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Experimental Demonstration of Sandia PV Smoothing Algorithm Using Coordinated Battery and Traditional Generation System

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In 2012, Sandia National Laboratories created a flexible, PV power smoothing algorithm incorporating multiple distributed resources (e.g., batteries, fuel cells, natural gas engine-generator). Simulations of this algorithm showed a significant reduction in battery state of charge range and power conditioning system size if the battery was paired with a traditional power generator (gas genset). To verify these benefits, the output power from the 500 kW PV plant at the PNM Prosperity Site was smoothed with the Prosperity 500 kW, 330 kWh battery in conjunction with the Mesa del Sol (MdS) gas engine-generator at the Aperture Center.

Research Objective and Numerical and Experimental Analysis

- **Objective: Reduce the cost of battery-based PV-smoothing systems by novel control schemes which allow a battery size reduction.**
- **Hypothesis: Smoothing PV power variability with a coordinated battery and inexpensive gas genset allows the required battery capacity and cost to be reduced.**
- **Approach: An innovative control scheme was developed to reduce PV-smoothing costs by reducing the required battery capacity by employing a coordinated natural gas genset. Numerical simulations indicate a reduction in the state of charge (SOC) range when the battery is coordinated with a gas genset. The distributed control demonstration is underway involving a utility-scale PV/storage system at the PNM Prosperity site and a building-scale microgrid at Mesa del Sol.**

A multi-year effort to demonstrate a distributed, coordinated PV-smoothing controller.

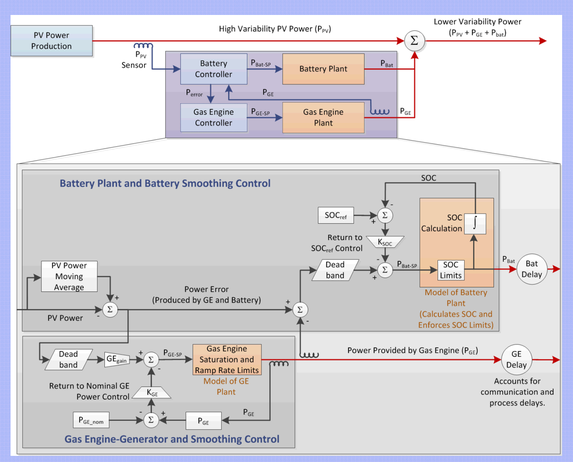
FY12: Establish Battery PV-Smoothing Control

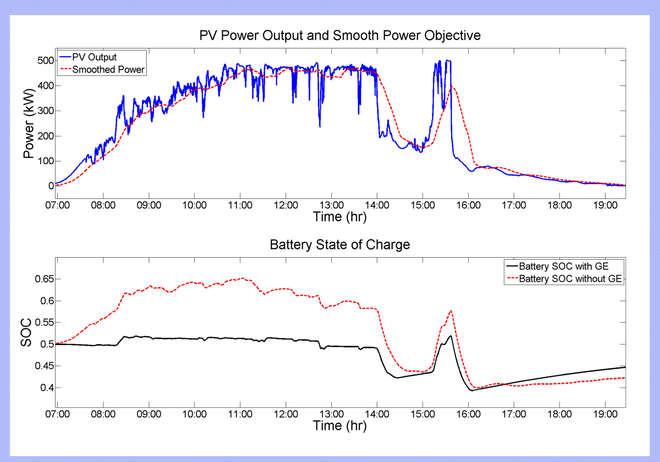
Sandia created and implemented and algorithm to smooth the Public Service Company of New Mexico (PNM) 500 kW_{AC} Prosperity PV site using a 500 kW, 330 kWh valve-regulated lead-acid (VRLA) smoothing battery. The algorithm uses the moving average or low pass filter of PV output power to determine the target battery output power.

A. Ellis and D. Schoenwald, PV Output Smoothing with Energy Storage, Sandia Technical Report, SAND2012-1772, March 2012.

FY13: Simulate and Optimize Control with Multiple Distributed Energy Resources

The Sandia smoothing algorithm was modified and optimized to include control signals for a natural gas-engine genset and a fuel cell located at the aperture center at Mesa del Sol. This modification reduced the operating state of charge (SOC) range of the battery.





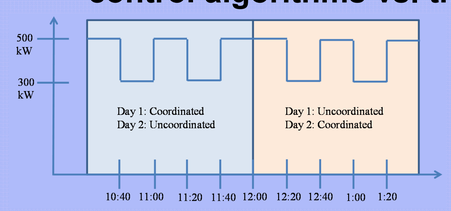
J. Johnson, A. Ellis, A. Denda, K. Morino, T. Shinji, T. Ogata, and M. Tadokoro, PV Output Smoothing using a Battery and Natural Gas Engine-Generator, IEEE PVSC, Tampa Bay, FL, 16-21 June, 2013.

FY14: Demonstration of Control

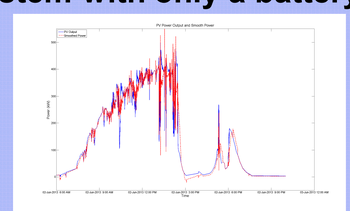
To verify the simulation results, the coordinated, distributed control system will be tested by (1) creating a step change in the PV output by disconnecting a portion of the PV system and (2) real time coordinated control + artificially replaying the PV output signal into the battery energy management system to determine uncoordinated behavior.

The coordinated control tests must overcome the physical separation of the PV, battery, and gas engine.

Test methods to compare experimental coordinated and uncoordinated control algorithms vs. the baseline system with only a battery



Test 1: Creating highly-repeatable, artificial PV variability by switching off a portion of the PV system during a day without clouds.



Test 2: Record coordinated smoothing algorithm during a day with variable irradiance. Compare uncoordinated response by replaying PV output power into the PNM Battery Energy Storage System.

Preliminary Results

Sandia, PNM, and Japanese partners performed three days of configuration work and baseline testing 7-9 Aug, 2013.

- **This was the first time a smart grid distributed controller of this kind has been implemented with corporate and utility partners!**
- **Great learning experience for all members of the collaboration and many major technical challenges were resolved surrounding communication and controller settings. Final tests are being run on 21-23 Oct, 2013.**
- **August testing verified communication latency will not influence results of experiments and the PI data dropouts which cause temporary control errors do not cause significant smoothing over/undershoot.**

Impact

- **The Sandia coordinated, distributed, PV-smoothing controller reduces the variability of renewable energy resources for less capital cost by using smaller batteries and power conditioning systems. This technology allows higher penetrations of PV and wind on electricity grids, especially constrained microgrids.**
- **This program has strong and continued support from utility and industry partners, allowing for full-scale demonstrations of novel microgrid operations paradigms.**
- **Furthermore, this real-time controller can be implemented for other battery-based services, for example, reducing the Area Control Error (ACE) for utility-scale power systems.**

Research completed in close partnership with PNM, MdS, UNM, and NEDO partners: Shimizu, Tokyo Gas, and Toshiba.

National Nuclear Security Administration

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