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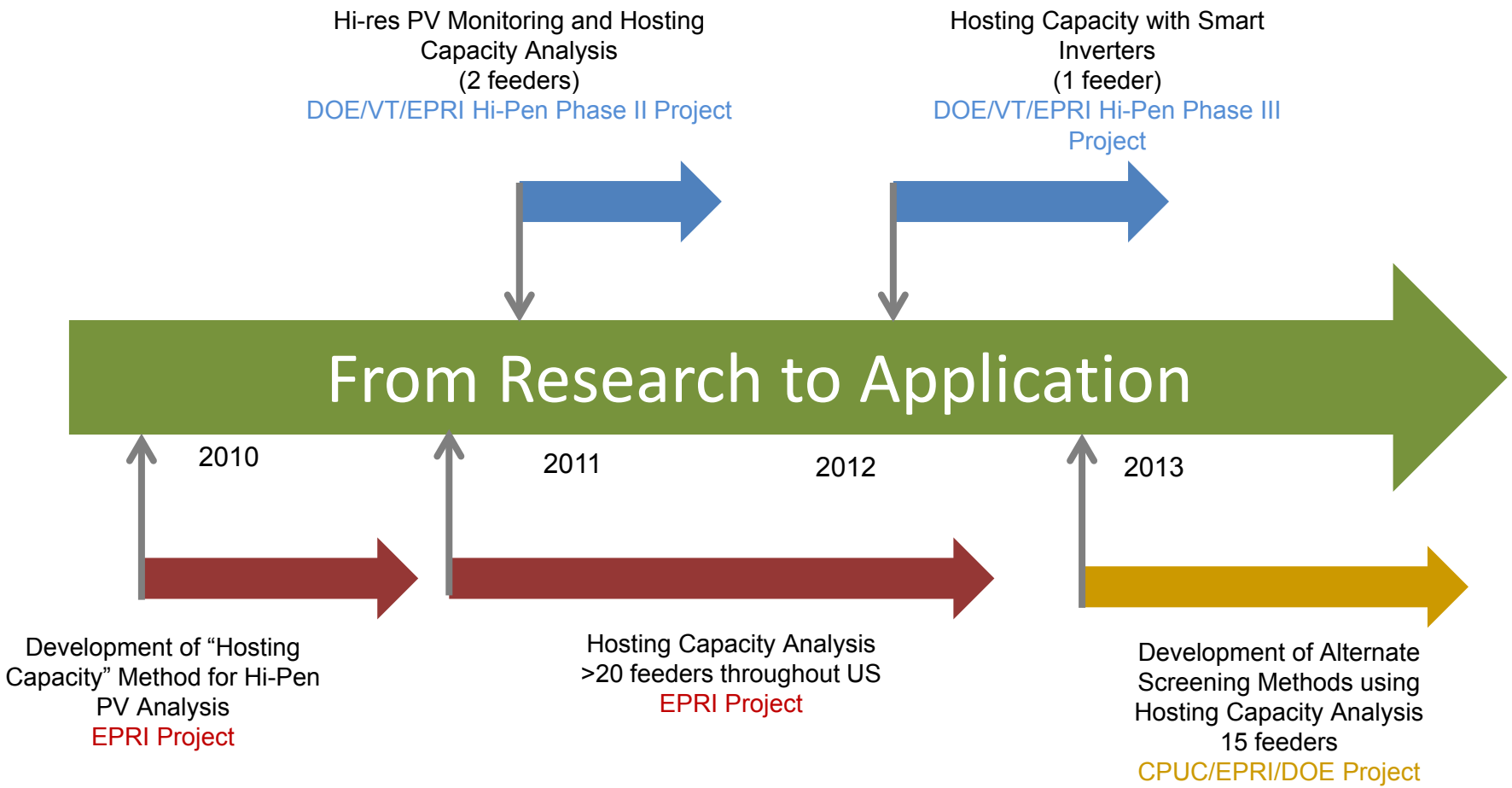
ALTERNATIVE SCREENING METHODS

PV HOSTING CAPACITY IN DISTRIBUTION SYSTEMS

Leveraging Work Throughout Industry



Overview

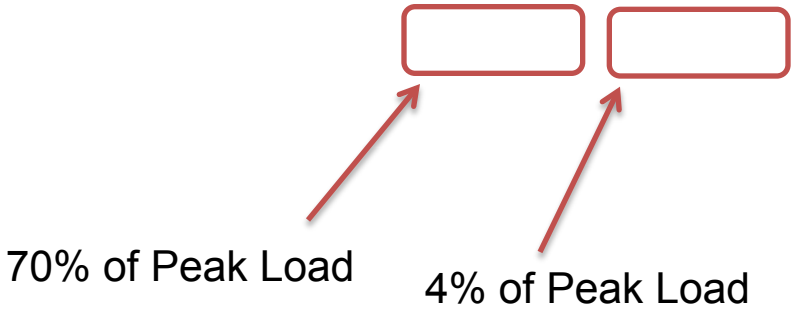
- **Background**
  - > **More PV interconnected at distribution level than any other DG**
    - **Small rooftop PV**
    - **Large, MW-class systems**
  - > **Increased pressures for utilities to**
    - **accommodate higher levels of PV**
    - **expedite interconnection process**
- **Project Objective:** 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?

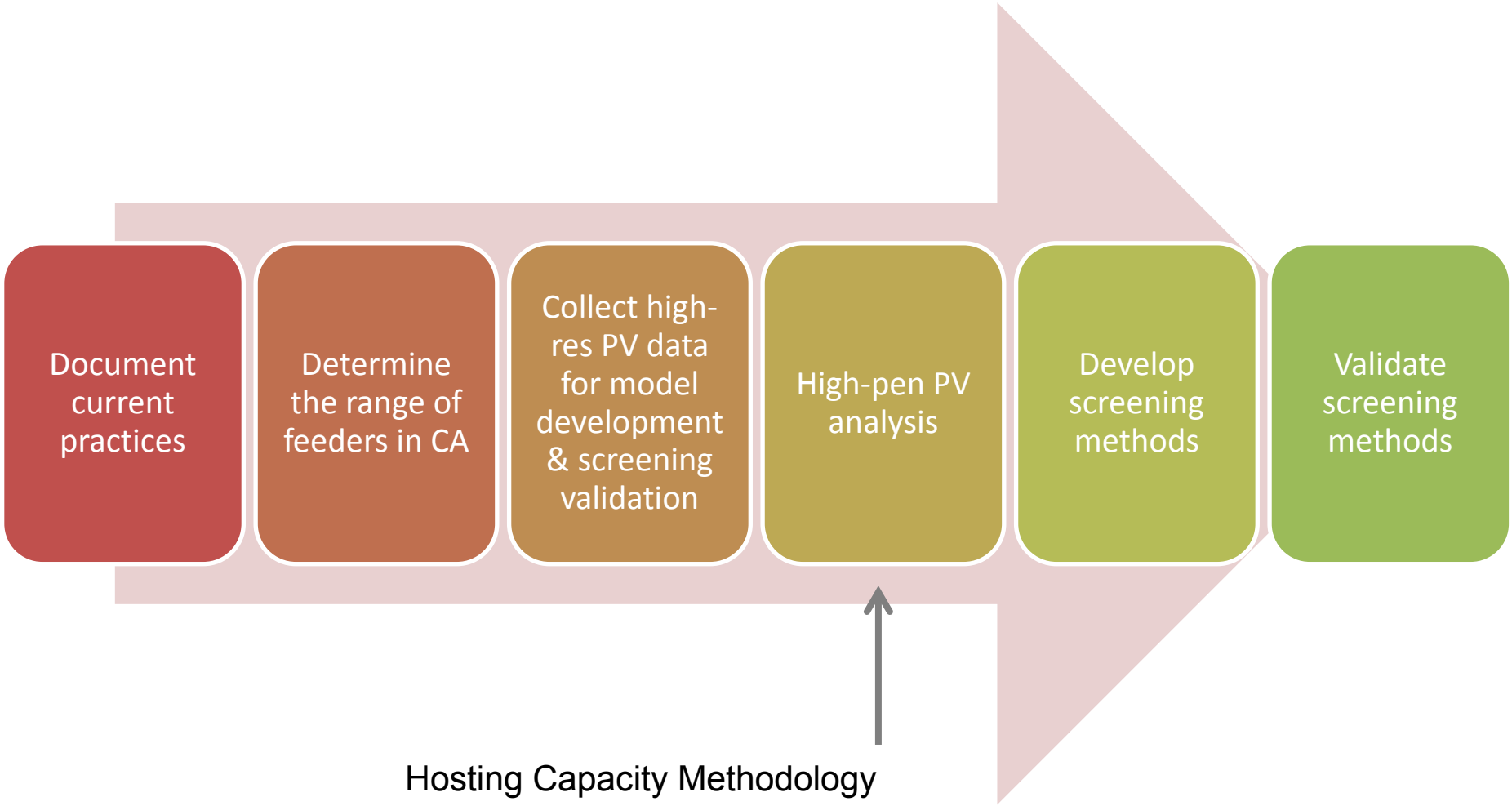
- Feeder's ability for hosting PV w/o adverse impact on performance depends upon many feeder-specific factors
- 15% "rule-of-thumb" is not very accurate in determining whether an issue may arise
- Simple characteristics used to classify/screen feeders (i.e. peak load level) may not be sufficient
- Example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

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

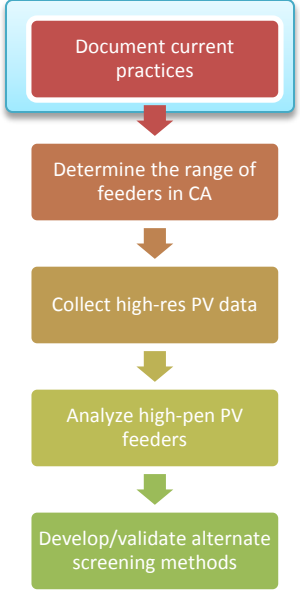
Feeder Characteristics	Feeder A	Feeder B
Voltage (kV)	13.2	12.47
Peak Load	5 MW	6 MW
Minimum Load	0.8 MW	0.7 MW
Minimum Daytime Load	1.1 MW	0.7 MW
Existing PV (MW)	1.0	1.7



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

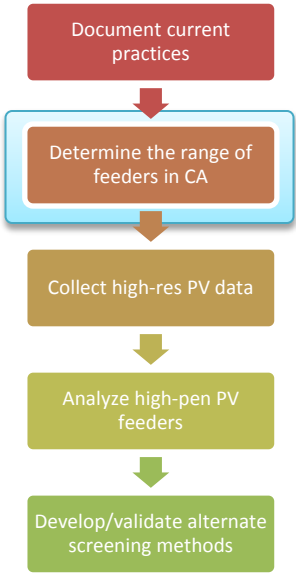
Step 1: Current Screening Practices

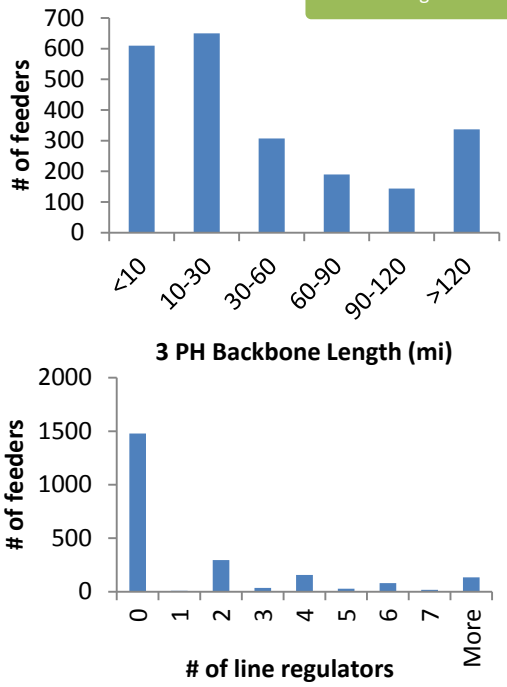


- Task Purpose
  - > Investigate and document current practices for screening PV interconnection requests among California utilities and from other sources outside California.
- Approach
  - > Consider federal, state, and local interconnection procedures pertaining to CA (Rule 21, WDAT, SGIP)
  - > Consider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

Step 2: Define Feeder Configurations in CA

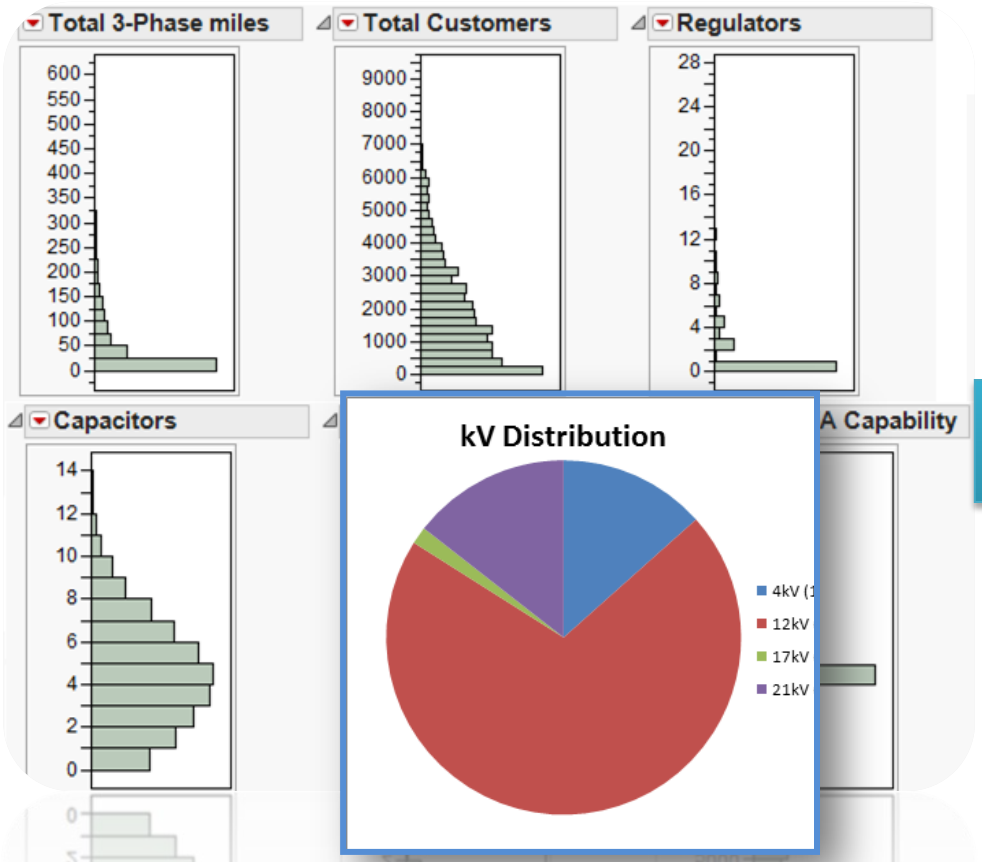
- Purpose of task
  - > Determine the range of feeder configurations and characteristics for CA utilities
  - > The representative feeders selected will be used in developing and validating the proposed screening methodology
- Approach
  - > Develop database of feeder characteristics for statistical 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



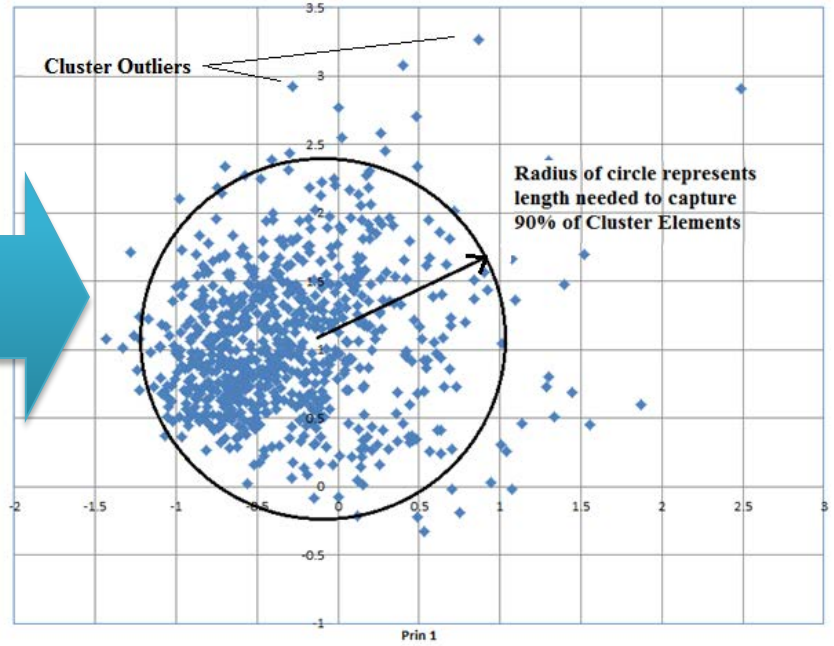


Evaluate Distribution Feeder Characteristics

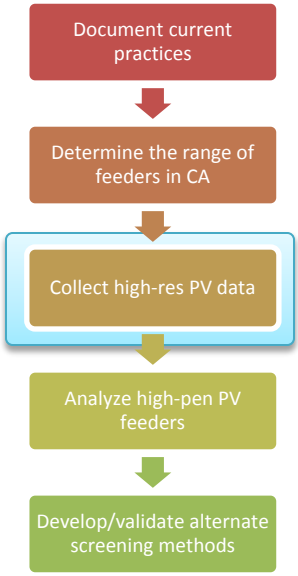
Clustering of data to select feeders



- 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

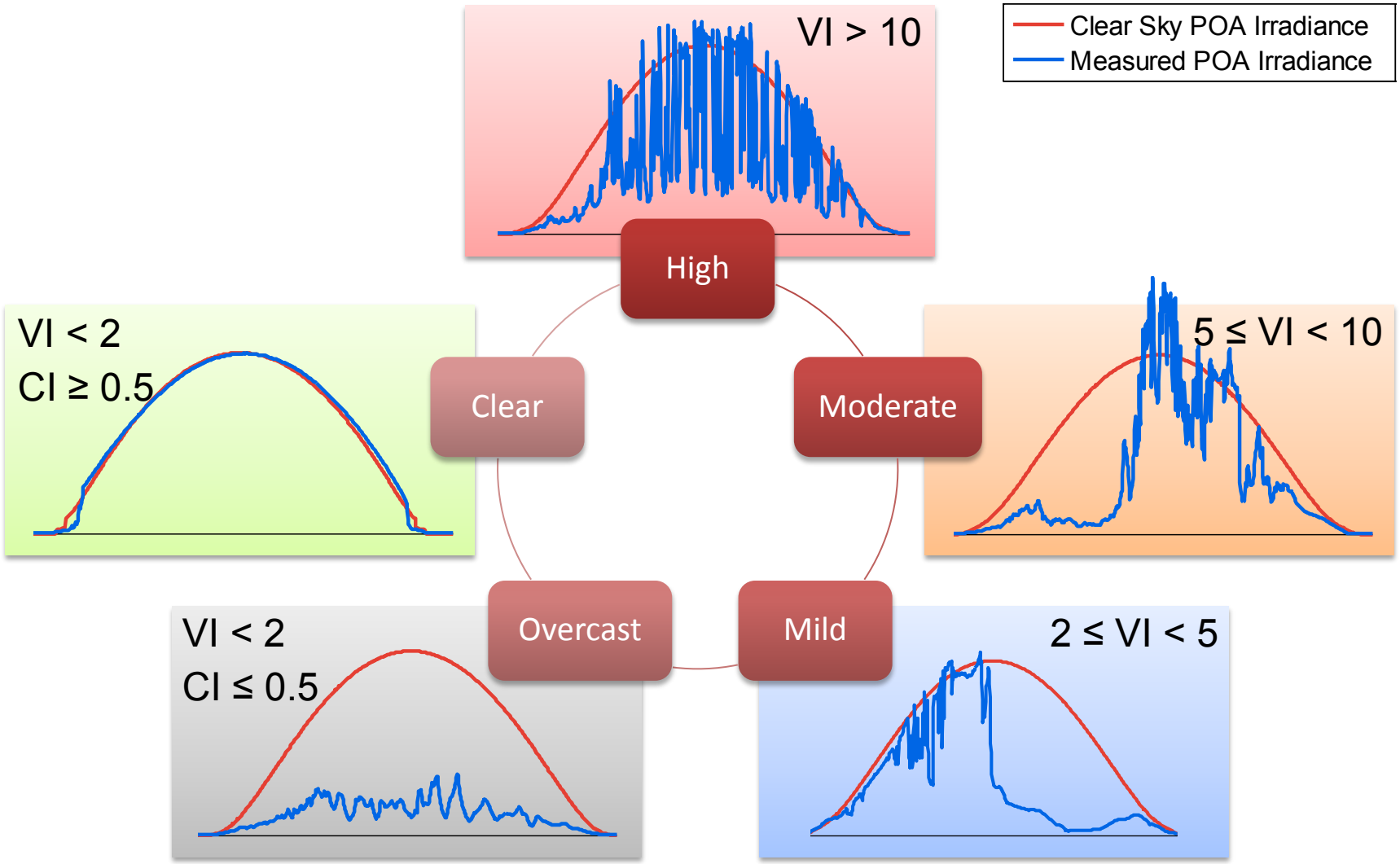
Leveraging a Utility Research Project

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

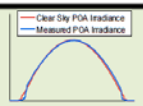
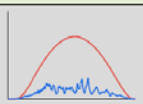
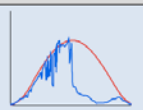
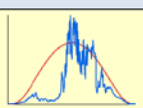
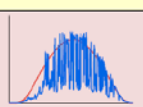
Classifying Solar Days

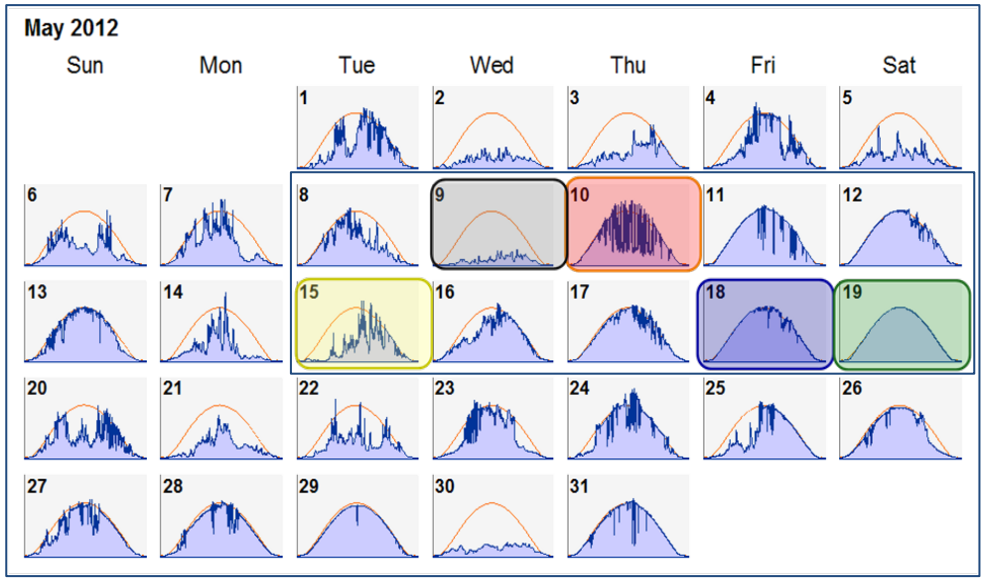
Applied Sandia's variability index (VI) with clearness index (CI) to classify days

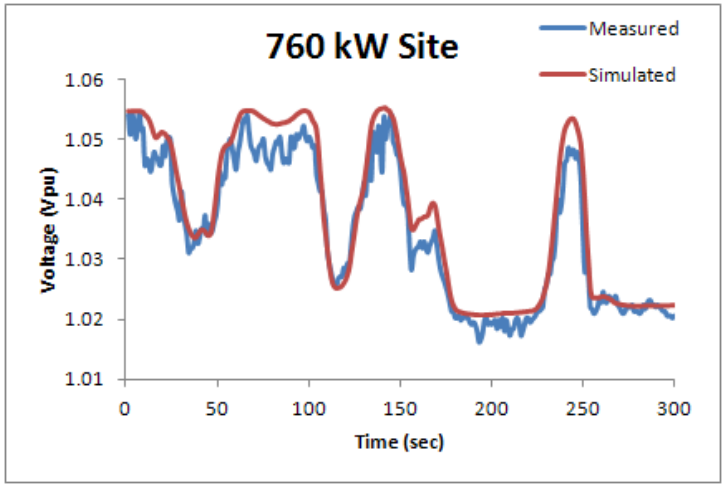


Solar PV Measurements for Modeling

- 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

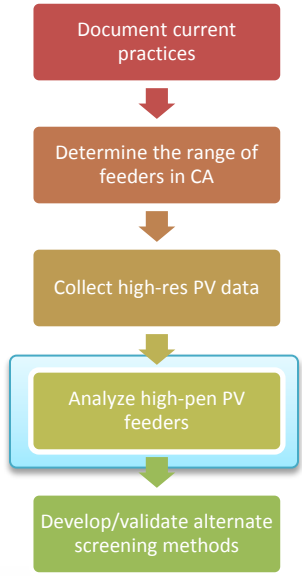


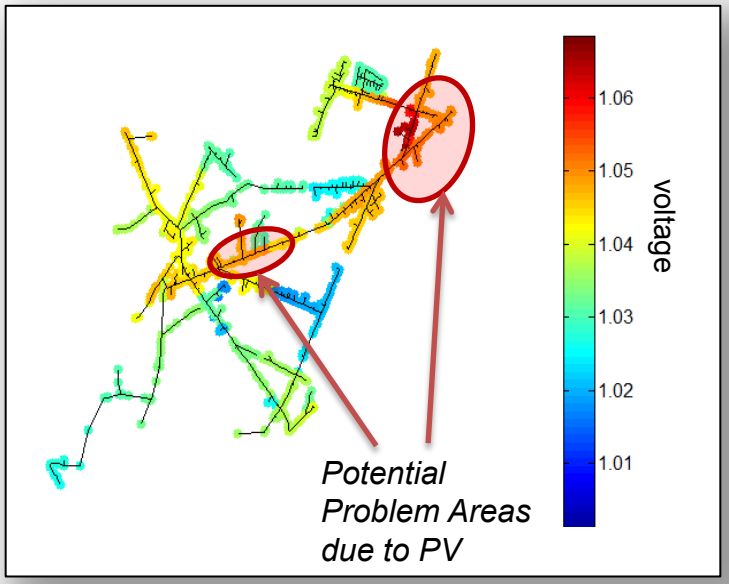


- Input to solar model
- Validation of feeder response to PV in OpenDSS

Step 4: Modeling and Hi-Pen Analysis

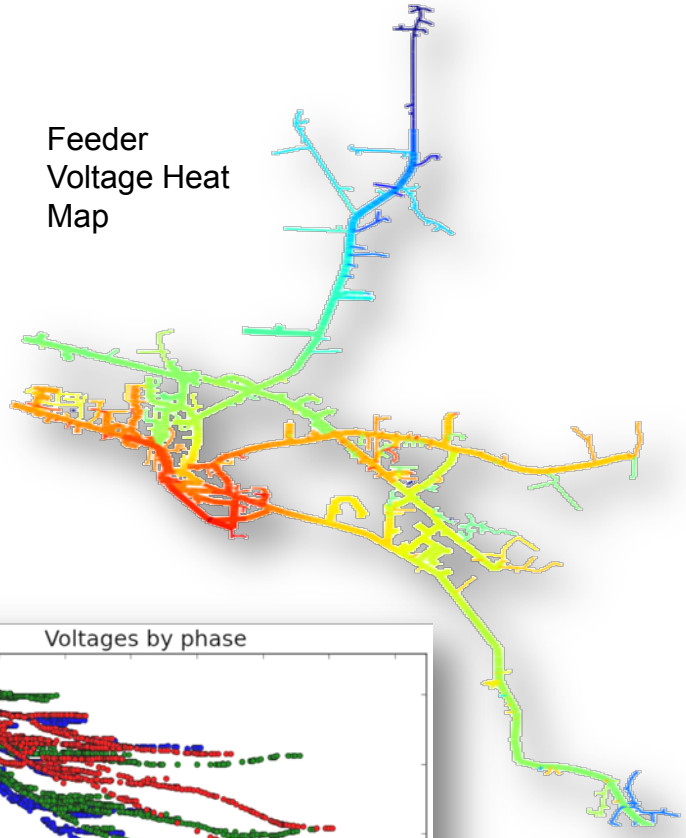
- Purpose of Task
  - > Perform high-penetration assessment of the test feeders to determine each specific feeder's hosting capacity for solar PV
- Approach
  - > Utilize EPRI's Distributed PV (DPV) Feeder Analysis Method for determining feeder impacts and hosting capacity
  - > Simulate a wide range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

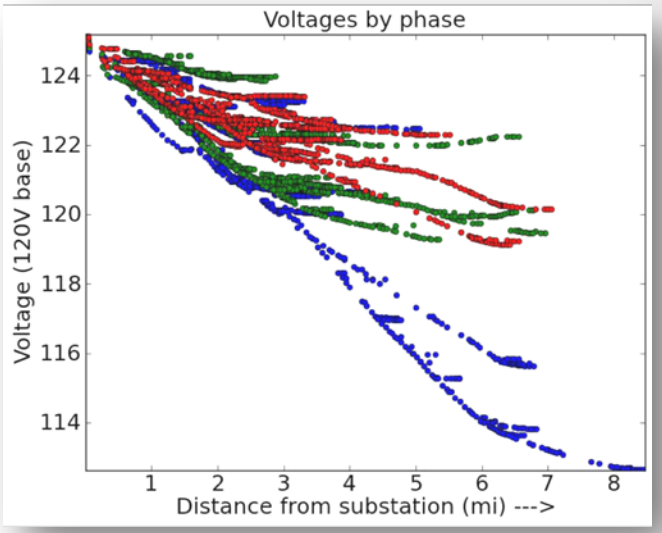




Feeder Modeling

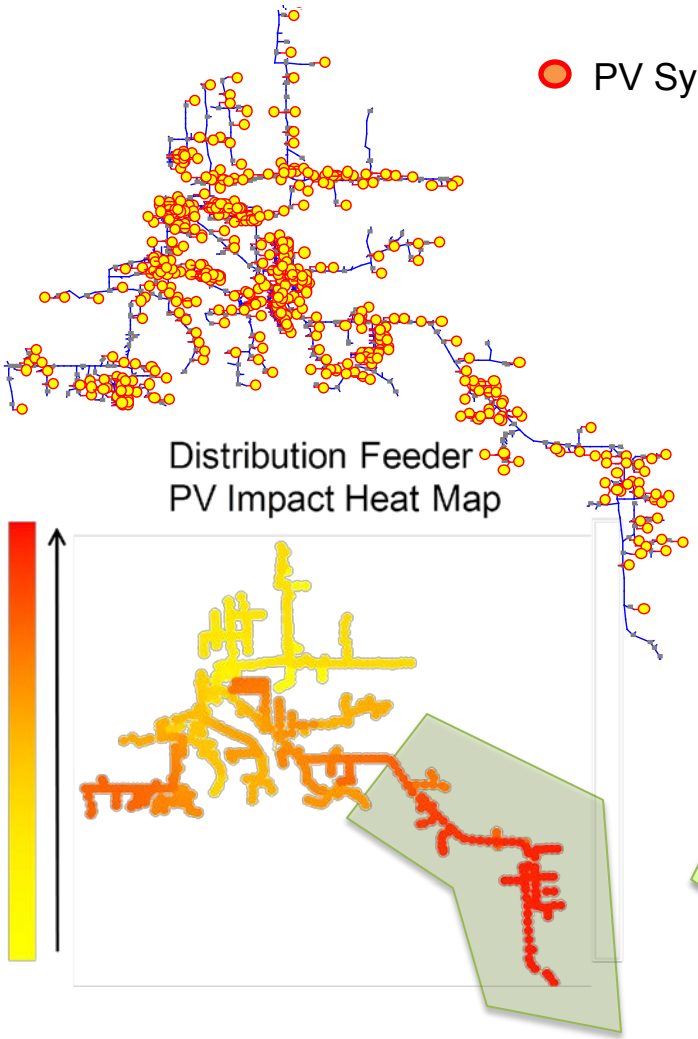
- Detailed distribution models
  - > Full three-phase
  - > Test and control feeders
- Work with participating utility to obtain base feeder data
  - > Add secondary transformers and service drops
  - > Incorporate time-series load data
- Convert model to OpenDSS (open source)
- Validate/verify model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

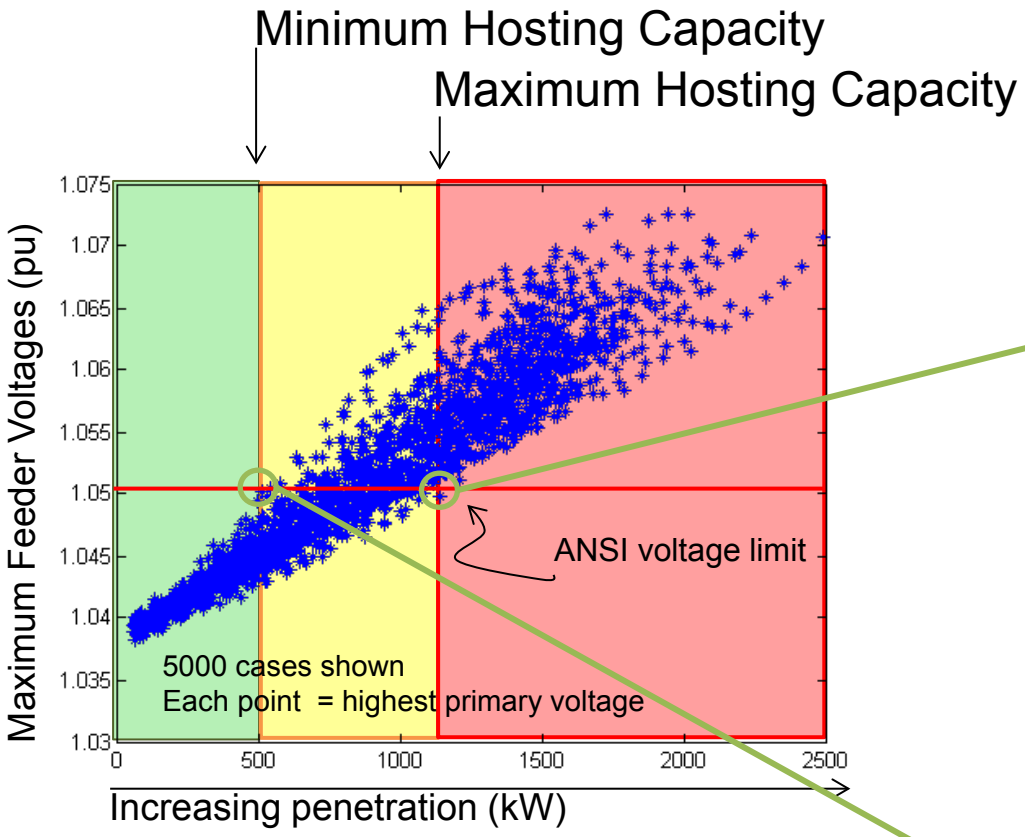
Steady State Stochastic Analysis

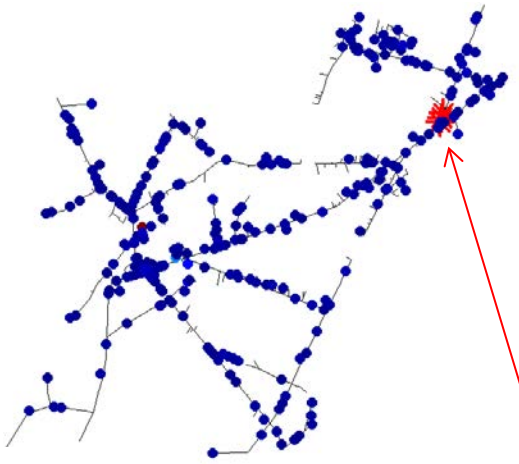
Time Series Analysis

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.

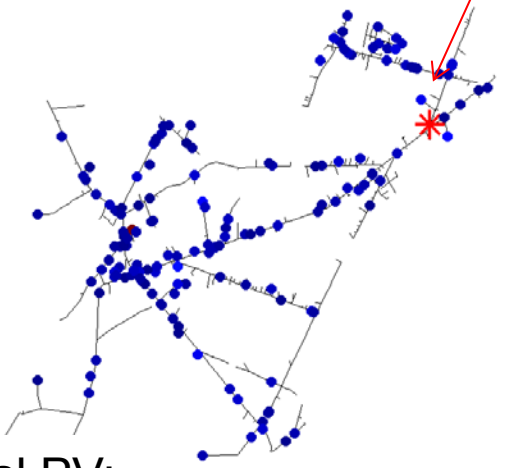
Hosting Capacity Explanation





Total PV:
1200 kW

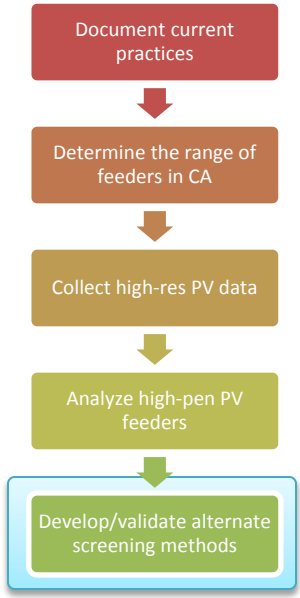
Voltage violation



Total PV:
540 kW

No observable violations regardless of size/location

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