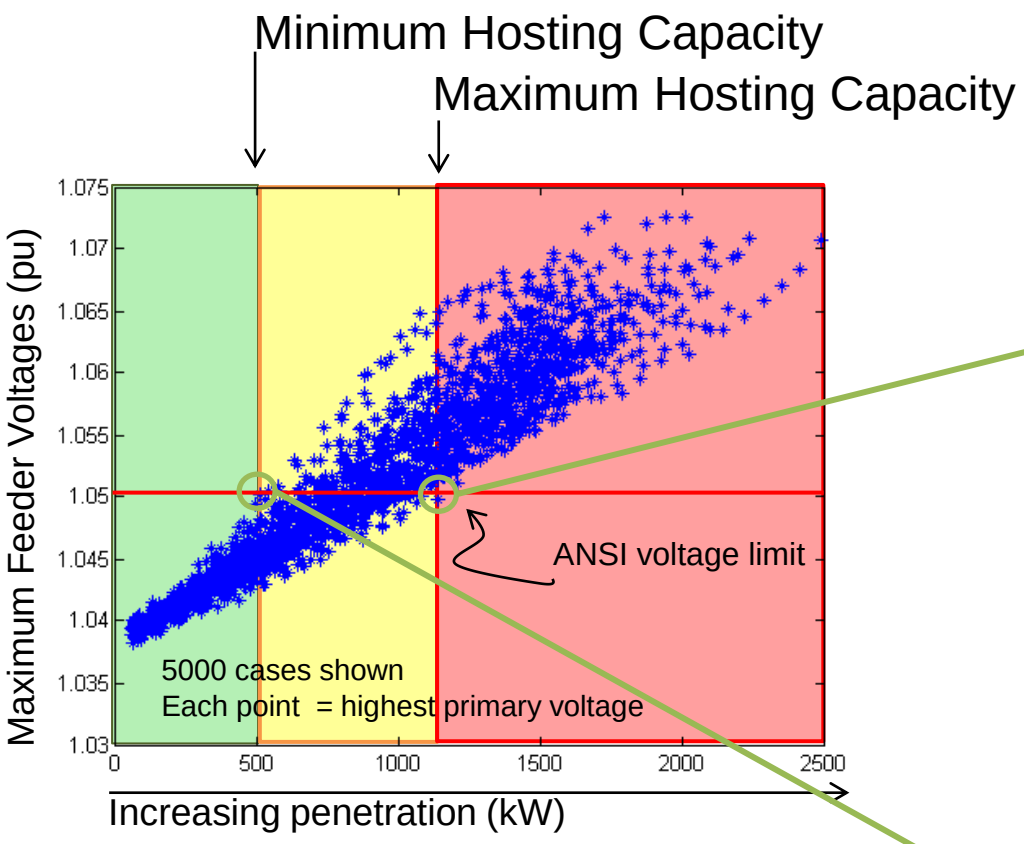
Steady State Stochastic Analysis

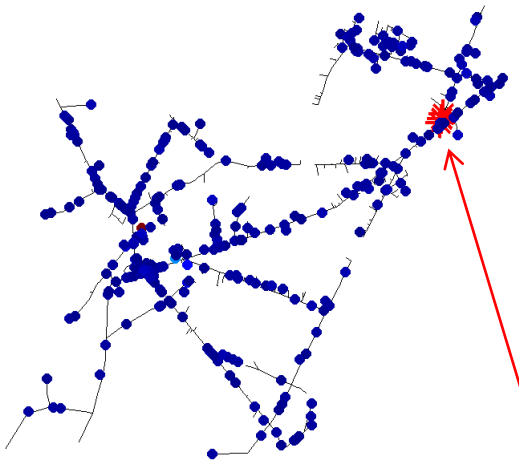
Time Series Analysis

Combination of stochastic and time series analysis combines location-specific and time-varying impacts of solar PV

For full details on analysis approach see public report: *Stochastic Analysis to Determine Feeder Hosting Capacity for Distributed Solar PV.* EPRI, Palo Alto, CA: 2012. 1026640.

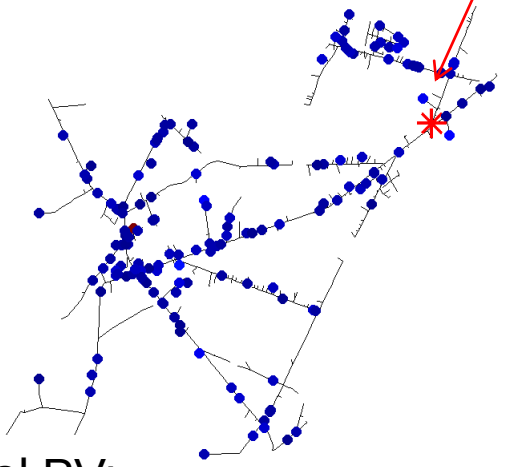
Hosting Capacity Explanation





Total PV:
1200 kW

Voltage violation



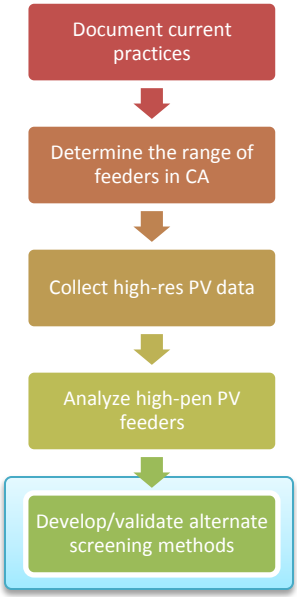
Total PV:
540 kW

No observable violations regardless of size/location

Possible violations based upon size/location

Observable violations occur regardless of size/location

Final Step: Develop and Validate Screening Methodology



- Purpose of Tasks
  - > Develop and validate a practical screening criterion for evaluating new interconnection requests
- Approach
  - > Use results from hi-pen analysis, analyze key factors determine max. and min. hosting capacity
  - > Develop screening methodology/approach
  - > Validate approach using control group of feeders and corresponding modeling and simulation results with measurement data

Focus Areas and Key Deliverables

Focus Areas

- Grid Integration
- Screening
- Hosting capacity
- Interconnection analysis
- Open-source modeling
- Solar PV monitoring

Key Deliverables

- Database of CA feeder characteristics
- Comprehensive analysis results from wide range of CA feeders
- Alternative method for screening new PV interconnection requests

Project Team

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Q &A AND DISCUSSION