SAND2018-9713PE

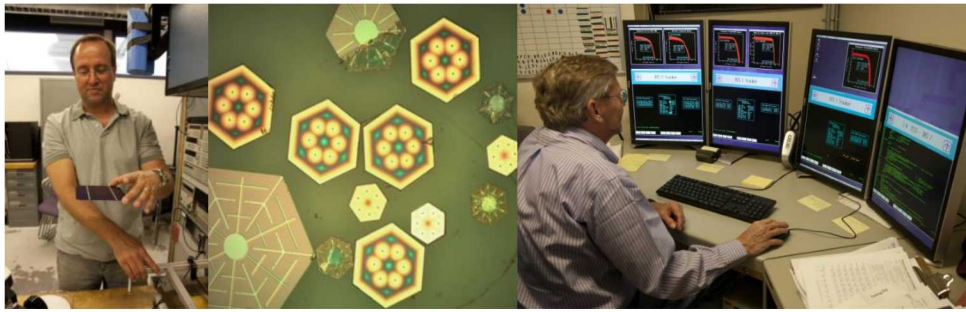
Hosting Capacity Studies

Exceptional service in the national interest

Sandia National Laboratories

Matt Reno, Jay Johnson
Sandia National Laboratories, Albuquerque, NM

Workshop for the definition of the National Priorities for Research, Technological Development and Training of Human Resources: Smart Grids and Microgrids
Cuernavaca, México
18-20 Septiembre 2018



U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525.

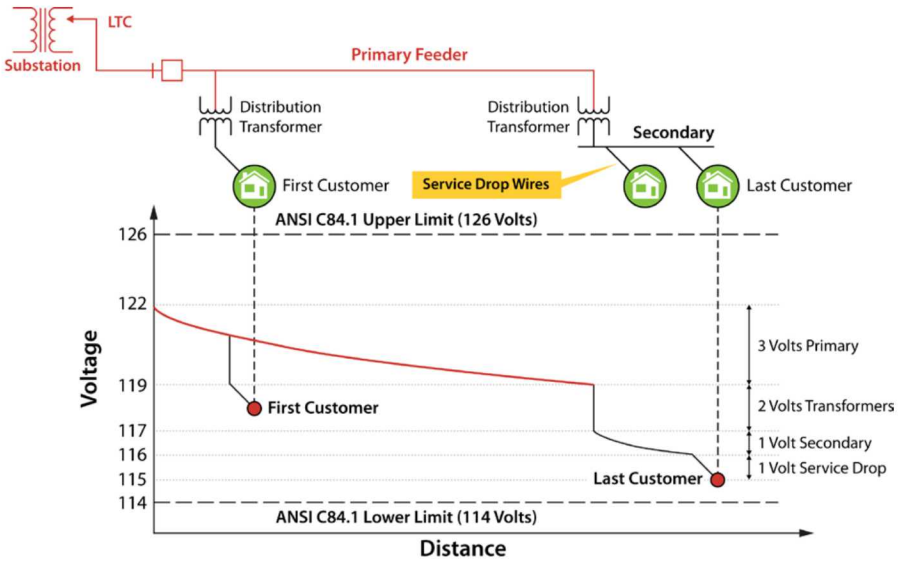
Background

- Goal
  - Wide-spread deploy of renewable energy systems on distribution circuits
- Problem
  - Distribution systems have not been designed for bidirectional power flows
  - Voltage limits and protection challenges as the penetration of PV/DER increases
- Definition
  - Hosting Capacity: the maximum amount of PV that can be accommodated on a feeder without impacting reliability

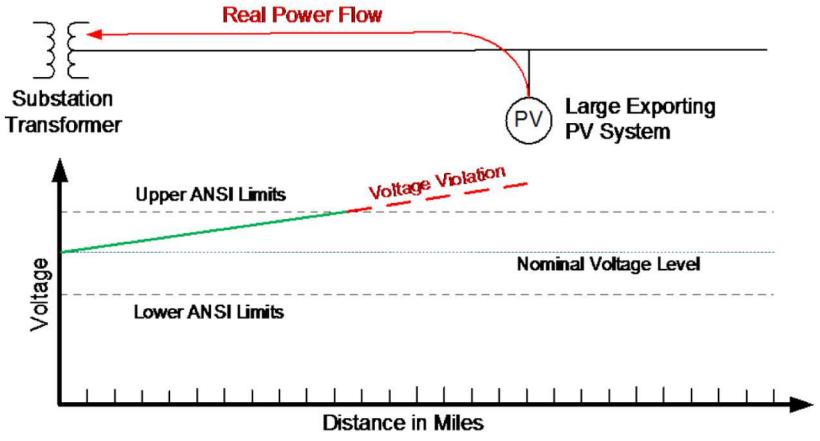
Image: Ota City, Japan, https://solarpanelscompany.com

Voltage Regulation Challenges

- Active power injection from PV systems on the feeder will produce higher voltages.
- Variable PV generation may cause temporary voltage violations (per ANSI C84.1) because the ramp rates are faster than voltage regulation equipment.



Feeder voltage profile without distributed generation.



Feeder voltage profile with distributed generation.

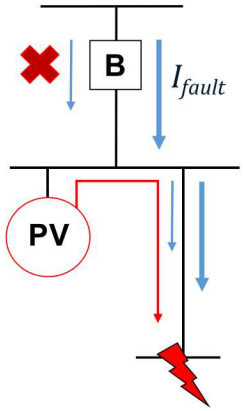
Movie showing distribution voltages over a day: "EPRI High Penetration Solar Impacts," https://youtu.be/t51Cwb5ZpUA

Images: B. Palmintier, et al., On the Path to SunShot: Emerging Issues and Challenges in Integrating Solar with the Distribution System, NREL/TP-5D00-65331, May 2016.

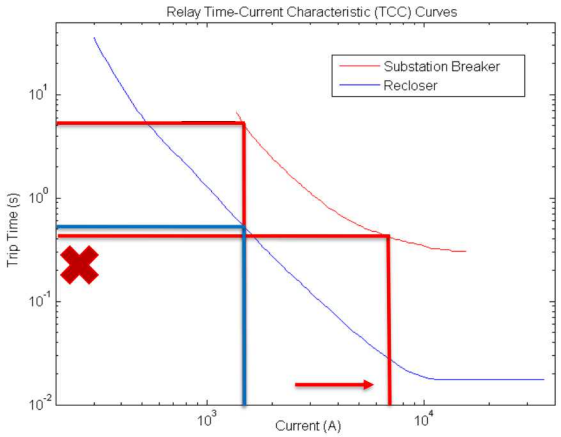
Distribution System Protection Challenges

- There are a range of protection difficulties that may emerge with high-penetrations of distributed generation:
  - Under-reach: PV current feeds the fault and does not trip the breaker
  - Coordination loss: the smallest protection zone is not the first to trip
  - Sympathetic tripping: more than one feeder branch trips during a fault
  - Nuisance tripping: I_{PV} trips protection devices not on the faulted circuit
  - Thermal limits: line or transformer current exceeds its rating

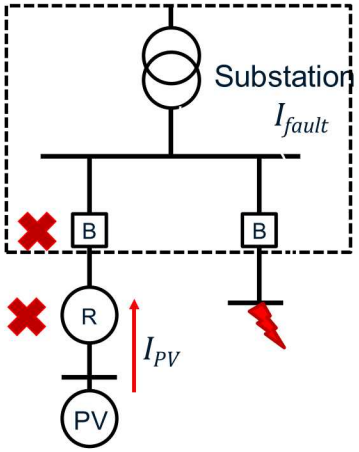
Under-Reach



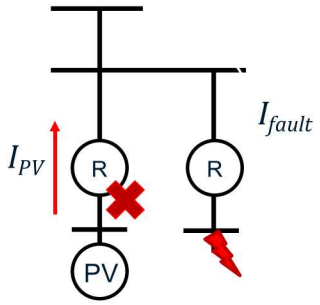
Coordination Loss



Sympathetic Tripping



Nuisance Tripping



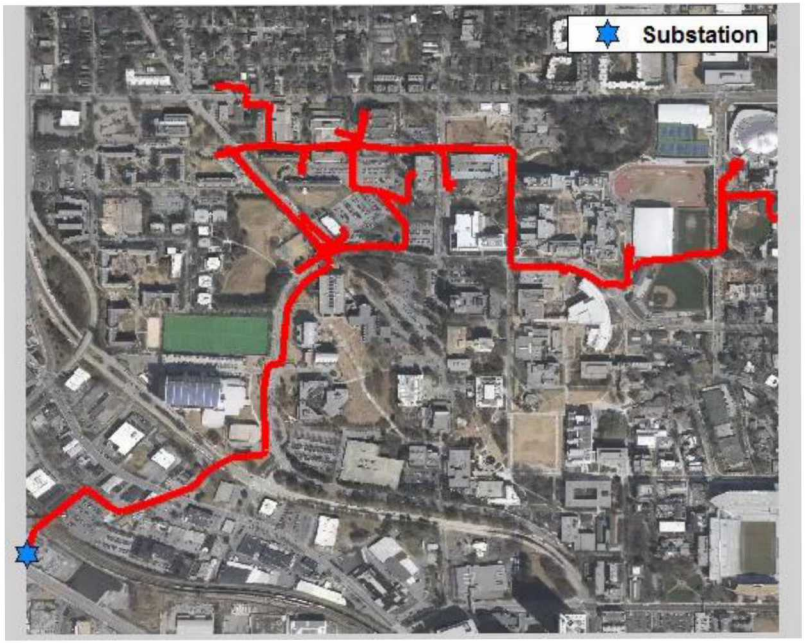
Wide range of high renewable penetration protection issues covered in R. Seguin, J. Woyak, D. Costyk, J. Hambrick, B. Mather, "High-Penetration PV Integration Handbook for Distribution Engineers," National Renewable Energy Laboratory, Golden, CO NREL/TP-5D00-63114, 2016.

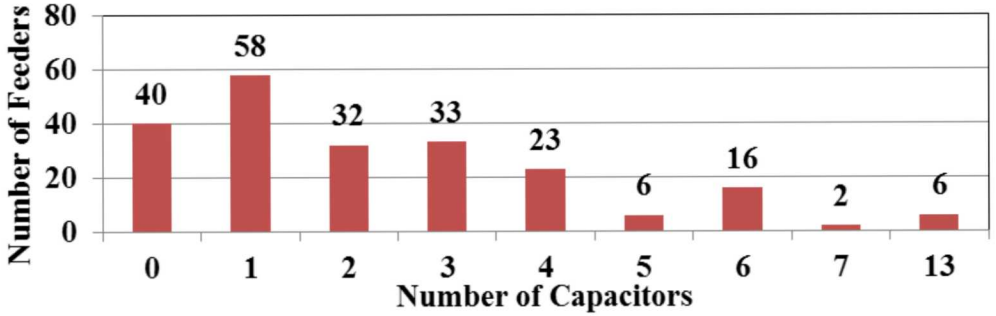
Hosting Capacity Studies

- **Research question**: how much PV can be installed on a given feeder before voltage or protection problems emerge?
- **Approaches**:
  - Streamlined analysis: rough calculations based on, e.g., voltage headroom
  - Clustering: one feeder study represents a collection of similar feeders
  - Detailed analysis: study all feeders with protection settings (~10 hrs/feeder)
- **Types of studies**:
  - Locational hosting capacity: determine largest allowable PV system at a specific location
  - Detailed hosting capacity analysis: study of multiple combinations of PV size and location
- The following locational hosting capacity studies focus on voltage violations and thermal line limits

Distribution Systems for Analysis

- The PV hosting capacity analysis was performed for a large range of different distribution systems in order to analyze the risks associated with different feeder topologies and characteristics
- 216 actual distribution systems located in the United States (~10 different utilities)

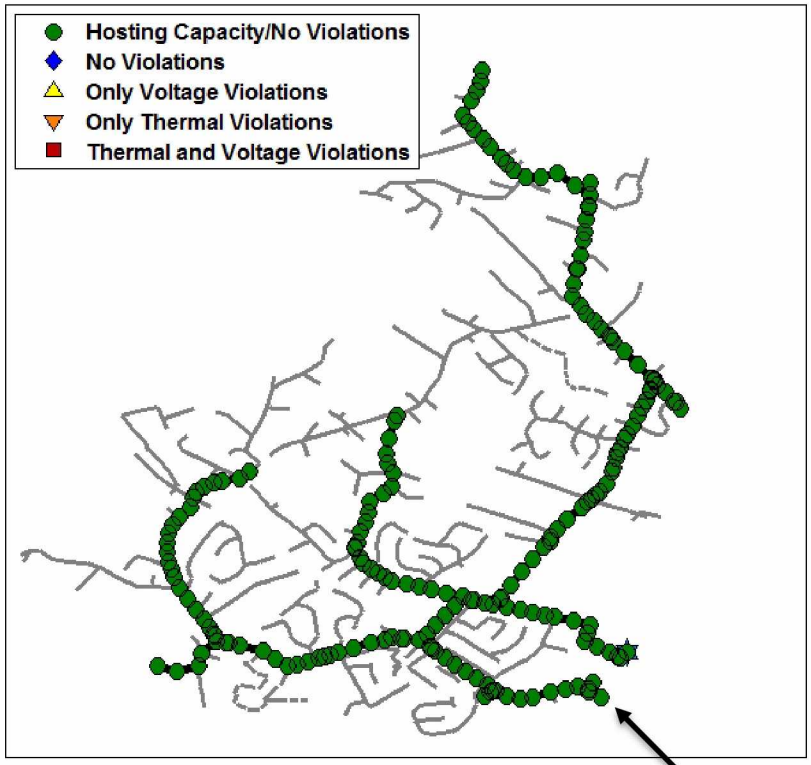


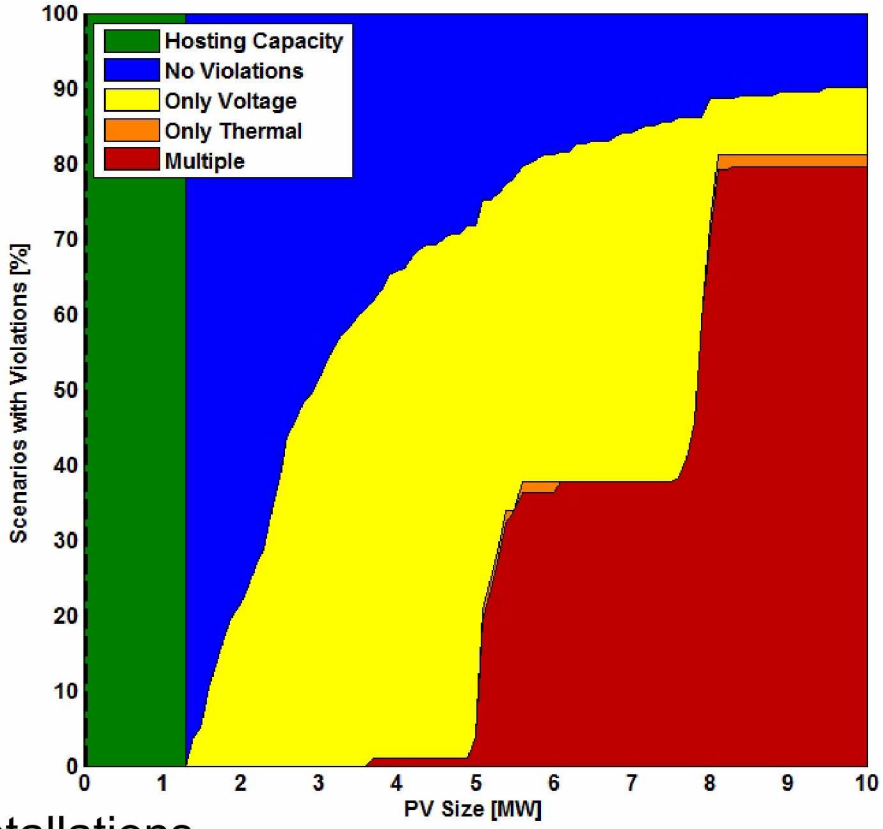


Voltage Level	4 kV	12 kV	12.47 kV	13.2 kV	13.8 kV	16 kV	19.8 kV	20.78 kV	22.9 kV	24.9 kV	33 kV	34.5 kV
Feeders	18	43	96	3	8	2	16	6	3	9	1	11

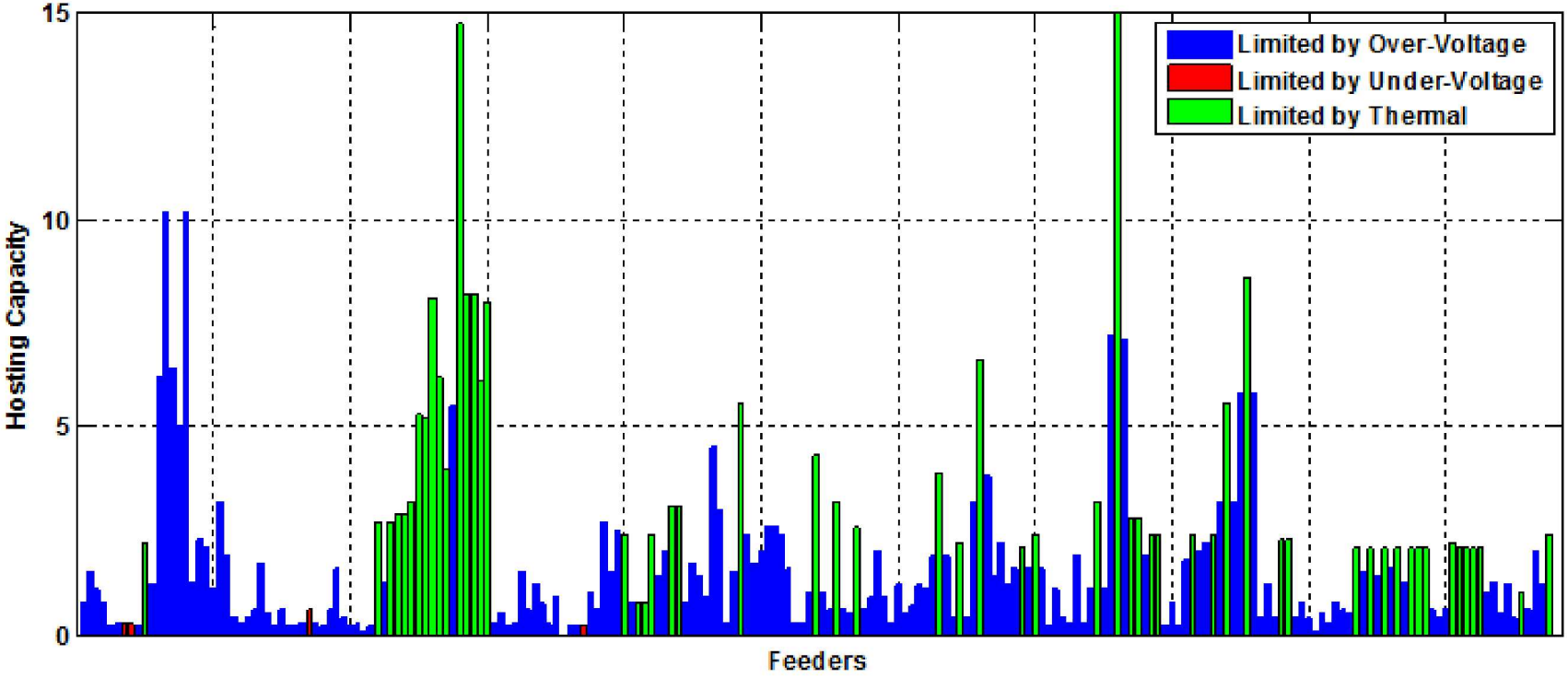
Example results

Impact signature shows the percentage of feeder simulations where reliability issue(s) appear for a set of PV system installations





Results



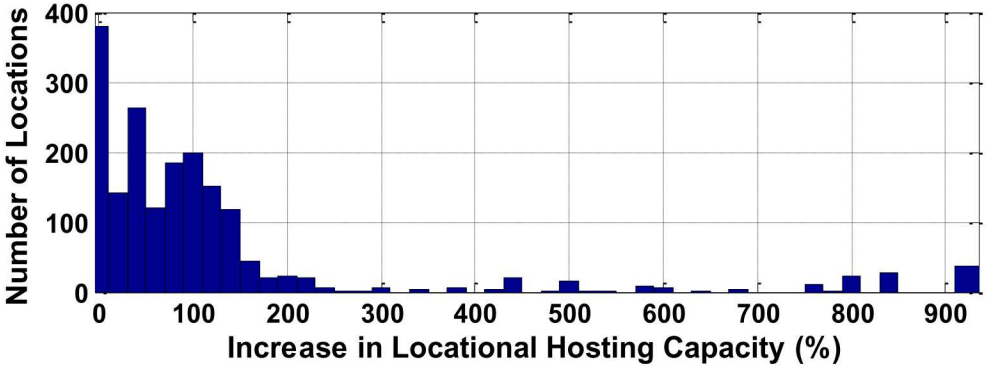
For the 216 feeders:

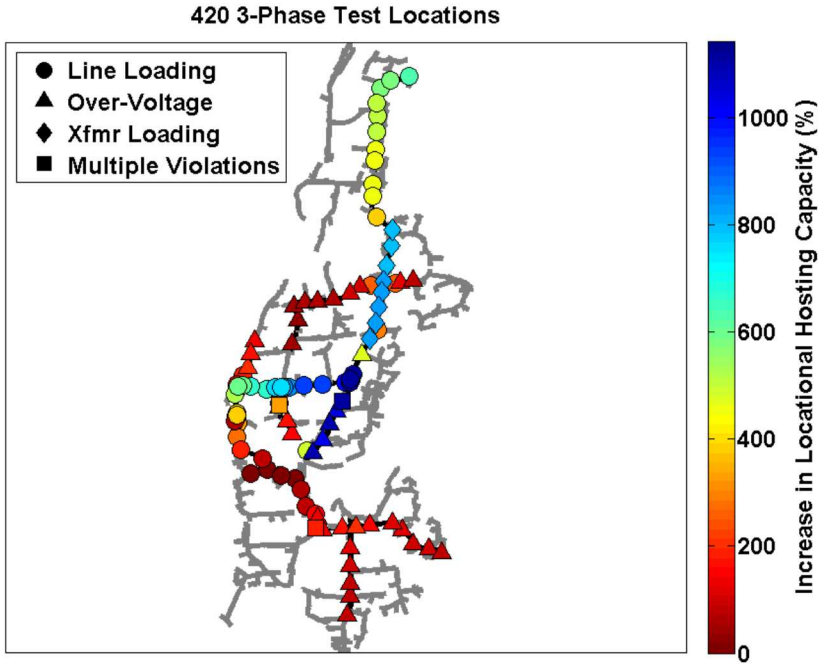
- 70% limited by over-voltages
- 3% limited by under-voltages
- 26% limited by the thermal ratings

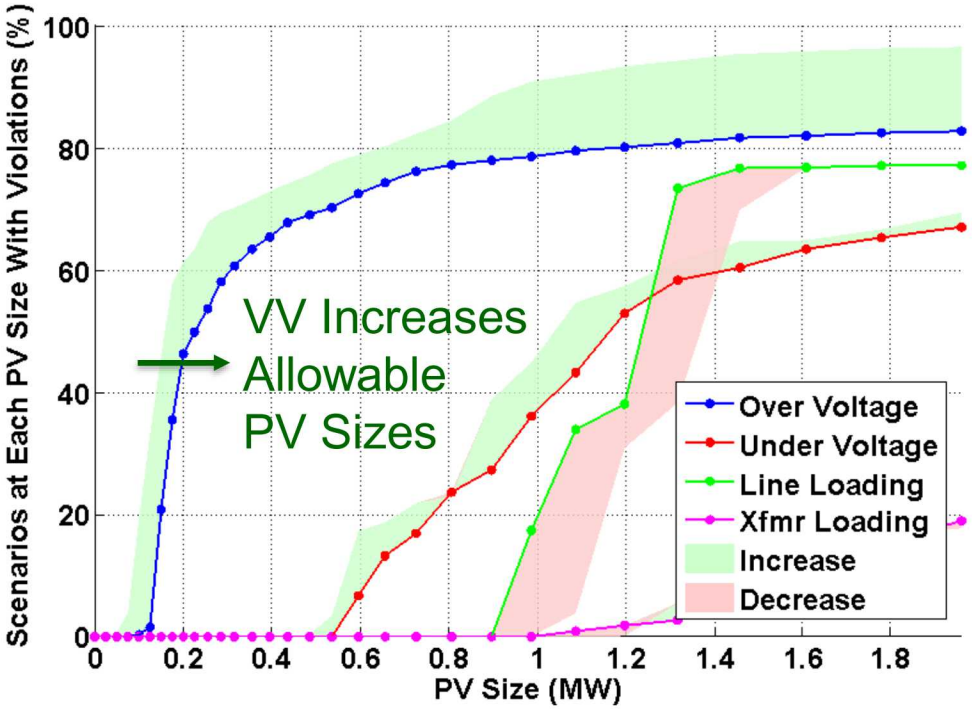
M. J. Reno and R. J. Broderick, "Statistical analysis of feeder and locational PV hosting capacity for 216 feeders," *2016 IEEE Power and Energy Society General Meeting (PESGM)*, Boston, MA, 2016, pp. 1-5.

Hosting Capacity With Volt-Var

Advanced inverter functions present new opportunities to increase feeder hosting capacity







Conclusions

- Locational hosting capacity analysis can provide the feeder impact signature and risk regions
  - Accurate protection analysis is required for detailed hosting capacity analysis
  - Settings for all protection equipment is required
- Hosting capacity is highly location-dependent
  - Information about PV size and location are important for running studies
  - Tracking this information will be valuable for Mexican distribution operators to conduct simulations in the future
- Advanced inverters can mitigate voltage constraints.
  - Protection constraints are typically less restrictive.
  - Initial laboratory results indicate active power curtailment will reduce fault current and could increase hosting capacity, if hitting protection limits.

Sandia National Laboratories

Thank You!

Matt Reno
Electric Power Systems Research
Sandia National Laboratories
mjreno@sandia.gov

Jay Johnson
Renewable and Distributed Systems Integration
Sandia National Laboratories
jjohns2@sandia.gov