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Improving Distribution Network PV Hosting Capacity via Smart Inverter Reactive Power Support

John Seuss[1], Matthew J. Reno[2], Robert J. Broderick[2], Santiago Grijalva[1]
[1]Georgia Institute of Technology, Atlanta, GA, USA
[2]Sandia National Laboratories, Albuquerque, NM, USA

Motivation

Utilities with many PV interconnection requests want to know how large of a PV system their feeders can handle without issue. This research seeks to find how much larger PV these feeders can handle with local Volt/Var control.

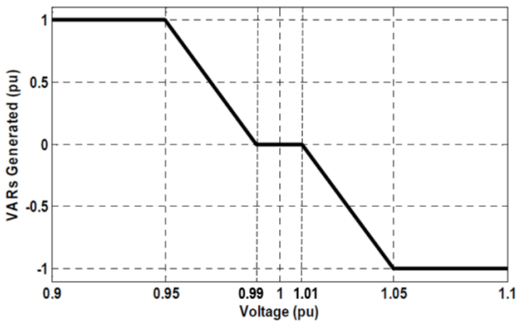
Objectives:

- Quantify increase in allowable PV with and without Volt/Var control in five real-world feeder models
- Investigate the trade-off between a costlier oversized inverter and larger allowed PV installation size

Analysis Methodology

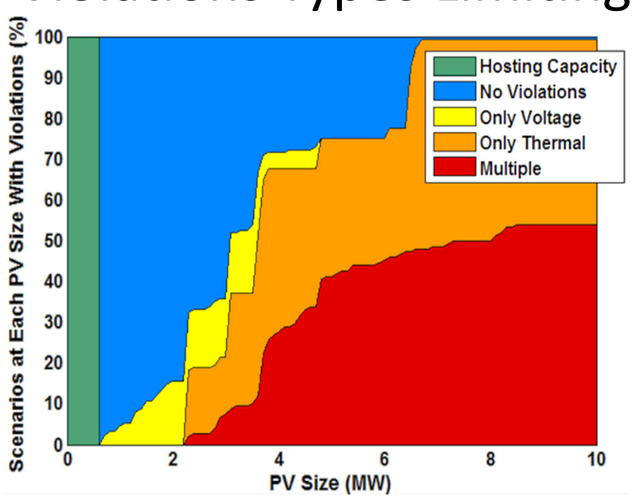
For each feeder, a PV system is tested on each 3-phase, medium-voltage bus. The size of the system is increased and any voltage deviations outside ANSI limits or thermal violations over line ratings are recorded. All possible worst-case scenarios are examined.

Then, Volt/Var control is implemented on the PV inverter and the tests are run again. The control uses the Volt/Var curve shown below. Since peak PV output is assumed, the inverter is initially over-rated by 20%. The improvement in the size of PV able to be installed at buses previously limited by voltage violations is quantified.

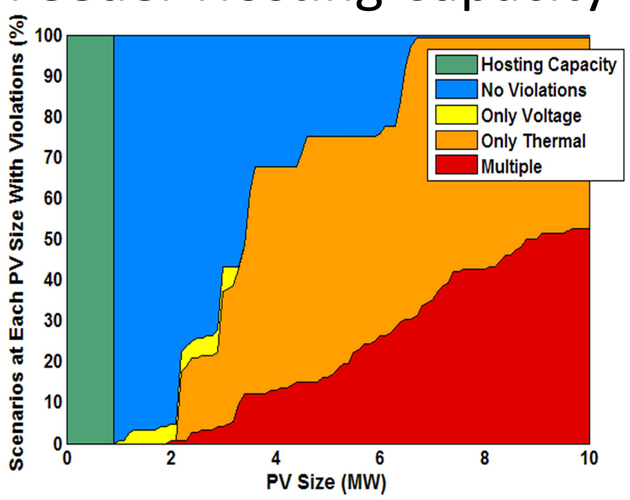


Volt/Var Control Curve

Violations Types Limiting Feeder Hosting Capacity

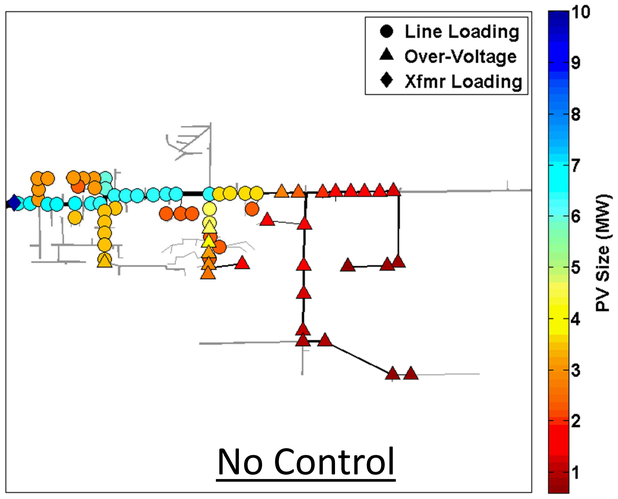


No Control

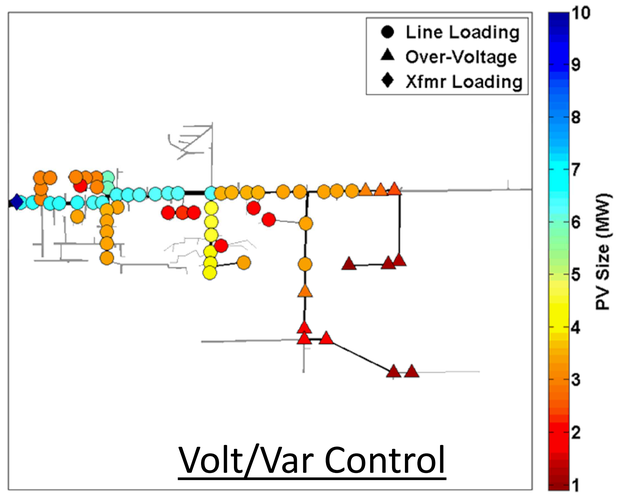


Volt/Var Control

First Violation Seen per Interconnection Location



No Control



Volt/Var Control

Summary of Improvements in Five Test Feeders

Feeder #	Voltage (kV)	Peak Load (MVA)	Base HC (kVA)	HCI (kVA)	HCI (%)
1	12.47	1.7	600	300	50
2	12.47	7.1	500	600	120
3	12.47	6.2	1000	600	60
4	12.47	1.17	300	300	100
5	12.47	0.93	600	800	133.3
6	12.47	3.98	1400	600	42.9
Avg.	**12.47**	**3.51**	**733**	**533**	**84.4**

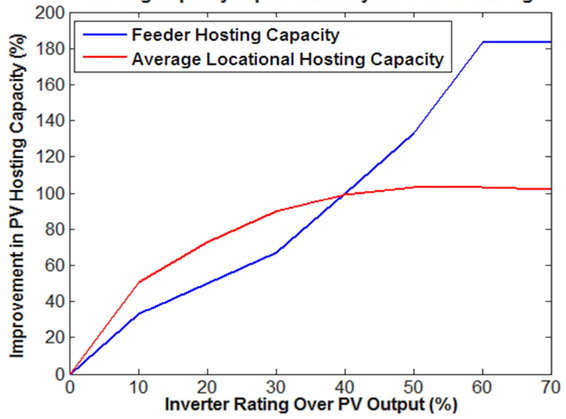
Hosting Capacity Improvement (HCI)

Feeder #	Avg. Base LHC (kVA)	Avg. LHCI (kVA)	Avg. LHCI (%)	Max LHCI (kVA)	Max LHCI (%)
1	1748	1094	72.7	1900	135.7
2	6306	1780	45.3	3500	212.5
3	2176	571	31.5	2200	115.8
4	1015	1584	160.7	4500	500.0
5	3000	1908	109.4	4600	418.2
6	5007	631	32.3	1000	71.4
Avg.	**3209**	**1261**	**75.3**	**2950**	**242.3**

Locational Hosting Capacity Improvement (LHCI)

Impact of Inverter Rating

The size of the inverter relative to the maximum PV output determines how many vars are available to mitigate voltage violations. But, there comes a point where Volt/Var control cannot further correct PV-induced problems regardless of inverter size. The plot below shows the diminishing returns in overall feeder hosting capacity and average locational hosting capacity for increased inverter size.



Conclusions

Overall, the implementation of Volt/Var control on the PV inverter increases the size of PV that can be hosted anywhere in a feeder where PV size is limited by voltage violations. At some particular installation locations, the allowed PV size is increased by several times. Ultimately, these improvements are limited by the vars available to the PV inverter and the thermal limits of the feeder lines and equipment.

Requiring an over-sized inverter would ensure larger PV systems do not cause voltage violations. However, there are limited improvements to be gained, so only slightly over-sized inverters are practical.

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