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Data Needs and Sources for DGPV integration cost and impact analysis

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Benchmarking Distribution Grid Integration Costs Workshop
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NREL, Golden, CO

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Outline

- **Integration Concerns**
  - Distribution 101
  - Deployment patterns
- **Data Needs**
  - Know your problem
  - Utilities/DGPV/Research
- **Where to Find Data**
  - Resource Data
  - Grid Data
  - Other
- **Filling the Gaps**
  - Smart-DS project

Why Distribution?

Over 50% of all Solar PV is connected to the distribution system:

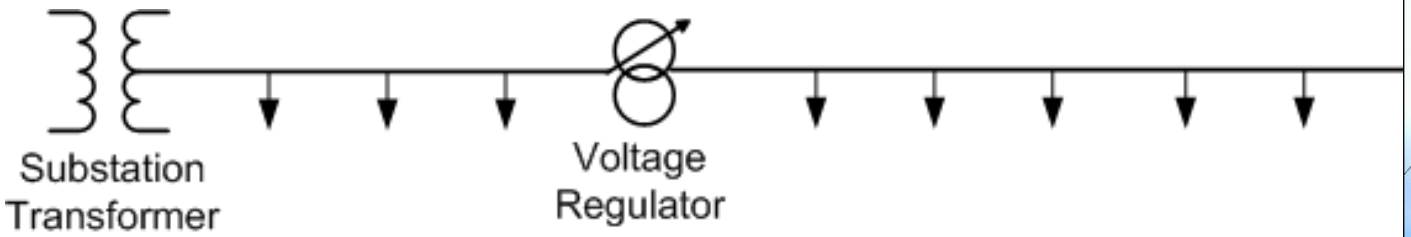
- Not just Residential and Commercial Scales
- Most utility-scale up to ~5MW (or more)

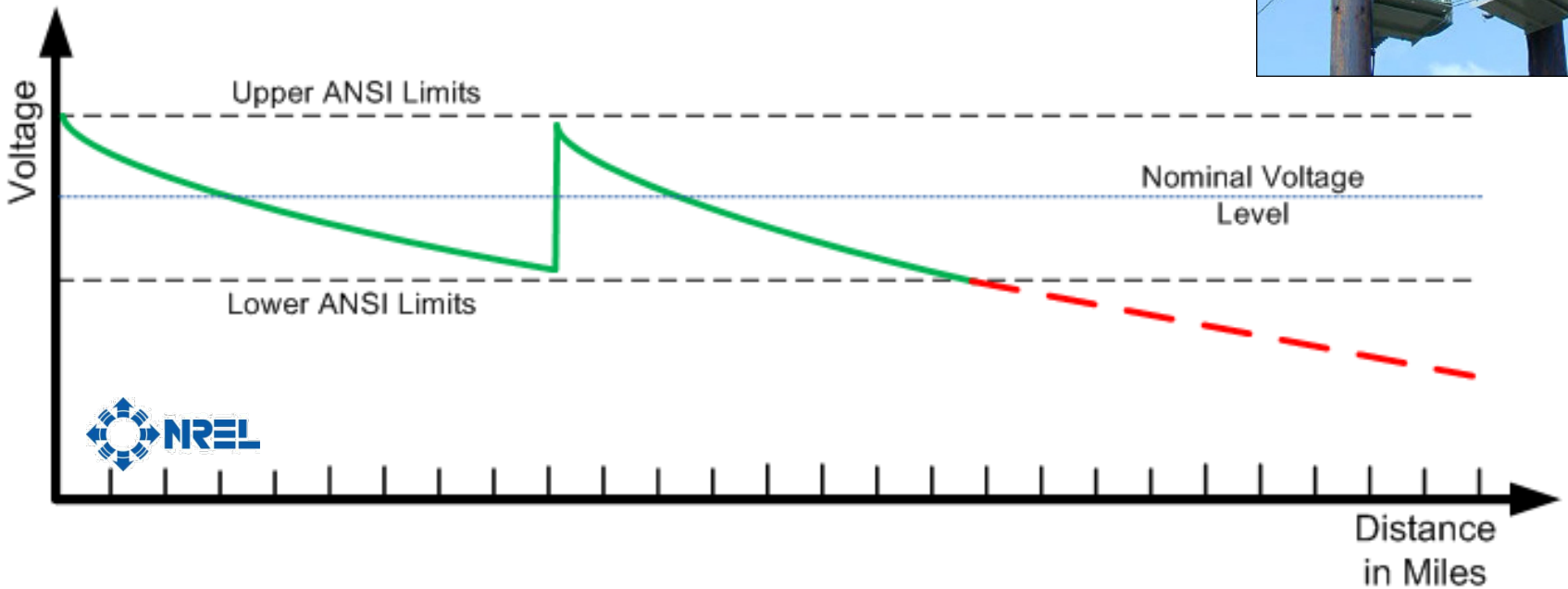
Utility Concerns with DG (and hence DGPV)

Concern	Number of Utilities (Out of 21)
Voltage regulation	16
Reverse power flow	11
Protection coordination	10
Increased duty on line regulators	8
Unintentional islanding	8
Secondary networks	6
Variability due to clouds	5
Capacitor switching	4

M. Coddington and J. Smith, "Current Utility Screening Practices, Technical Tools, Impact Studies, and Mitigation Strategies for Interconnecting PV on the Electric Distribution Systems," EPRI Report #3002003277, 2014.

Voltage Regulation: Load-only





B. Palmintier, R. Broderick, B. Mather, M. Coddington, K. Baker, F. Ding, M. Reno, M. Lave, and A. Bharatkumar, "On the Path to SunShot: Emerging Issues and Challenges in Integrating Solar with the Distribution System," National Renewable Energy Laboratory, Golden, CO, NREL Technical Report NREL/TP-5D00-65331, May 2016.

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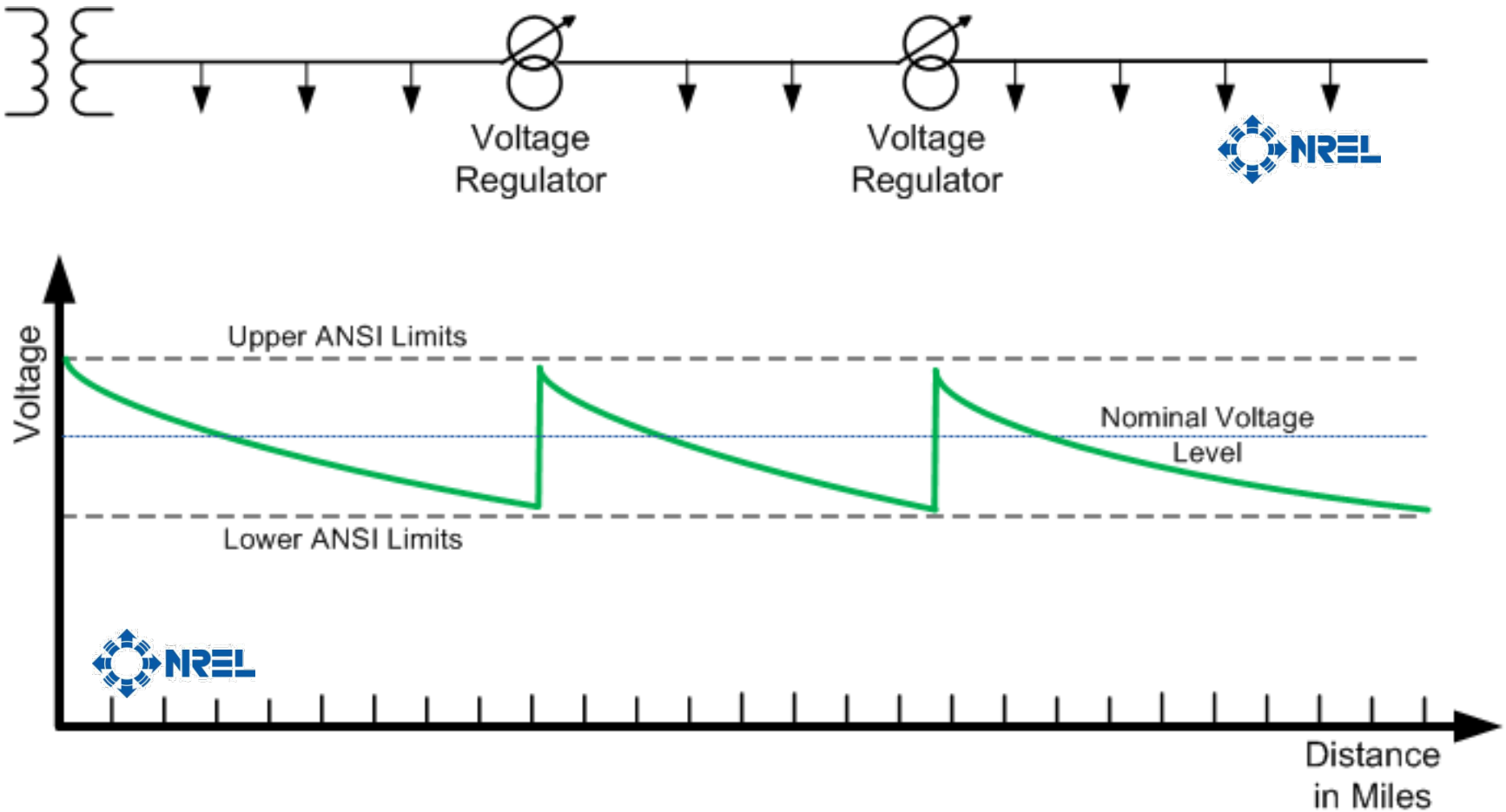

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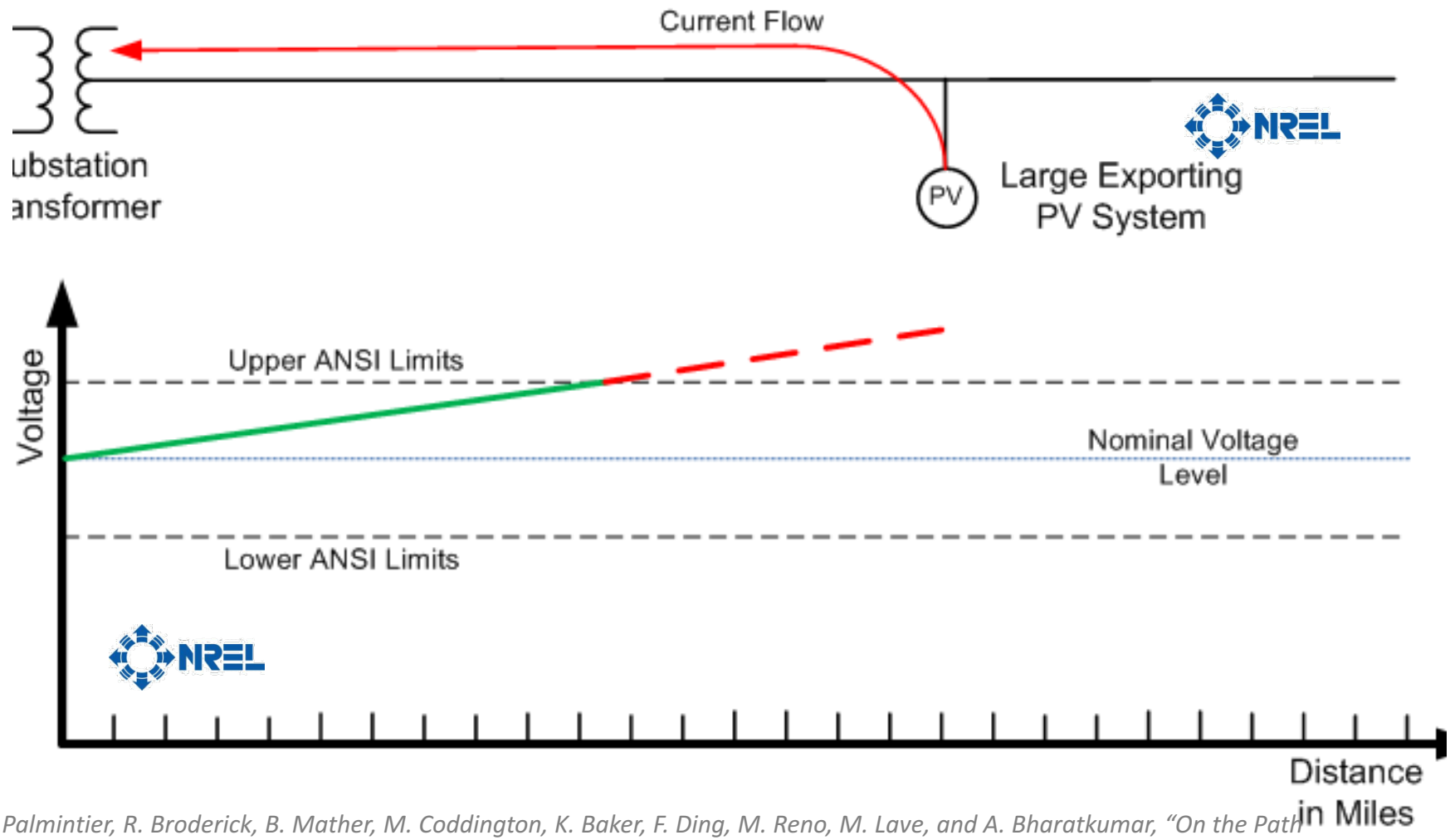
Voltage Regulation: DG-PV Challenge



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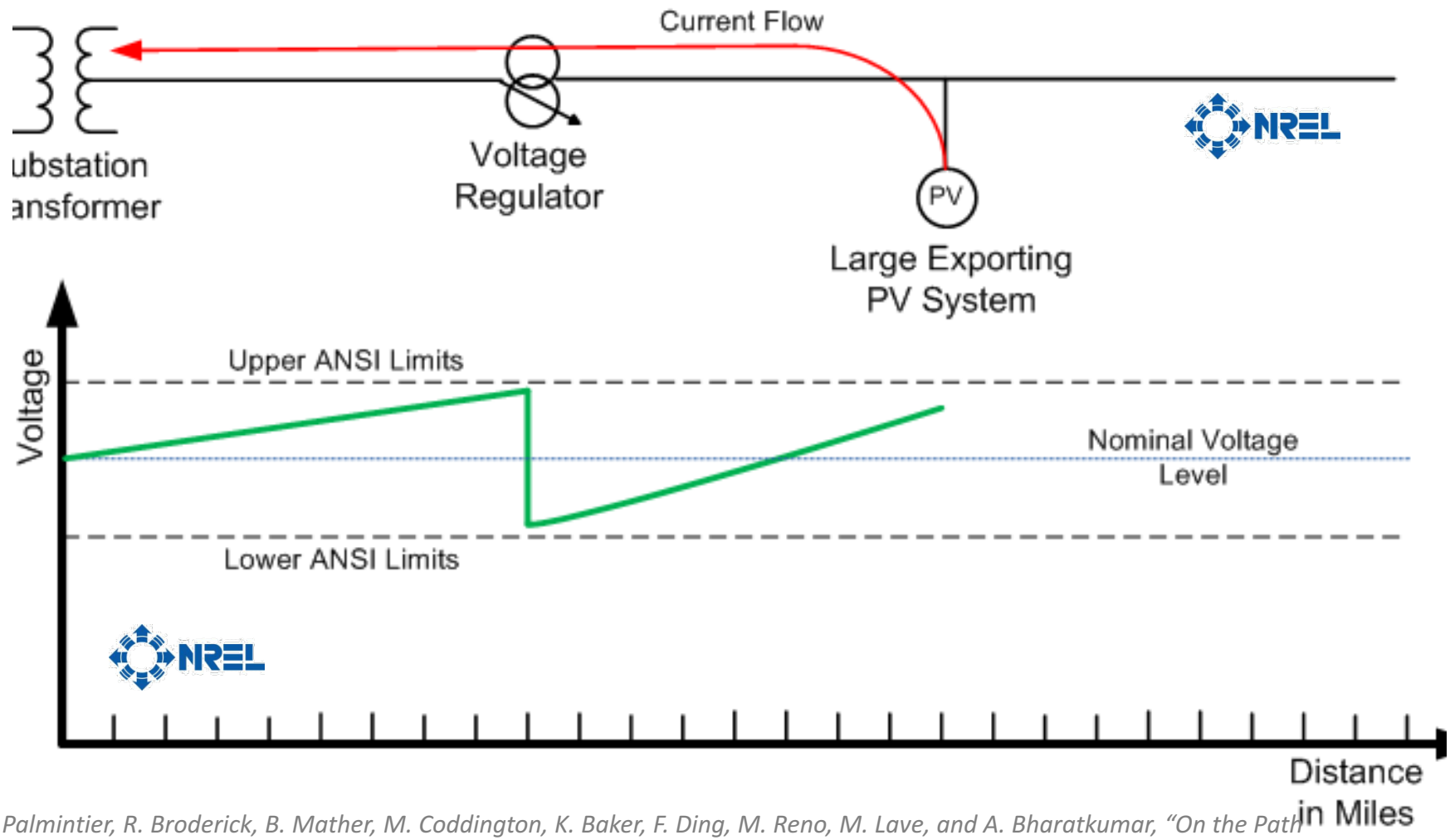
Voltage Regulation: DG-PV with Regulator



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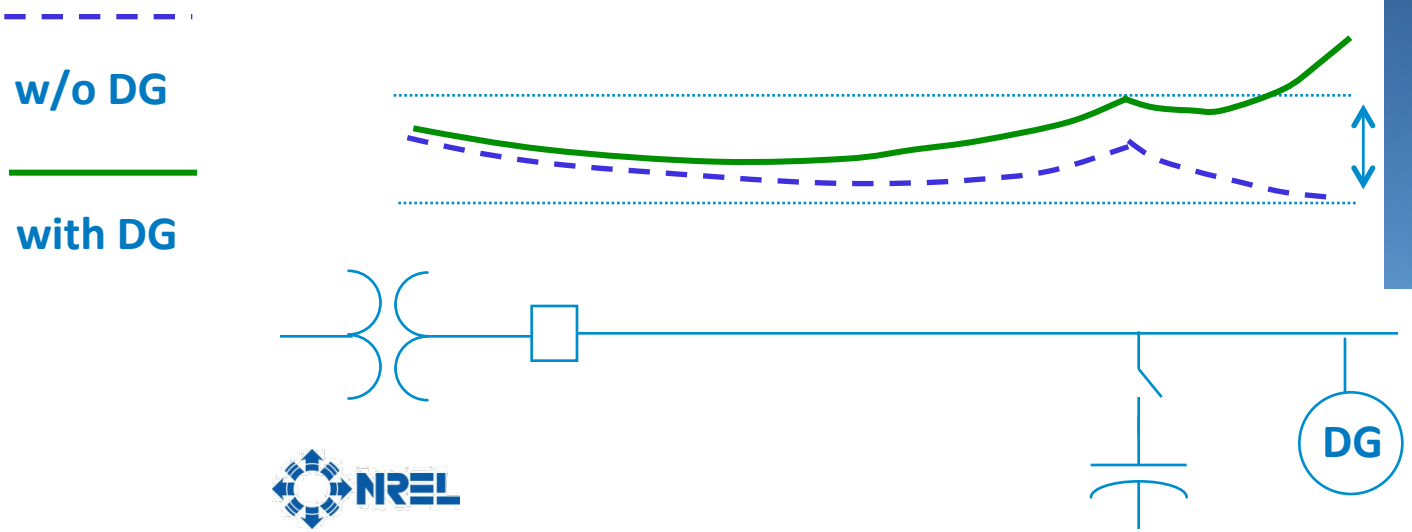
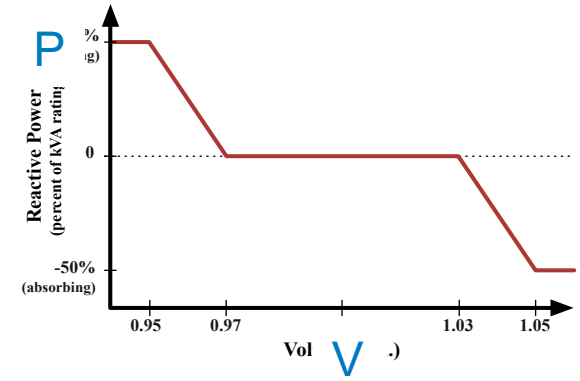
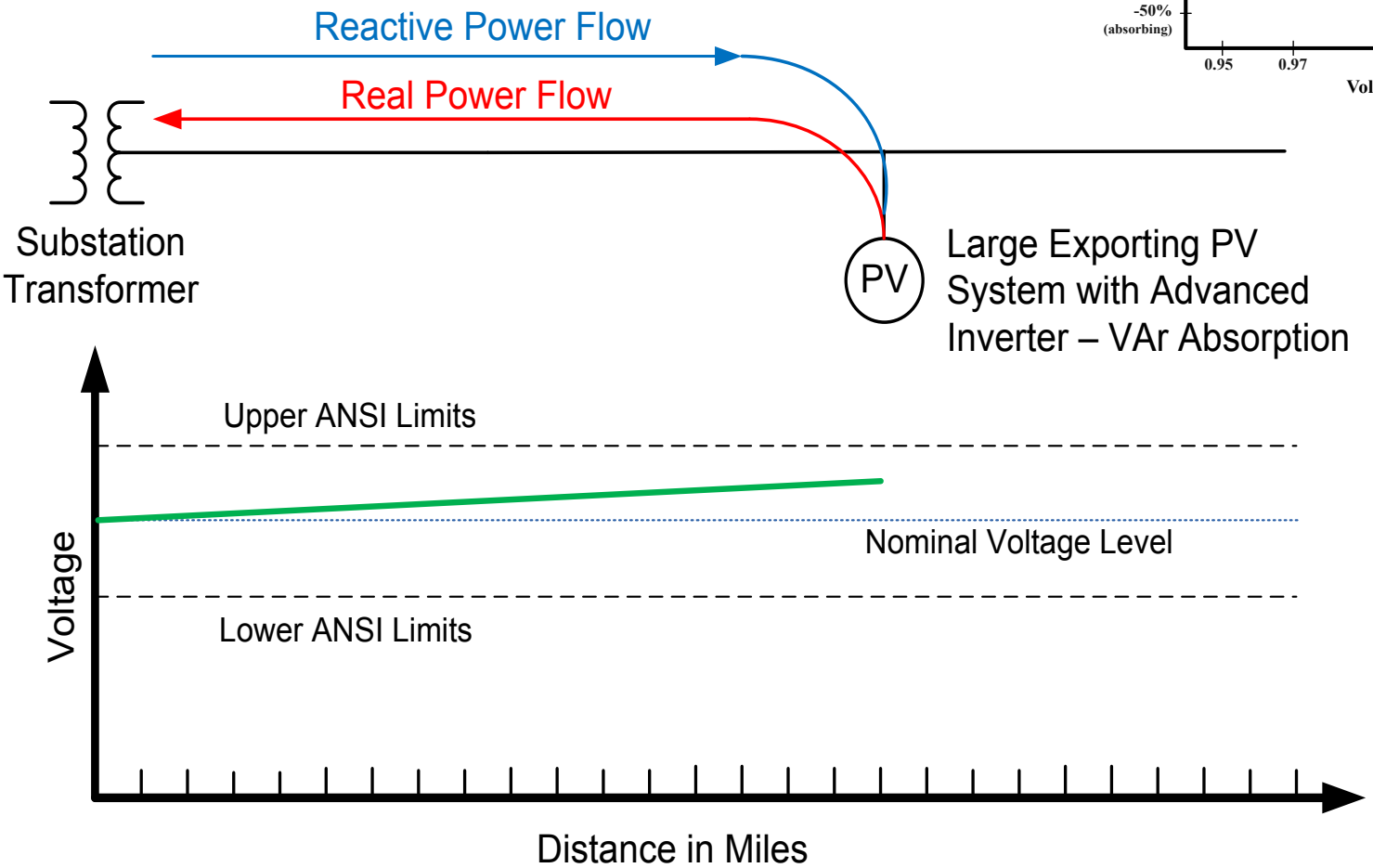
Voltage Regulation: DG-PV with Capacitor(s)



Voltage Regulation: Advanced Inverters





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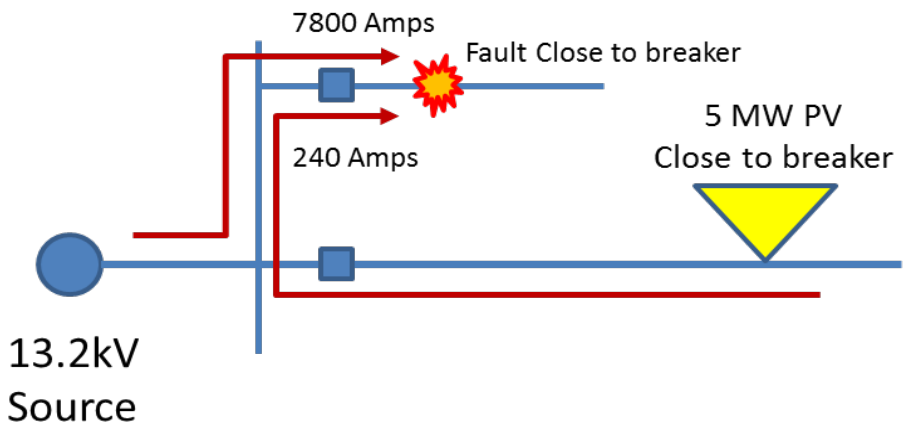
Faults: Why we have protection

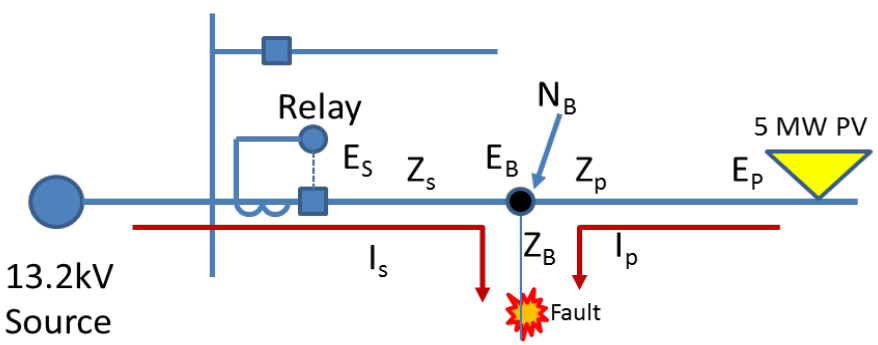
Protection Concerns

PV provides additional current:

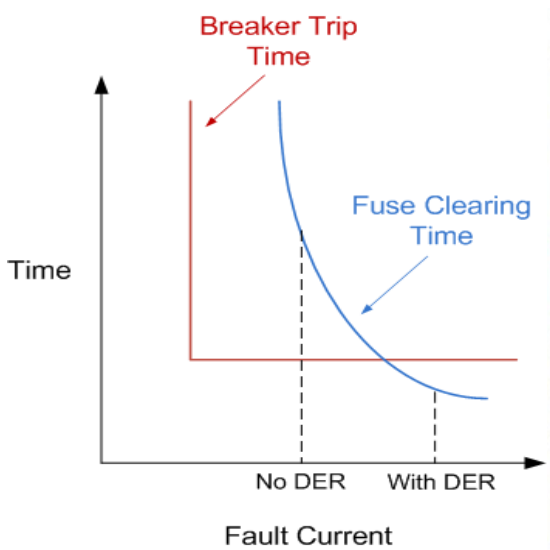
- Too much
- Too little
- Fuse vs. breaker timing

Note: PV current very short (compared to rotating machines)





Current from the PV (I_P) flowing through Z_B Raises voltage at N_B (E_B)
Thereby reducing current from source (I_S)



R. Seguin, J. Woyak, D. Costyk, J. Hambrick, and B. Mather, "High-Penetration PV Integration Handbook for Distribution Engineers," National Renewable Energy Laboratory (NREL), NREL/TP-5D00-63114, Nov. 2015.

Detailed Technical Modeling Required

Static Analysis **Lots of Data**

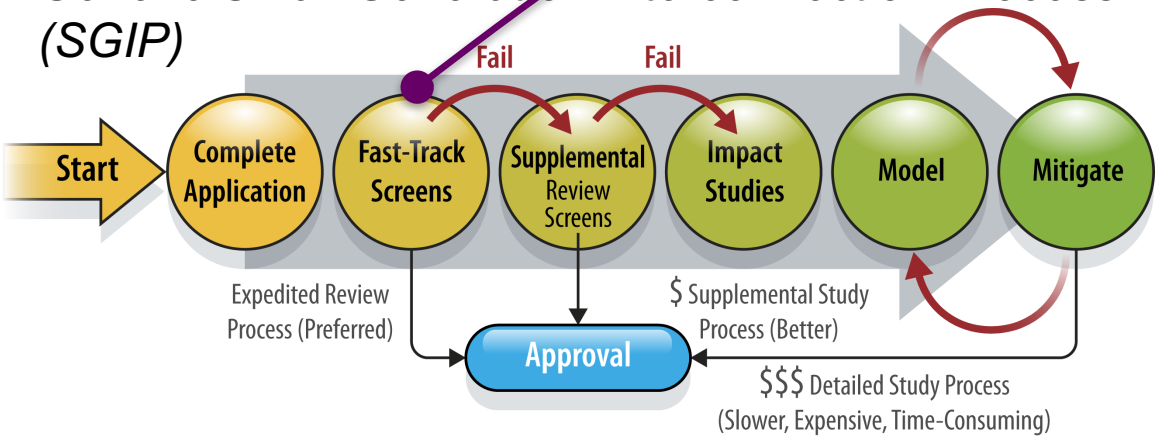
- Conservative Voltage impacts (Snapshot Powerflow)
- Protection Updates

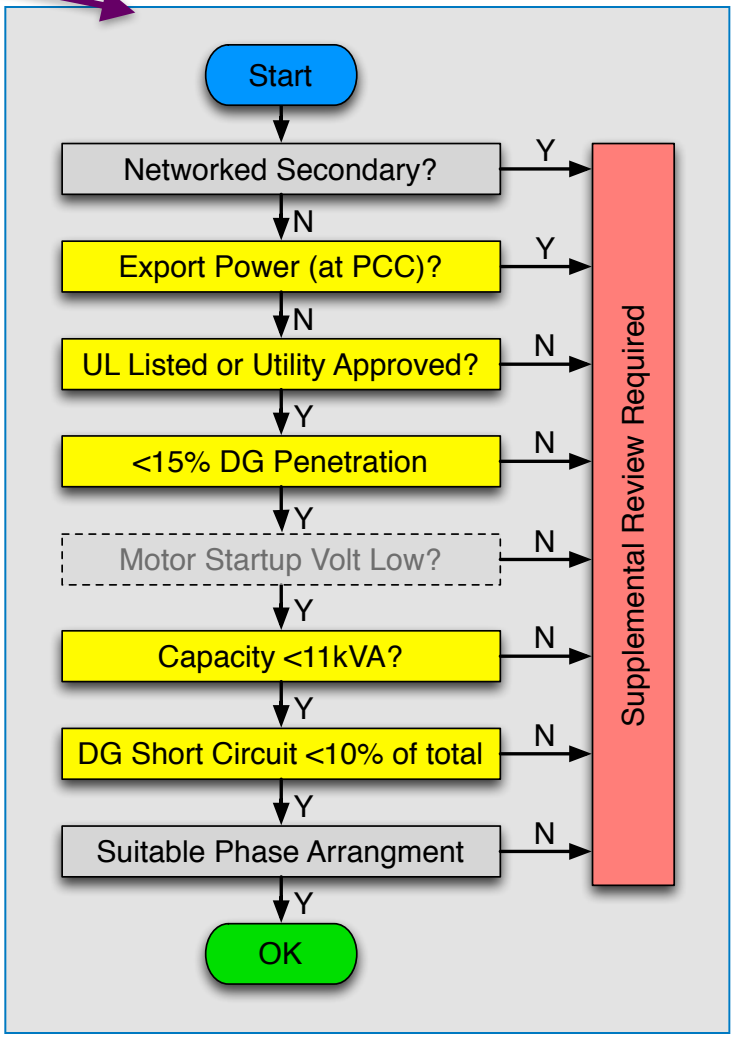
Quasi-Steady-State Analysis **Huge amounts of Data**

- Equipment wear & tear/upgrades
- More accurate voltage (ANSI allows temporary violation)
- Losses
- Advanced control based mitigation
- Storage

Interconnection Process

Generic Small Generation Interconnection Process (SGIP)





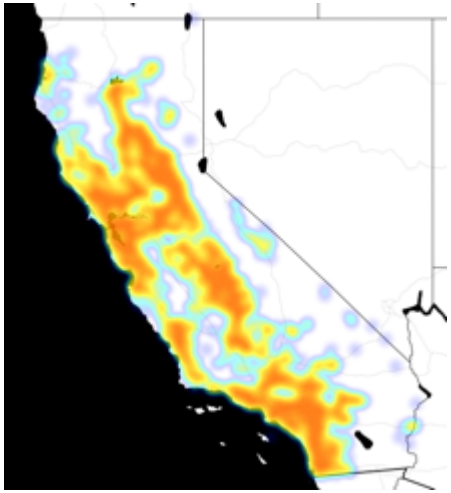
Simplified CA Rule 21 (early 2015)

- History of very long queues
- DER Owner typically pays for upgrades

Distributed Gen. Market Demand Model (dGen)

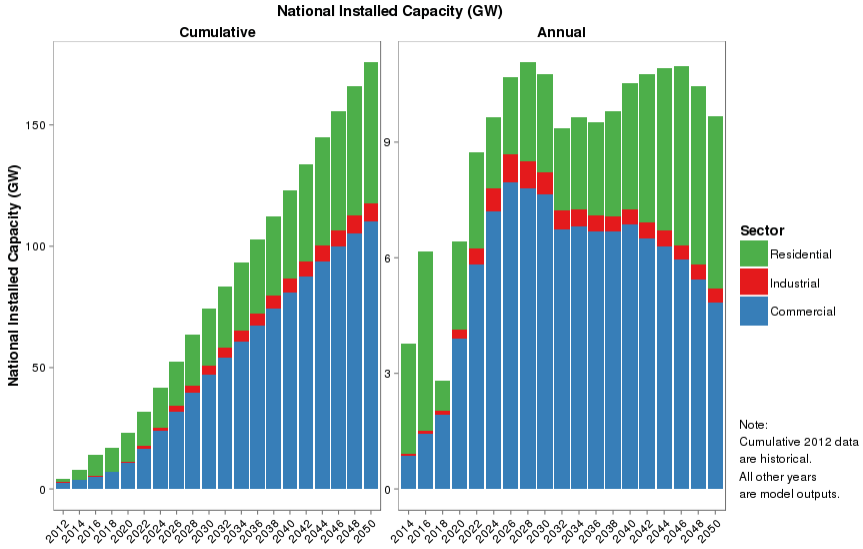
Project Overview:

- Forecasts customer adoption of distributed generation technologies (solar, storage, wind, geothermal) for residential, commercial, and industrial entities in the continental United States through 2050, given assumptions about future electricity costs, technology cost and performance, policy and regulation, and customer behavior
- High geographic resolution enables state, utility, or city-specific analysis w/ overlay of multiple spatial layers
- Major Studies: Sunshot Vision, Renewable Electricity Futures, ITC extension analysis



Project Details:

- Capabilities – DER capacity forecast, interaction of high VG w/ rates, interconnection, & policy
- Engagement –DOE Solar, DOE Wind, Utilities, State Regulators, Consulting
- Tools –Python/SQL/R, linked to ReEDS
- Data – Annual Technology Baseline, Wind and Solar datasets, URDB, DSIRE, EIA-AEO. All data in GIS framework
- Visualization: Automated scenario comparison report



(Top Left): Evaluate adoption potential for each 200m² cell; (Top Right): Spatial focus permits regional predictions; (Bottom): Results from BAU-Mid Costs Scenario in ITC Extension analysis

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- **Data Needs**
  - Know your problem
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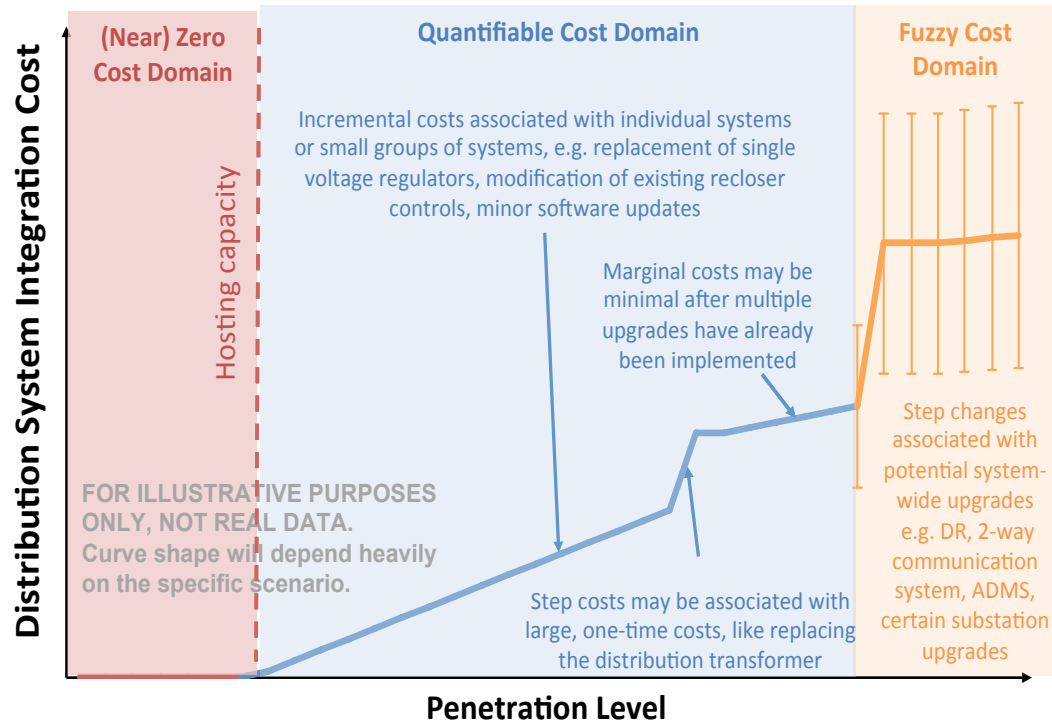
- **Where to Find Data**
  - Resource Data
  - Grid Data
  - Other
- **Filling the Gaps**
  - Smart-DS project

How much data do you need?

It depends!

- What are the questions (Value streams)?
- Whose perspective?
- Top down or bottom-up?
- Penetration level



Horowitz, Kelsey A. W., Bryan S. Palmintier, Barry Mather, and Paul Denholm. In Review. "Distribution System Costs Associated with the Deployment of Photovoltaic Systems." Renewable & Sustainable Energy Reviews.

Data Synchronization

- Big challenges:
  - Just getting data in one place
  - Cobble together time synchronized data
    - GMT, Timezones
    - Time resolutions
  - Filling in the gaps

Data & Assumptions for PV Impact Studies

Utilities

- Have Network Data
- Load + Solar Profiles
  - 1-4 time points
    - (Too?) Conservative
  - QSTS
    - Load Data?
    - Must Synchronize
- Control Settings
- Protection/Dynamics:
  - PV model for phasors
  - Improved Load models

Researchers

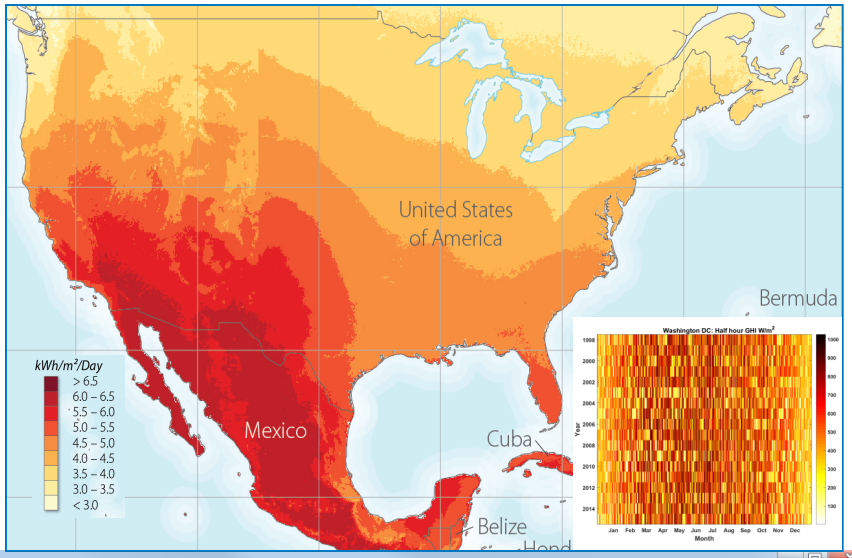
- REALISTIC Networks
  - Beyond Single Feeder
  - Reconfiguration
- REALISTIC Load + Solar Profiles
- REALISTIC Control Settings
- Comparable Test Cases
  - Fully Open Data
  - Avoiding the "Modified-118" problem
- T+D
  - Lots of data
  - 3ph Dynamic Modeling
  - Improved models

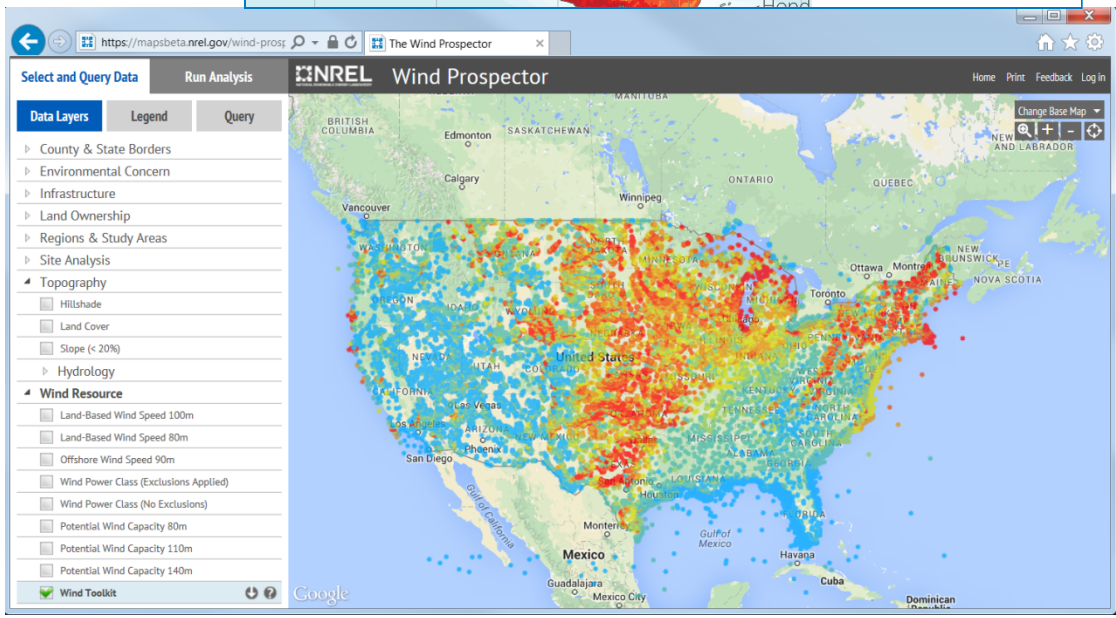
Data Requirements: Wind, Solar, and Load

- Weather is common driver
- Hourly wind, solar, and load data must be from same year for consistent analysis and plausible results
- Use of meso-scale weather models or actual VG production is state of the art (same as integration studies)
- Preserves underlying correlations between wind, solar, and load with temperature, other weather phenomena

Resource Data

- Solar:
  - NSRDB
  - CPR Solar Prospector
  - Commercial sources
- Wind:
  - Wind Toolkit
  - Others





Grid Data

- Networks
  - Test systems
  - Utility NDA
- Summary Data
  - Utility, EIA
- Cost Data
  - Historically hard
  - CA Component Cost database
  - NREL effort
- Distilled data:
  - CA's DRP
- Rate structures
- Load profiles

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CHANGING WHAT'S POSSIBLE

SMART-DS: Synthetic Models for Advanced, Realistic Testing: Distribution systems and Scenarios

PIs: Bryan Palmintier and Bri-Mathias Hodge, NREL

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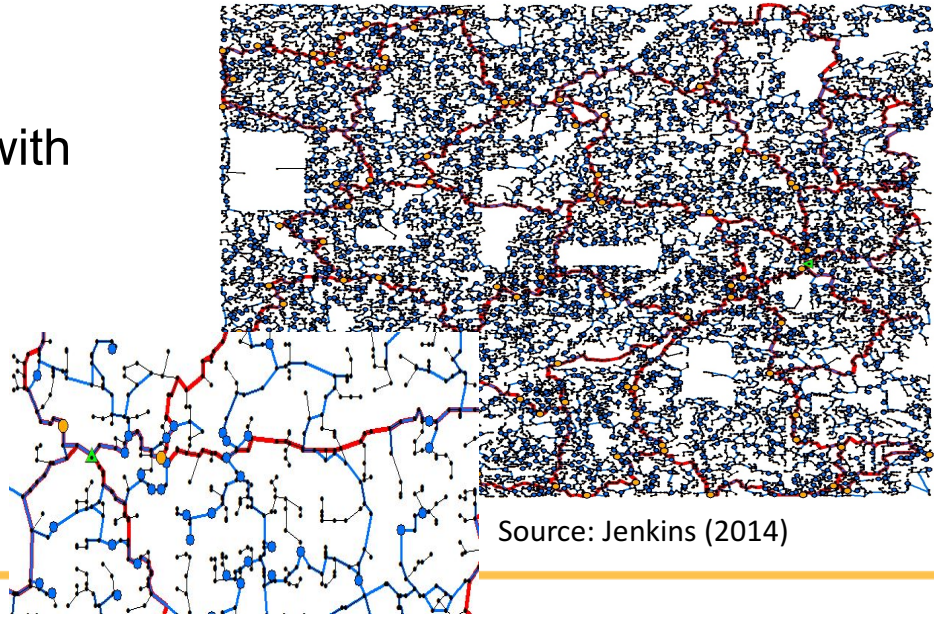
COMILLAS
MADRID

Smart–DS: Distribution Systems

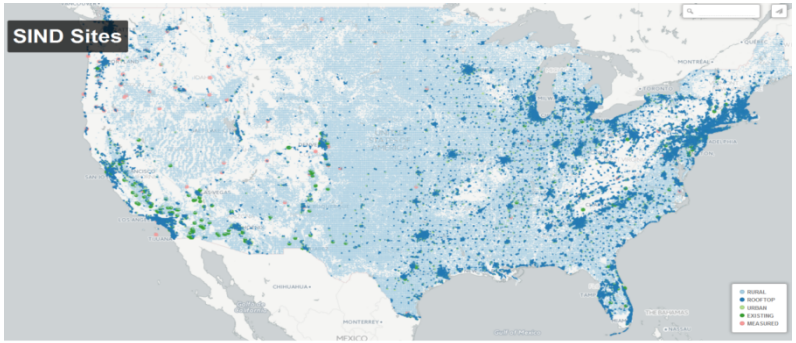
- Full-scale, high quality synthetic distribution system dataset(s) for testing distribution automation algorithms, distributed control approaches, ADMS capabilities, and other emerging distribution technologies
- Adapt MIT/Comillas-IIT Reference Network Model (RNM) for U.S. (to create RNM-US)
- Detailed statistical summary of the U.S. distribution system characteristics and costs
- Smart-DS Cases:
  - Multiple neighboring substations with attached feeders and switches
  - Milestone: 20+ substations, 400,000 Electrical Nodes
  - Target: 100+ substations, 500+ feeders, 1M+ customers
  - Maybe: T+D connections



Source: Jenkins (2014)

Smart–DS: Scenarios

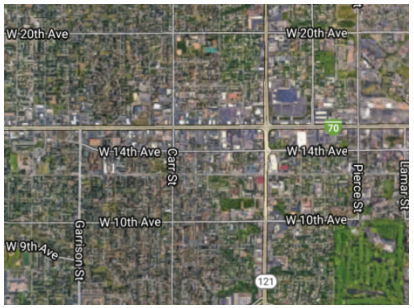
- Advanced, automated scenario generation tools for wind and solar generator data; creating bulk system generator mix realizations; and populating distribution feeder models with scenario data, including DERs
  - Time series data
  - World-class high spatial/ temporal resolution solar and wind resource data with forecasts



- Distribution scenarios: ZIP load snapshots, DER devices and functionality including solar PV, smart inverters, electric vehicles, batteries and demand response

- Transmission scenarios: API for matching time-synchronized resource data (wind, solar, weather) and generation mix to nodal, geo-coded transmission data

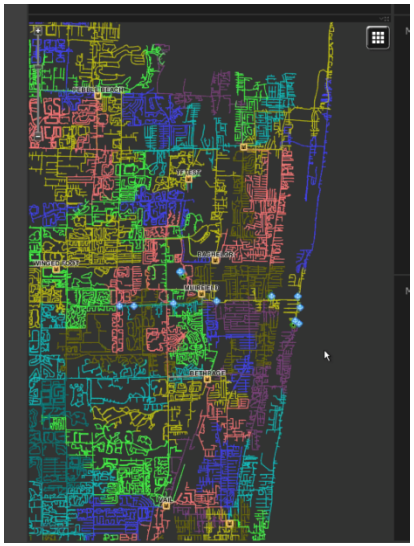
Building Synthetic Distribution: RNM-US



Satellite Image

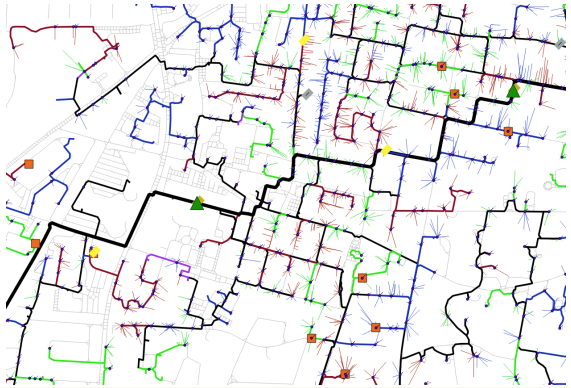
Customers & Streets

Catalog

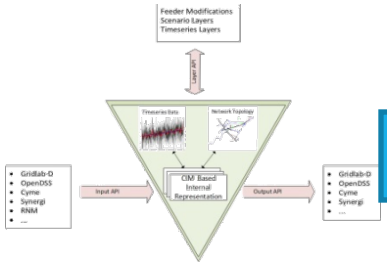


Real Grid Data

RNM-US



Synthetic Distribution Data

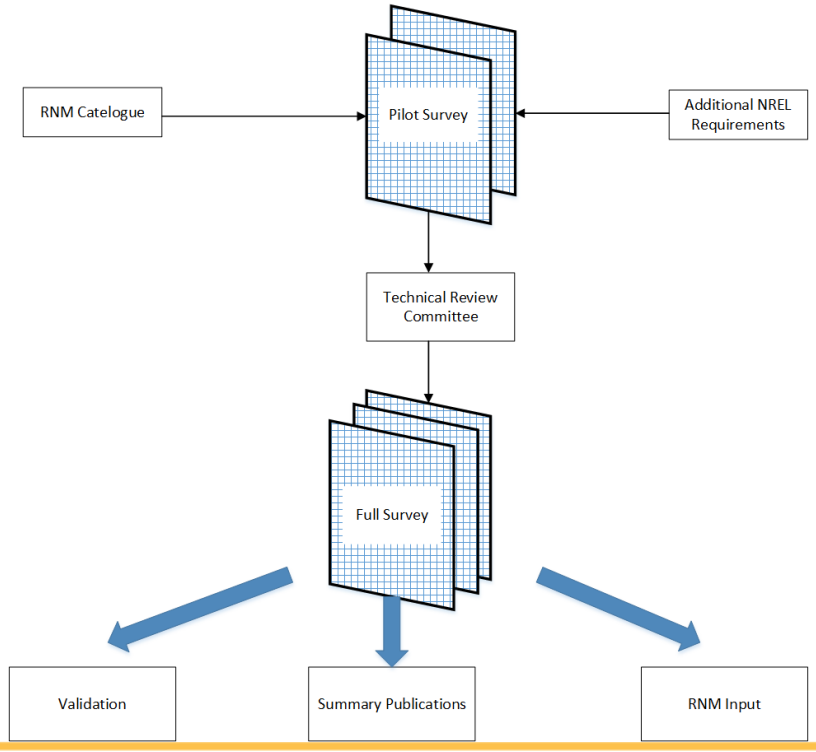


Post Processing

Test System

Distribution "Survey"

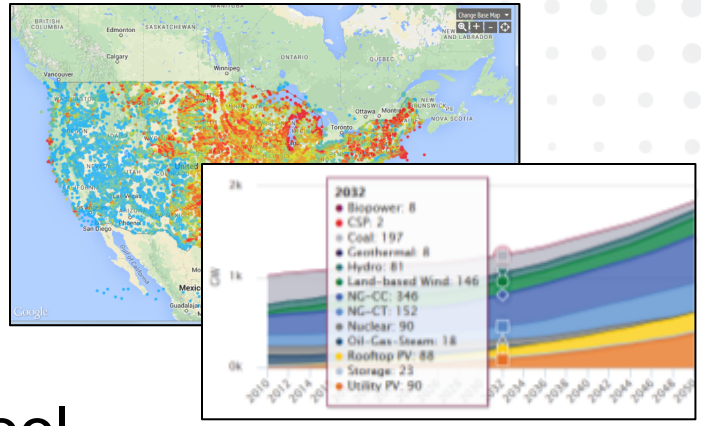
- Two goals: RNM-US Inputs, Validation
- Contents:
  - System Summary Tables: Feeders, Substations
  - Representative Feeders
  - Cost Table
- Data partners:
  - City of Loveland
  - SCE
  - Exelon
  - Duke Energy
  - APS
  - HECO*
  - LADWP*
- Will publish summary (anonymous)

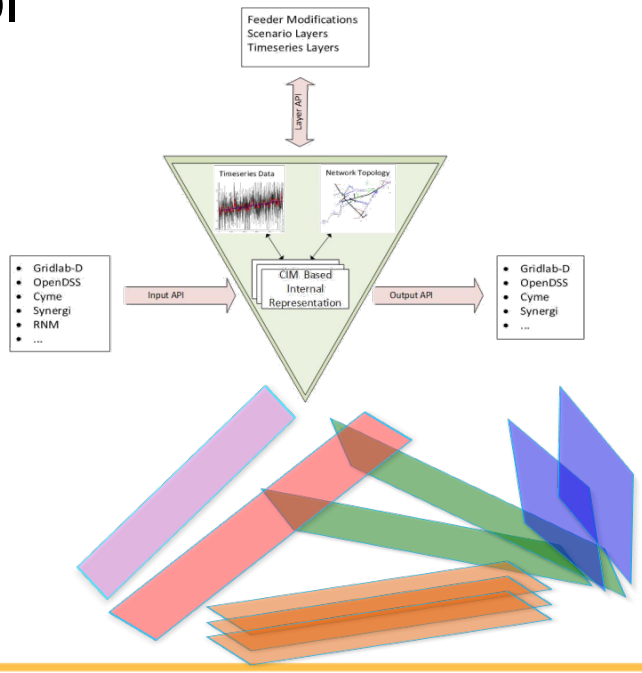


** Pending: Full system data coming through other projects*

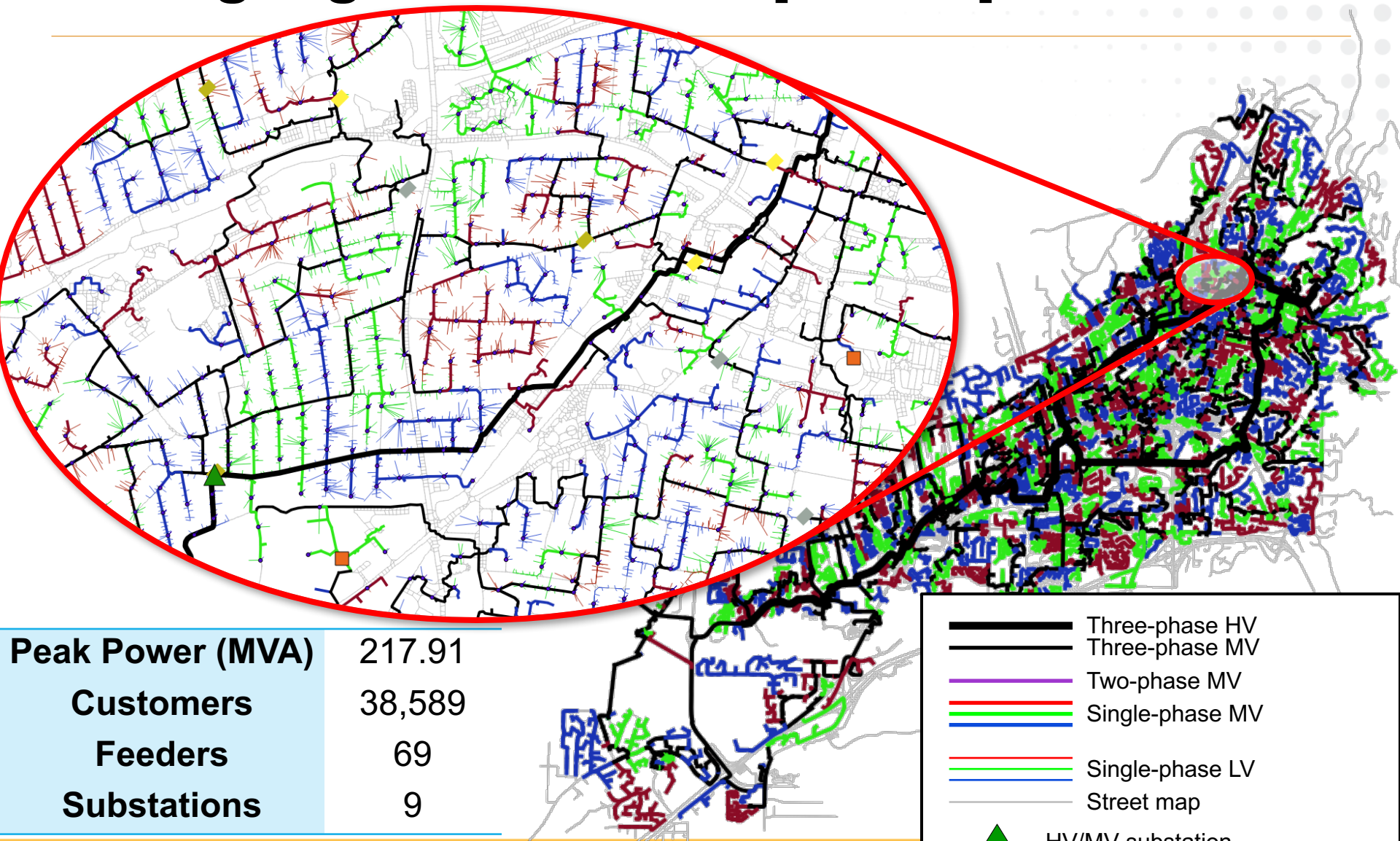
Scenario Tools

- Resource Data Tool
  - Wind, Solar & Forecasts
  - Transmission & Distribution
- Generation Mix Tool
- DiTTo: Distribution Transformation Tool
  - Many-to-1-to-many conversion
  - Merge, Modify, & Add
- Layers Automator
  - Sequence of modifications





Q4 Highlight: Demo #2+ [M1.2.3]



Peak Power (MVA)	217.91
Customers	38,589
Feeders	69
Substations	9

Santa Fe (NM) Area =150km^2

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Thank you!

Bryan.Palmintier@nrel.gov

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