Challenges and Solutions for Interconnecting Distributed Generation

David Palchak
National Renewable Energy Laboratory

India Smart Grid Forum – Distribution Utility Meet, Nov 2, 2018

Agenda

- Challenges of distributed generation
- Strategies for planning
- Beyond standards and codes
  - Compensation mechanisms
  - Forecasting PV growth

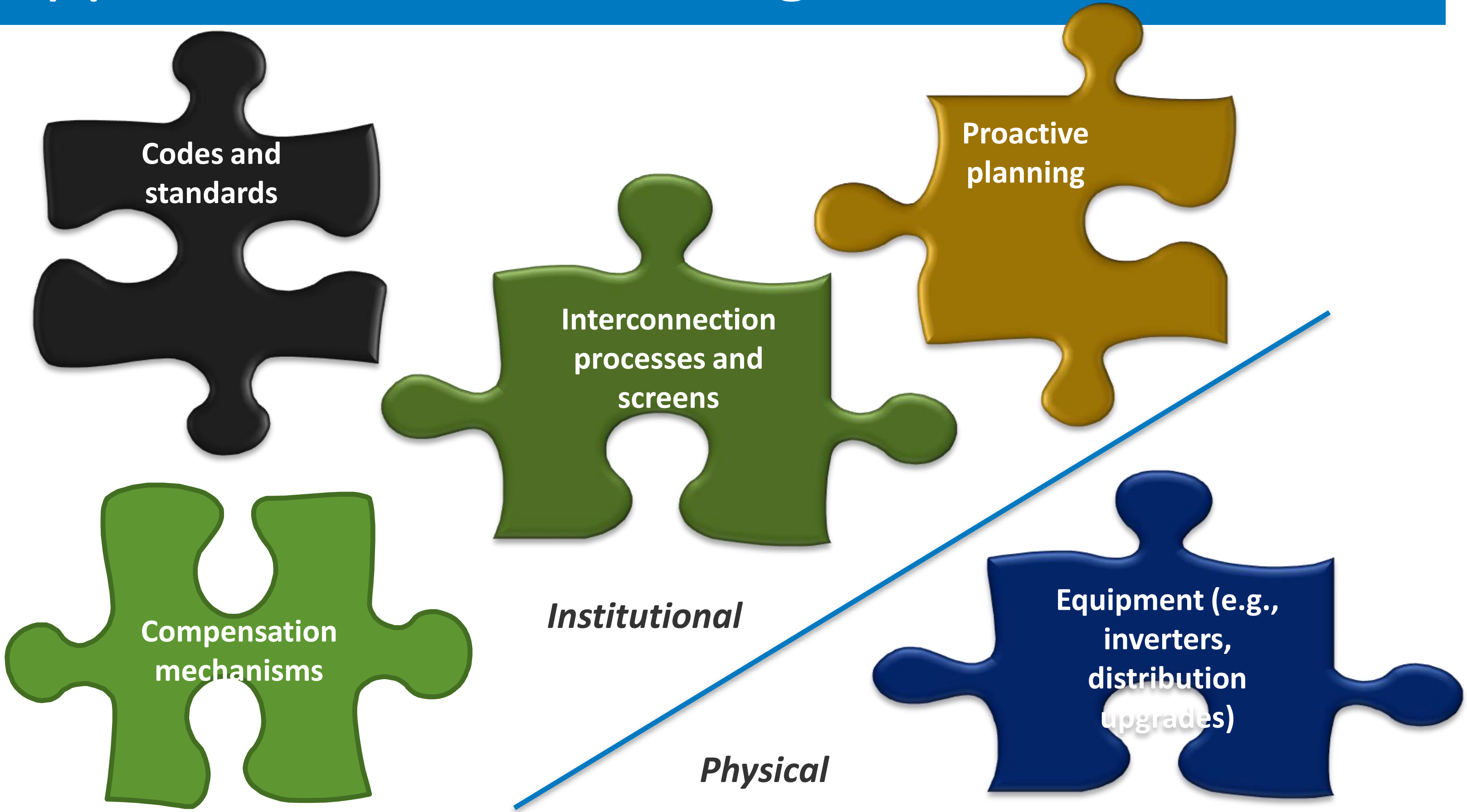
Major Technical Concerns for Utilities

- Voltage regulation
- Reverse power flow
- Protection coordination
- Unintentional islanding

Photo credit: David Palchak

Adapted from: Coddington, Michael, and Jeff Smith. 2014. *Current Utility Screening Practices, Technical Tools, Impact Studies, and Mitigation Strategies for Interconnecting PV on the Electric Distribution Systems*. EPRI Report #3002003277. Palo Alto, CA: EPRI

Approaches to addressing technical concerns



Foundational standards and codes establish interconnection requirements for all DPV systems

National electrical safety code

- Voltage standards for the electric utility transmission and distribution systems
- Example: ANSI C84.1 in the U.S.

Interconnection standards

- Criteria for how DPV interacts with the local distribution grid
- Example: New IEEE 1547-2018 standard requires use of smart inverters

Equipment standards

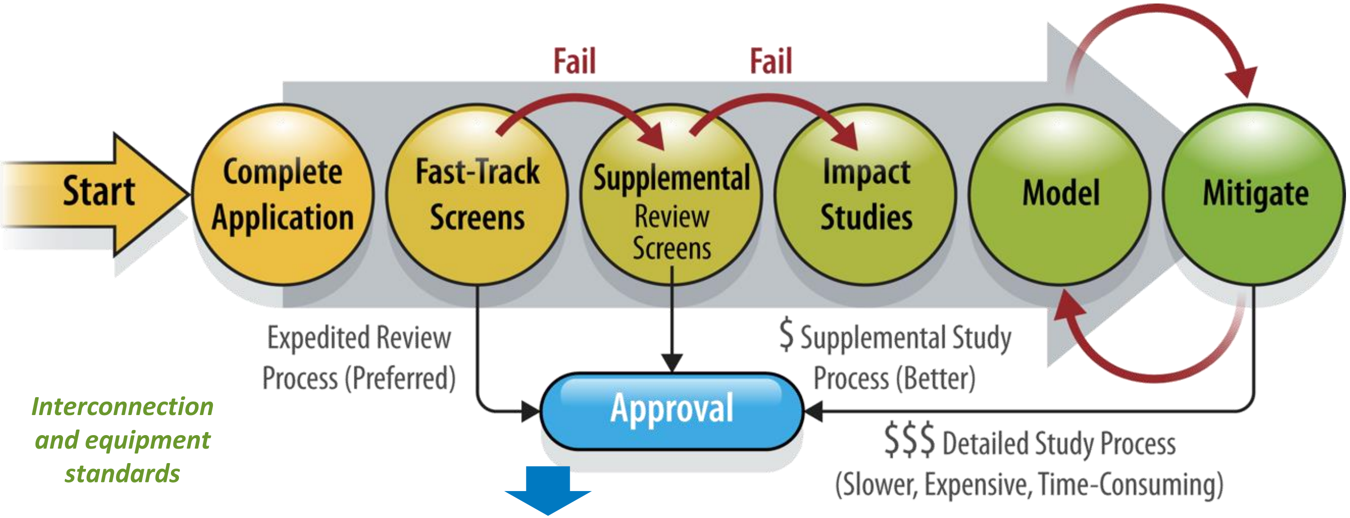
- Certification requirements for DPV equipment, harmonized with interconnection standards
- Example: UL 1741 in the U.S.

Building electrical codes

- Sets requirements for design, construction, and operation of DPV systems
- Example: National Electrical Code in the U.S.

Evolution in Planning: Interconnection process reviews grid interaction of a specific DPV system and location

- Determines need for detailed impact studies and mitigation strategies
- Streamlined approval process can improve viability for small systems



Interconnection and equipment standards

Building electrical codes

Obtain DPV Permit → Build DPV System → Inspect DPV System → Permission to Operate

Coddington, M. & Reiter, E. 2017. *Sun Screens: Maintaining Grid Reliability and Distributed Energy Project Viability through Improved Technical Screens.* https://www.nrel.gov/docs/fy17osti/67633.pdf.

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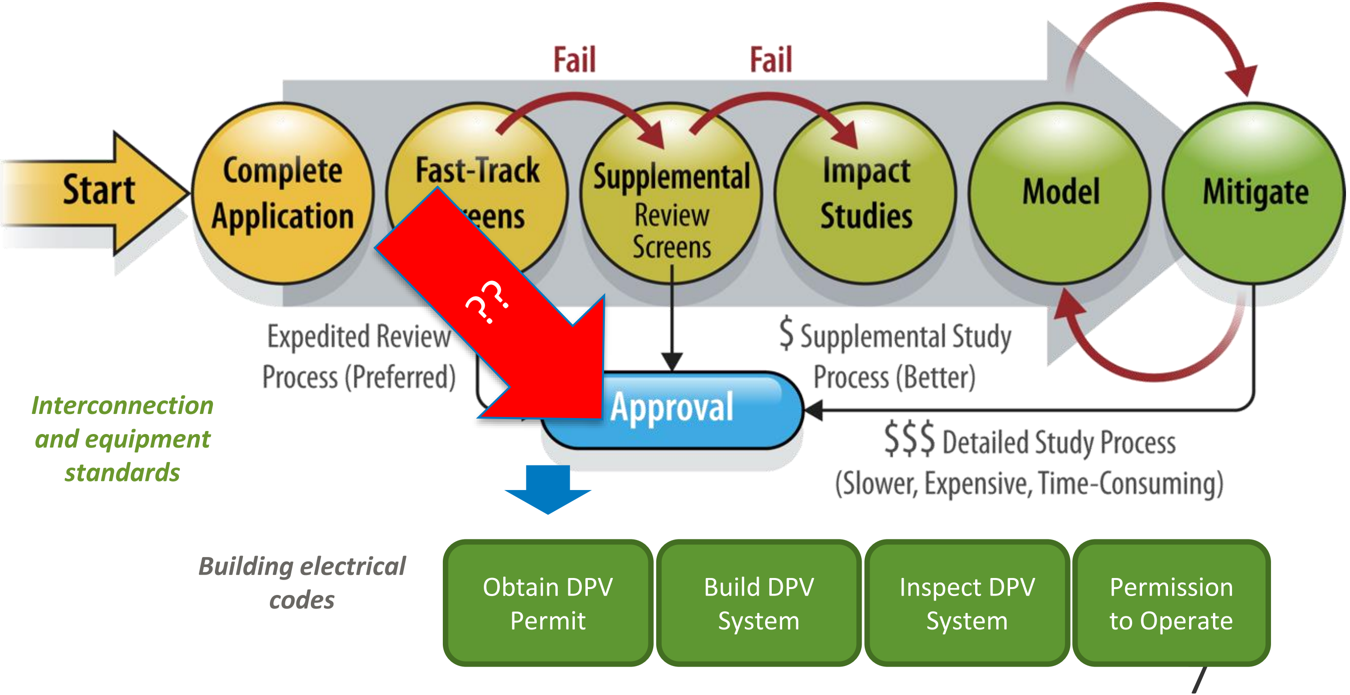

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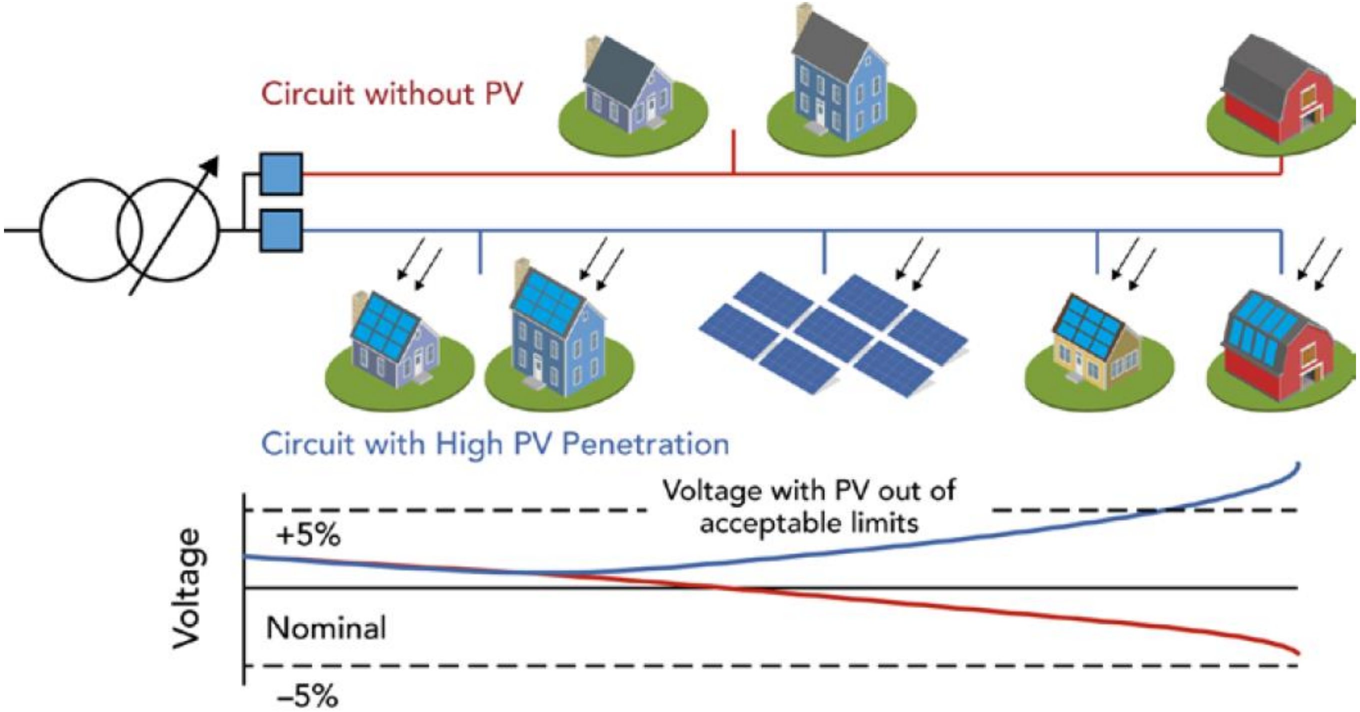
Voltage regulation: key technical concern about distributed solar PV (DPV)

Voltage deviations

Increase in local voltage from DPV may lead to over- or under- voltages for adjacent customers



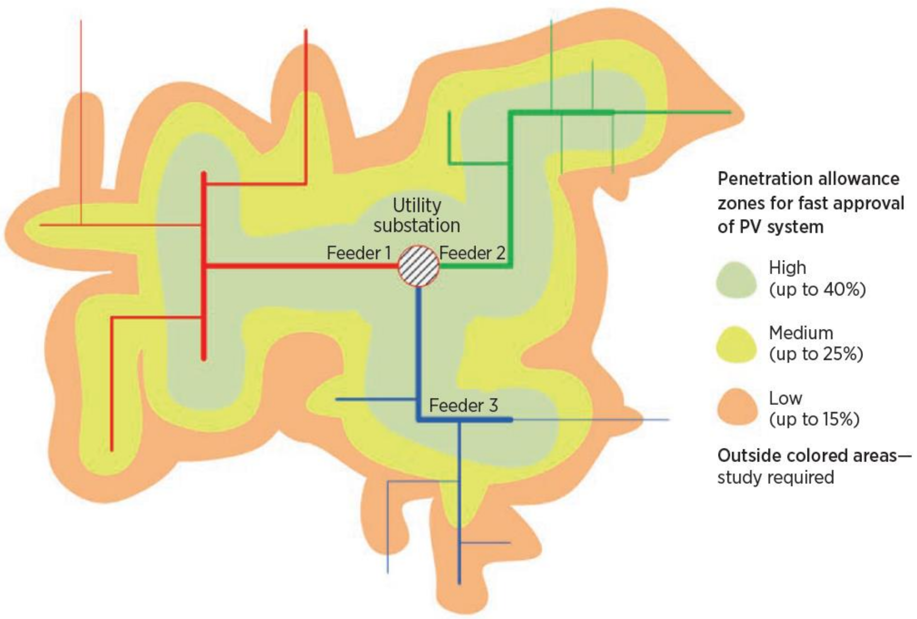
Source: Coddington, Miller, & Katz. 2016. Grid-Integrated Distributed Solar: Addressing Challenges for Operations and Planning, Greening the Grid. NREL/FS-6A20-63042. https://www.nrel.gov/docs/fy16osti/63042.pdf.

Evolution in planning: Getting beyond rules-of-thumb

Preemptively analyze DPV suitability

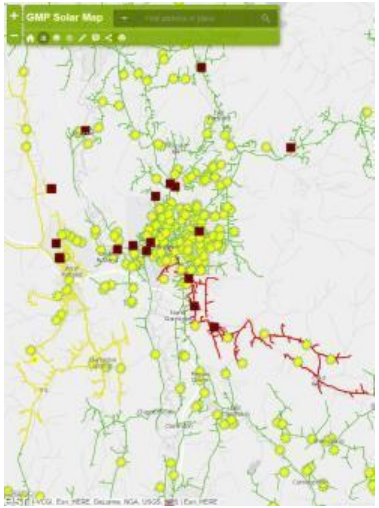
1. Forecast DG growth on each circuit
2. Establish the hosting capacity and allowable "penetration level"
3. Determine available capacity on each distribution circuit
4. Plan upgrades and expedite interconnection procedures
5. Publish the results

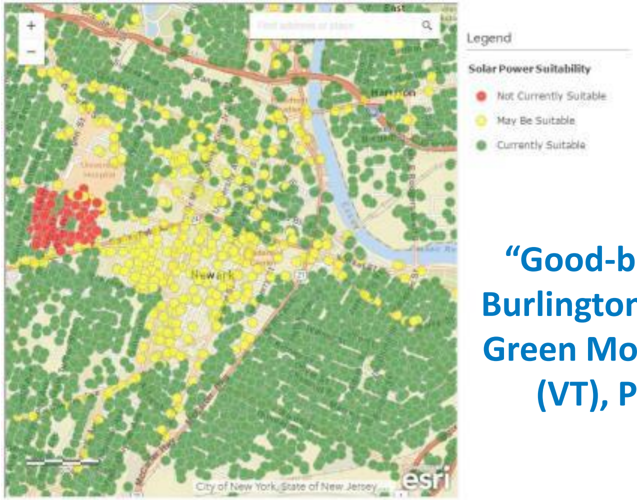
Example Interconnection Capacity Analysis Map



Evolution in Planning: Addressing interconnection concerns with capacity and mapping

- Three levels of sophistication:
  - Restricted zones (where can’t I build a system?)
  - Address-level search (can I build a system here?)
  - Feeder mapping (where should I build a system?)





“Good-bad-maybe” : Burlington Electric (VT), Green Mountain Power (VT), PSE&G (NJ)

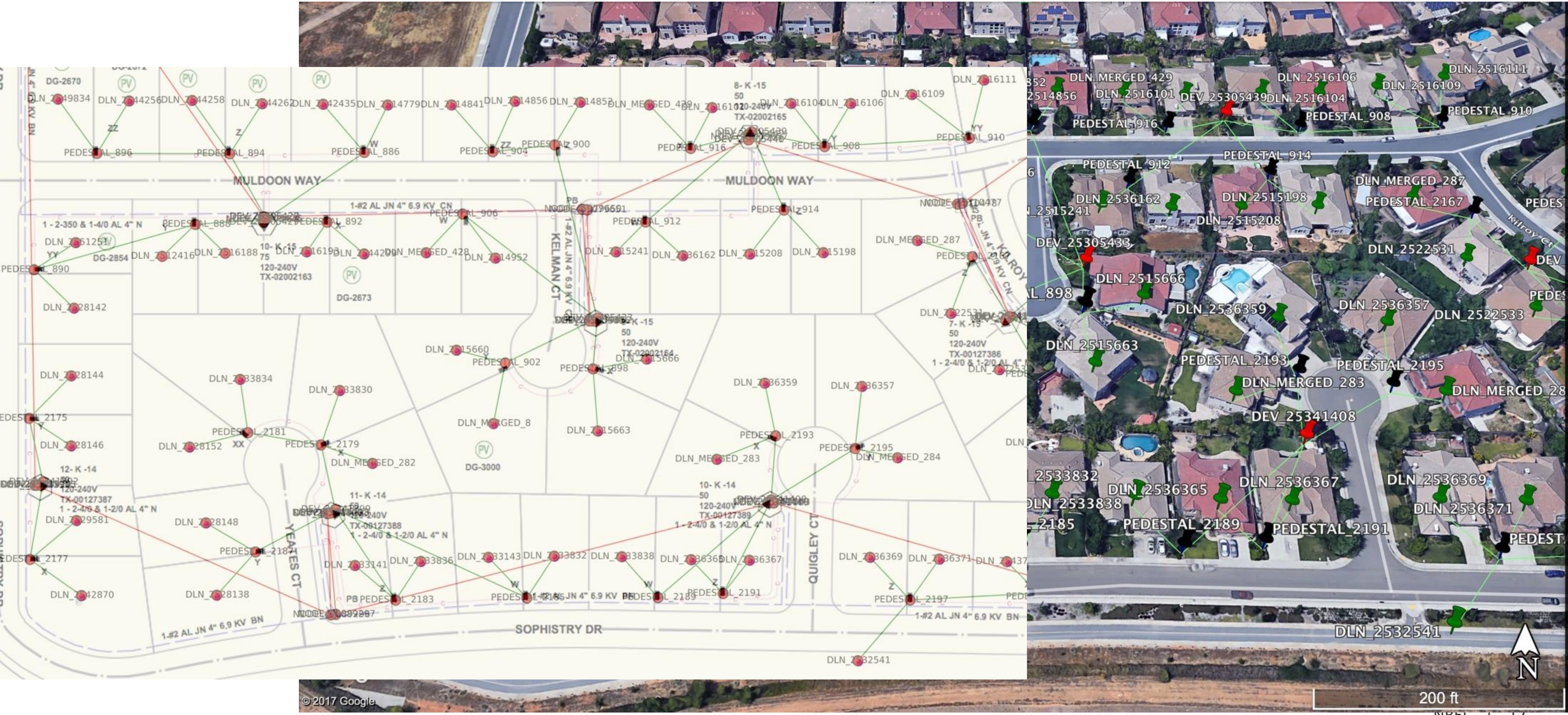
Evolution in Planning: Building tools to speed interconnection processes - enabling smart inverters for voltage control

- PREconfiguring and Controlling Inverter Set-points (PRECISE) for of smart-inverters
- Utility-agnostic tool to pre-configure inverters and allow greater penetration levels

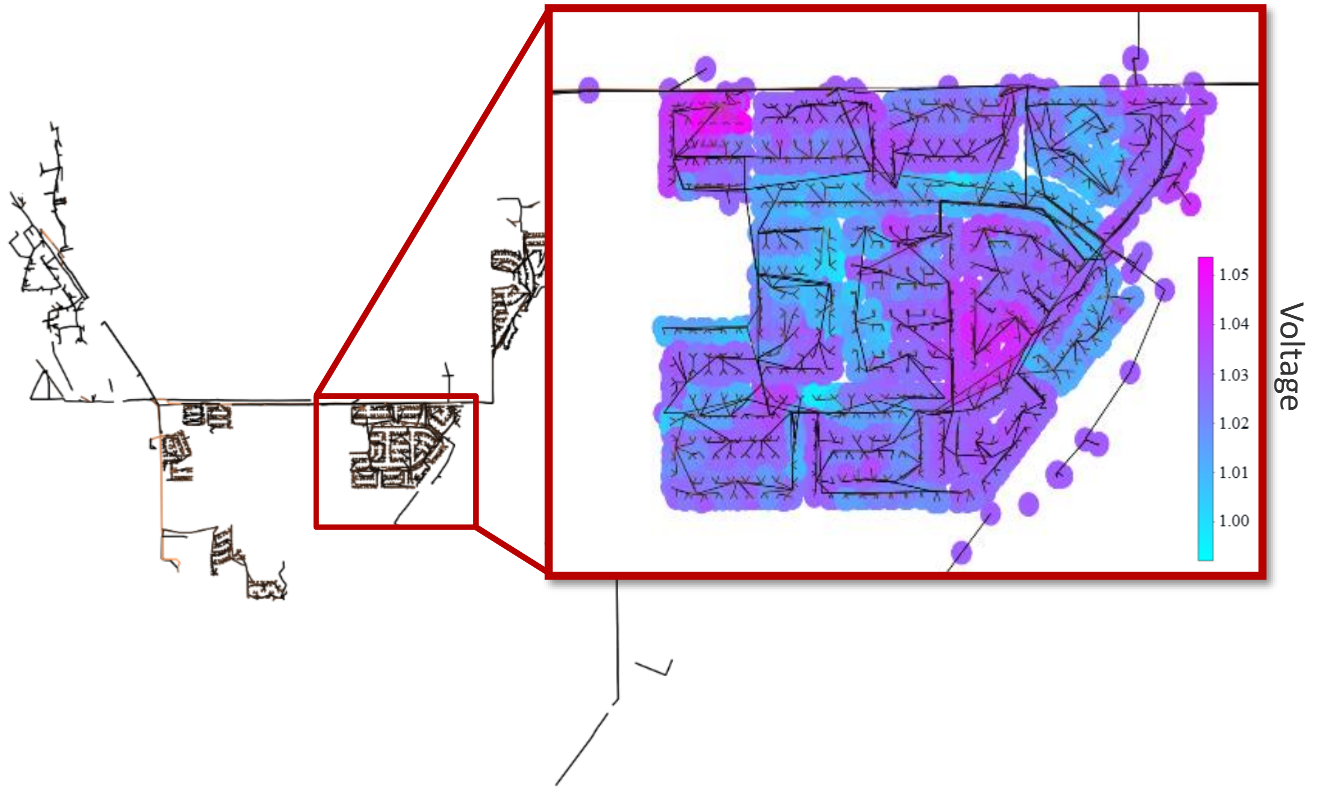
PRECISE

Step	Action
1 PV Interconnection Application	PRECISE obtains address of interconnection request
2 Distribution Feeder	PRECISE models the distribution feeder
3 Model Secondaries	PRECISE models secondaries using open street maps or GIS data
4 Configure Inverter Limits	PRECISE configures reactive power limits, active power limits, and power factor limits
5 Run Analysis	PRECISE runs analysis and exports the results

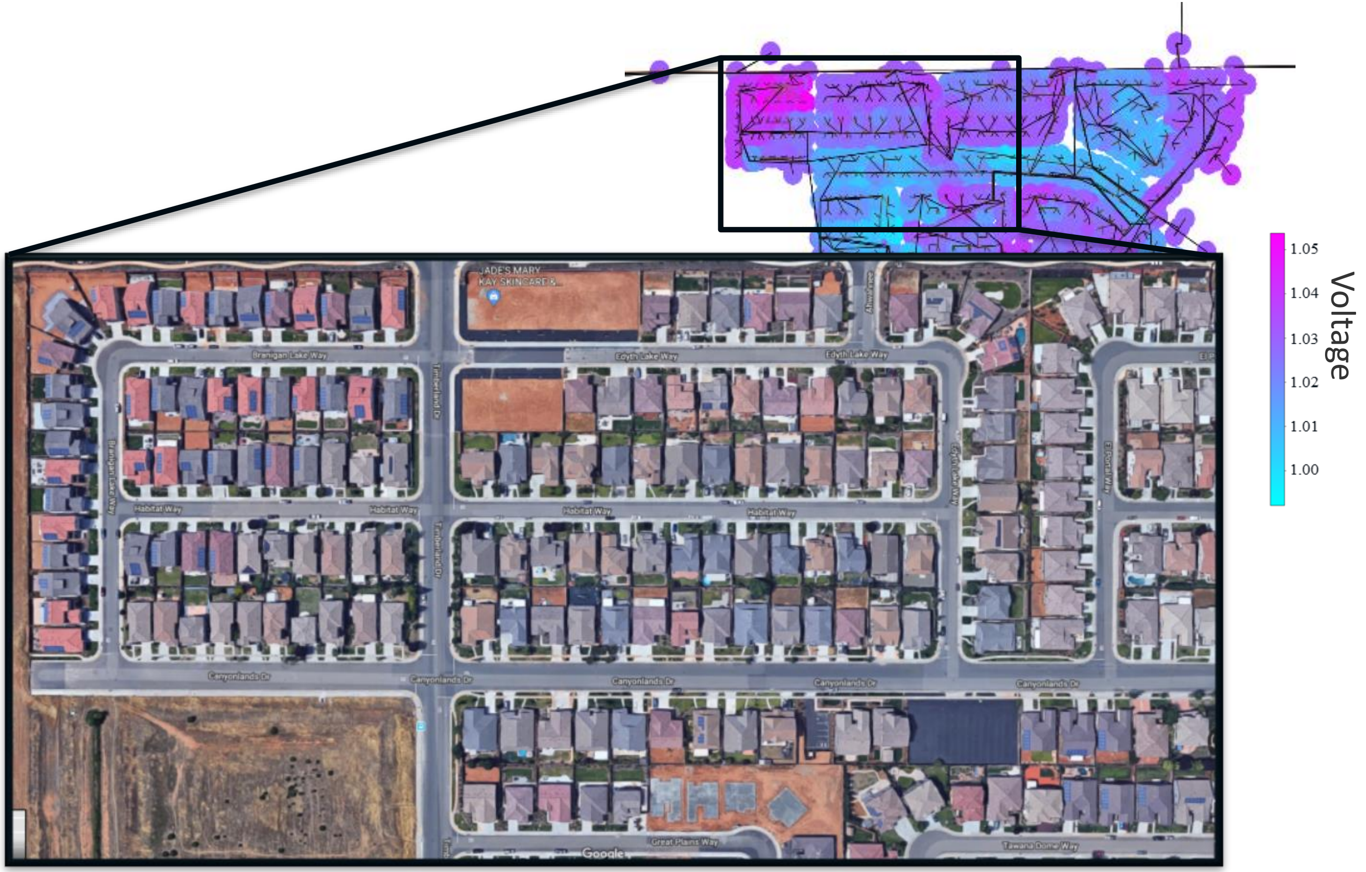
This new planning method focuses on modeling secondary lines, where voltage is most affected by rooftop PV



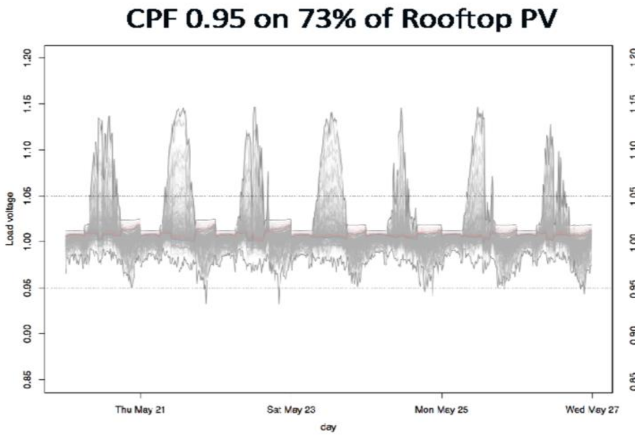
Secondary over voltages due to high PV penetration

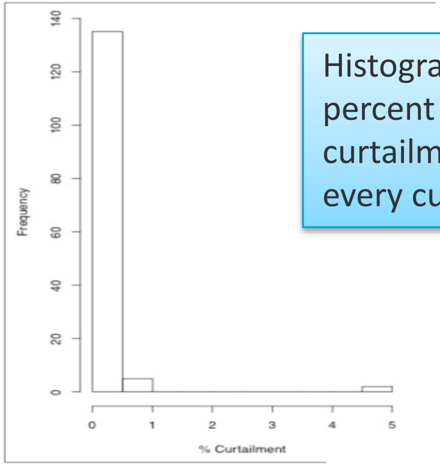


Real view of houses in the subdivision with over voltages



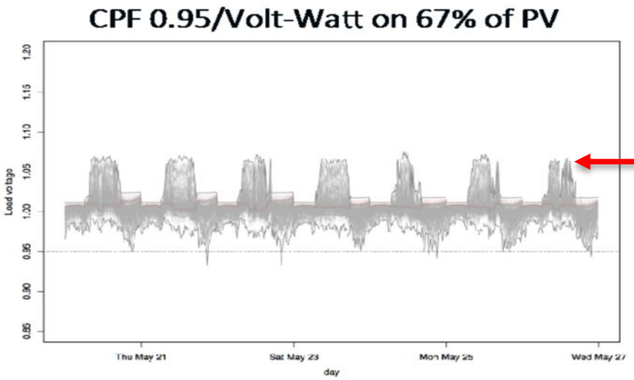
HECO example: Requiring rooftop PV to provide voltage support results in only small amounts of curtailment





Histogram of percent annual RE curtailment for every customer

Source: NREL/TP-5D00-68681



Limiting overvoltage to 1.05 results in 0% annual curtailment for most customers and up to 5% curtailment for only a handful of customers.
Analysis crucial for building stakeholder support for regulatory requirement

Beyond codes and standards

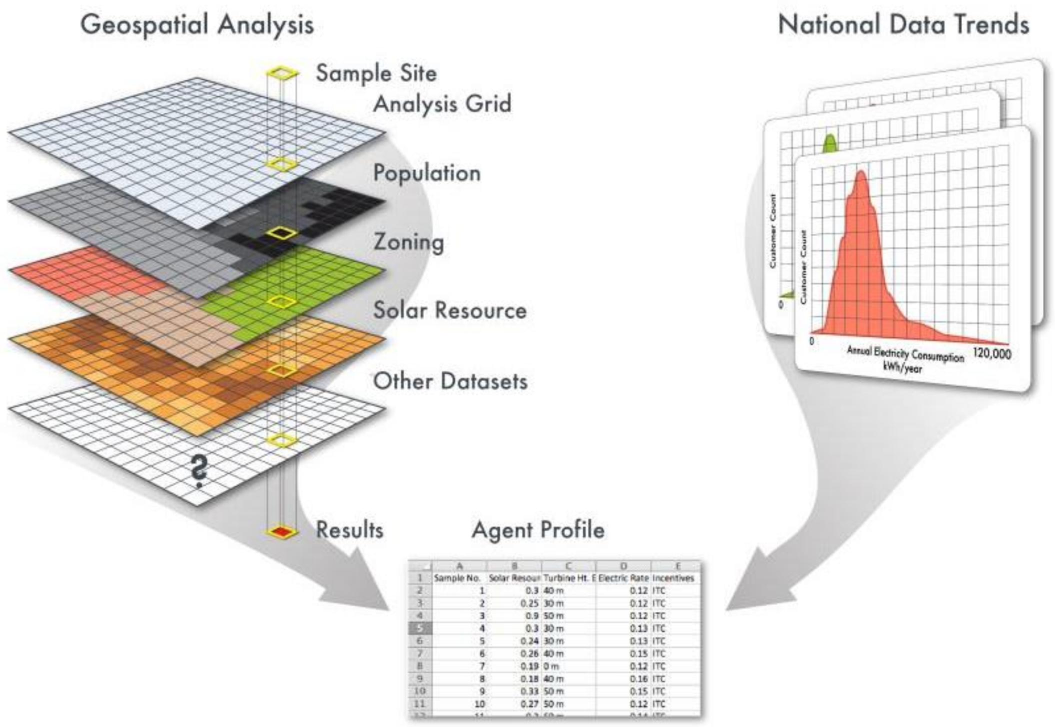
Compensation mechanisms and advanced planning

Another emerging measure in mature markets: "grid aware" compensation mechanisms

- Concept: compensate DPV generation based on time- and/or location-specific value to the distribution system
- Example approaches either under consideration in California:
  - Net energy metering based on time-of-use-rates
  - Net billing or buy-all/sell-all, with exports compensated at an administratively-set locational value
  - Net billing or buy-all/sell-all, with exports compensated based on their participation in energy or ancillary services markets (e.g., via an aggregator)

Source: Sustaining Solar Beyond Net Metering, GridWorks, https://gridworks.org/wp-content/uploads/2018/01/Gridworks_SustainingSolar_Online.pdf

Advanced planning - forecasting PV growth at the consumer level



Agent characteristics derived from population-weighted sampling to create a comprehensive and representative database of the analysis population

dGen model

- Forecasts adoption of distributed solar or other DERs based on inputs
- Agent-Based Model simulating consumer decision-making
- Incorporates detailed spatial data to understand geographic variation

Key messages

- Stakeholder processes to evaluate the value of new requirements (such as smart inverters) can help prepare distribution grids for high PV penetration levels in the long-term
- Aligning compensation with the locational value of PV can be used to help offset infrastructure upgrades