Quasi-Static Time-Series Photovoltaic Hosting Capacity Methodology and Metrics

Akshay Kumar Jain, Kelsey Horowitz, Fei Ding, Nicolas Gensollen, Barry Mather, Bryan Palmintier

Snapshot PV Hosting Capacity

- “Snapshot” or “static” hosting capacity study is the method for determining the amount of PV the feeder can host without adverse grid impacts that might require changes or upgrades to the distribution system.
- The analysis is historically conducted at worst-case time points.
- The first parameter violated determines the hosting capacity and is often the upper voltage limit as per ANSI standard C84.1-2016, Range A .
- However, this ANSI standard also allows infrequent violations of the voltage limit as long as they are corrected.
- Operation of voltage control devices which can regulate voltages cannot be captured faithfully using this study methodology.
- Similarly, behavior of some advanced control algorithms which could be used to expand the hosting capacity can not be captured.

QSTS PV Hosting Capacity Challenges

- To get the most accurate PV hosting capacity results, the QSTS simulations should be conducted at a time resolution that can adequately capture the time delays of the voltage control devices.
- Computational and data challenges have limited the efforts to use long (e.g. hourly) timesteps.
- Longer time steps may not accurately capture cloud-induced generation variability or corresponding regulator and capacitor control responses.
- A new set of metrics will have to be defined that conform more closely with the established ANSI standards and can allow infrequent parameter violations.

QSTS PV Hosting Capacity Metrics

The objective of this paper was to explore potential metrics for determining QSTS PV hosting capacity, however the threshold for these metrics will be determined by the comfort level of utilities in allowing voltage deviations or thermal violations on their system for small periods of time

Loading Metrics*:*

- *Moving n-hour average loading:* A *n*-hour moving average of each transformer’s and line’s loading as a percentage of its rated capacity is calculated.
- *Instantaneous over-loading:* The instantaneous loading of the transformers and lines should not exceed pre-determined threshold values.

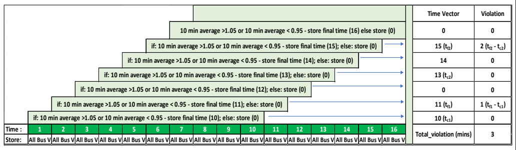

Figure. Moving n-minute average voltage metric

Voltage Metrics*:*

- *Moving n-minute average voltage:* Moving average voltage of each bus for a *n*-minute duration is determined and any violations outside ANSI Range A are stored to determine the total time outside limits.
- *Instantaneous maximum voltages:* The instantaneous voltages at any time point should not be outside ANSI Range B or, if Range B is exceeded in the base case, then the number of these instantaneous violations with PV should never be more than those in the base no PV case.

Control Equipment Operations*:*

High PV penetration can lead to increased state changes of the voltage control equipment. These increased mechanical movements can reduce their life span. In this paper, we only tracked the number of control device operations and did not use this as a limiting factor.

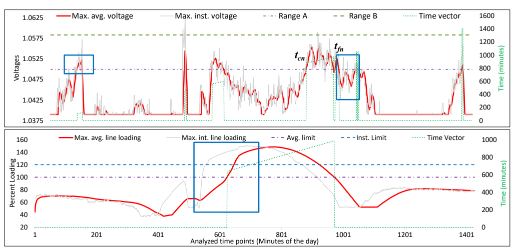

Figure a (top) Maximum instantaneous and average voltages, and violations captured in a time vector. Figure b (bottom) Maximum instantaneous and average percentage line loading, and violations captured in a time vector

Test Feeder

- The snapshot and QSTS PV Hosting Capacity studies were compared on a feeder model developed using real feeder data in the United States.
- The detailed feeder model consists of the primary network and added secondaries as well.
- Out of the 525,600 time points analyzed about 0.73% had ANSI Range A over voltage violations but only 0.0057% (~30) time points had the more serious Range B over-voltage violations.
- These can be attributed to sudden load drops which caused the quickly regulated voltage spikes.

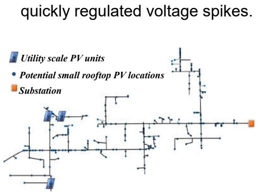

Figure: Test Feeder topology and PV unit locations

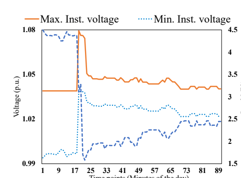

Figure. Voltage peak because of sudden load drop, quickly regulated

Snapshot vs QSTS PV Hosting Capacity

- Monte Carlo simulation was used to generate PV deployment scenarios covering 5% to 100% of the customers on the feeder, in a 5% step size.
- The study was repeated 10 times for each of these percentage penetration levels.
- 200 scenarios were analyzed at the peak and minimum loading time points.
- The PV hosting capacity limit was reached for deployment 8 at 65 percent PV penetration.

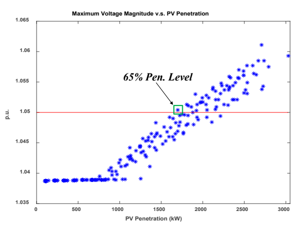

Figure. Maximum instantaneous voltage observed in each deployment and PV penetration scenario of the snapshot PV hosting capacity study.

QSTS Results:

- All the penetration levels for deployment 8 were analyzed using a year-long QSTS PV hosting capacity study with 1-minute resolution load and PV profiles.
- Our QSTS results suggest that snapshot hosting capacity may be conservative in some scenarios compared to violations allowable under the ANSI standard.
- In this case, our QSTS/dynamic hosting capacity was 35% higher than the snapshot analysis.

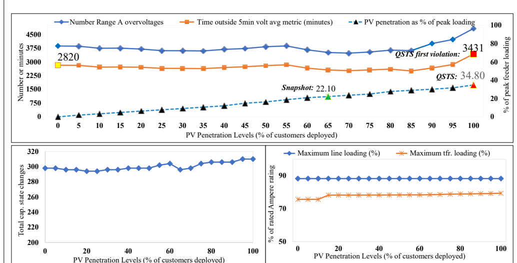

Figure. QSTS Results: (Top (a)) Number of overvoltage violations and total time for which the 5-minute average voltage was outside ANSI Range A; (Bottom left (b)) Sum of state changes of all capacitor banks; (Bottom right (c)) Maximum line and transformer loading observed at each PV penetration

References

- IEEE P1547.7 D110, “Draft Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection,” 2013.
- M.J. Reno, J. Deboever, B. Mather, “Motivation and requirements for quasi-static time series (QSTS) for distribution system analysis,” IEEE PES-GM, 2017.
- EPRI Distributed PV Monitoring and Feeder Analysis. Available at: http://dpv.epri.com/hosting_capacity_method.html, accessed July 2018.
- D. Zhu, A.K. Jain, R. Broadwater, F. Bruna, “Feeder Voltage Profile Design for Energy Conservation and PV Hosting Capacity Enhancement,” Electric Power Systems Research, vol. 164, 2018.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

Innovative Smart Grid Technologies (ISGT 2019)
Washington, D.C
February 17-20, 2019
NREL/PO-5D00-73304