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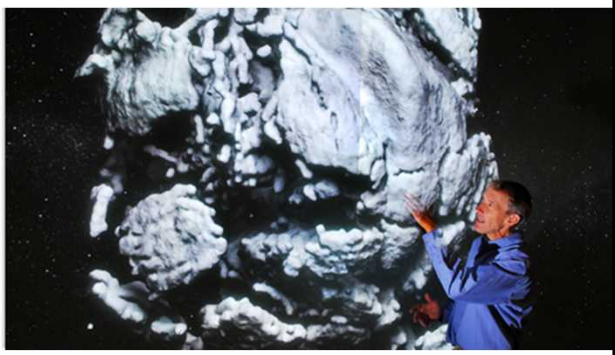

DER Controls for PV Smoothing and Grid Support Services

U.S.–Japan Collaborative Smart Grid Project Workshop, 27 Oct 2015

Jay Johnson

Photovoltaic and Distributed Systems Integration, Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Outline

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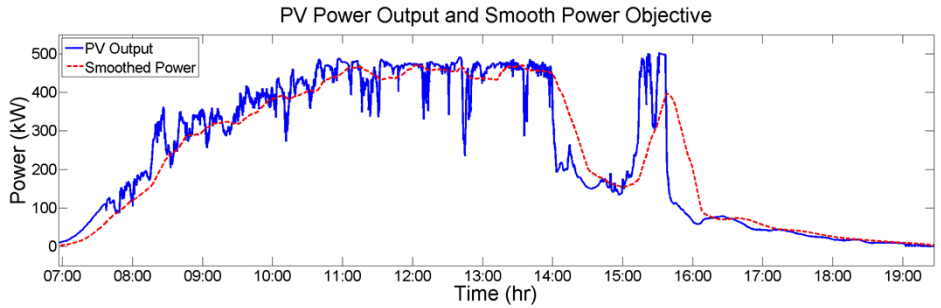
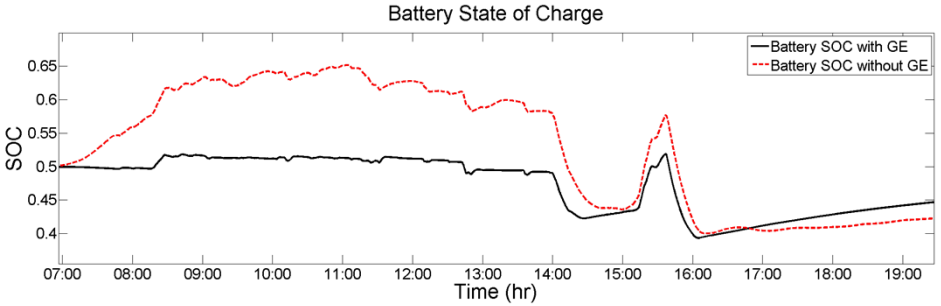
- Previous Research
  - Research Objective
  - Coordinated and Uncoordinated Control Systems
  - Results from Demonstration
- Proposed Future Research
  - Virtual Power Plant (VPP) concept
  - Co-optimization of ancillary services
  - Control methods
  - Proposed demonstration at MdS and Prosperity
- Conclusions

Research Objective

- Reduce battery operation in PV-smoothing systems by novel control schemes.
- Smoothing PV power with a coordinated battery and gas genset reduces the required battery capacity and increases battery life.





Simulations demonstrate a reduction in battery operation (SOC range) when the battery is paired with a gas engine-generator (GE).

Research Partners: PNM, NEDO, TOKYO GAS, SHIMZ, TOSHIBA, UNM, Mesa del Sol, Sandia National Laboratories

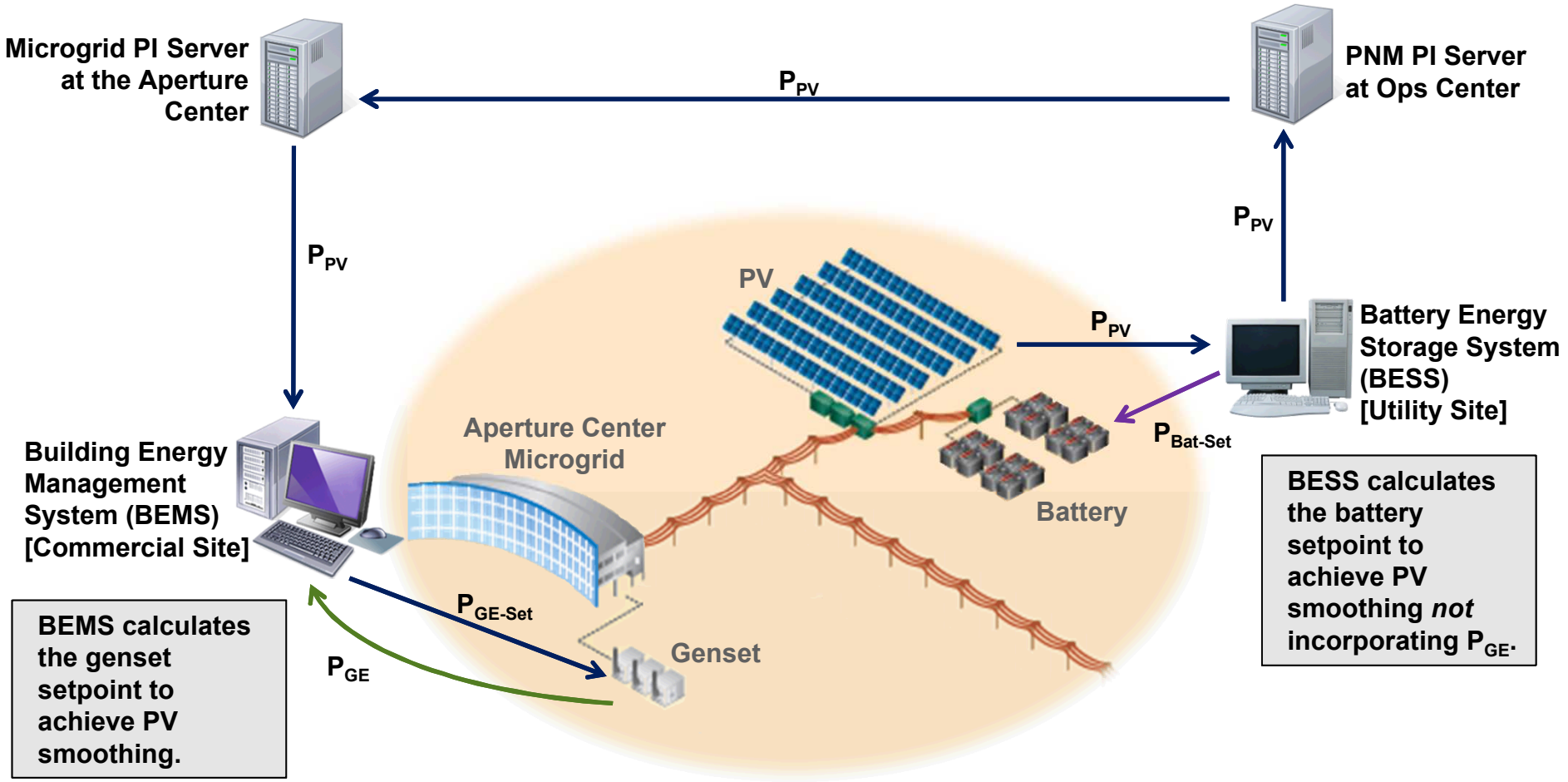
Special Thanks: Abraham Ellis[1], Atsushi Denda[2], Kimio Morino[2], Jon Hawkins[3], Brian Arellano[3], Takao Ogata[4], Takao Shinji[4], and Masayuki Tadokoro[4]

[1]Sandia National Laboratories
[2]Shimizu Corporation
[3]Public Service Company of New Mexico (PNM)
[4]Tokyo Gas Co., Ltd.

Acknowledgment of support to Dr. Imre Gyuk, Electricity Storage Program Manager, DOE Office of Electricity

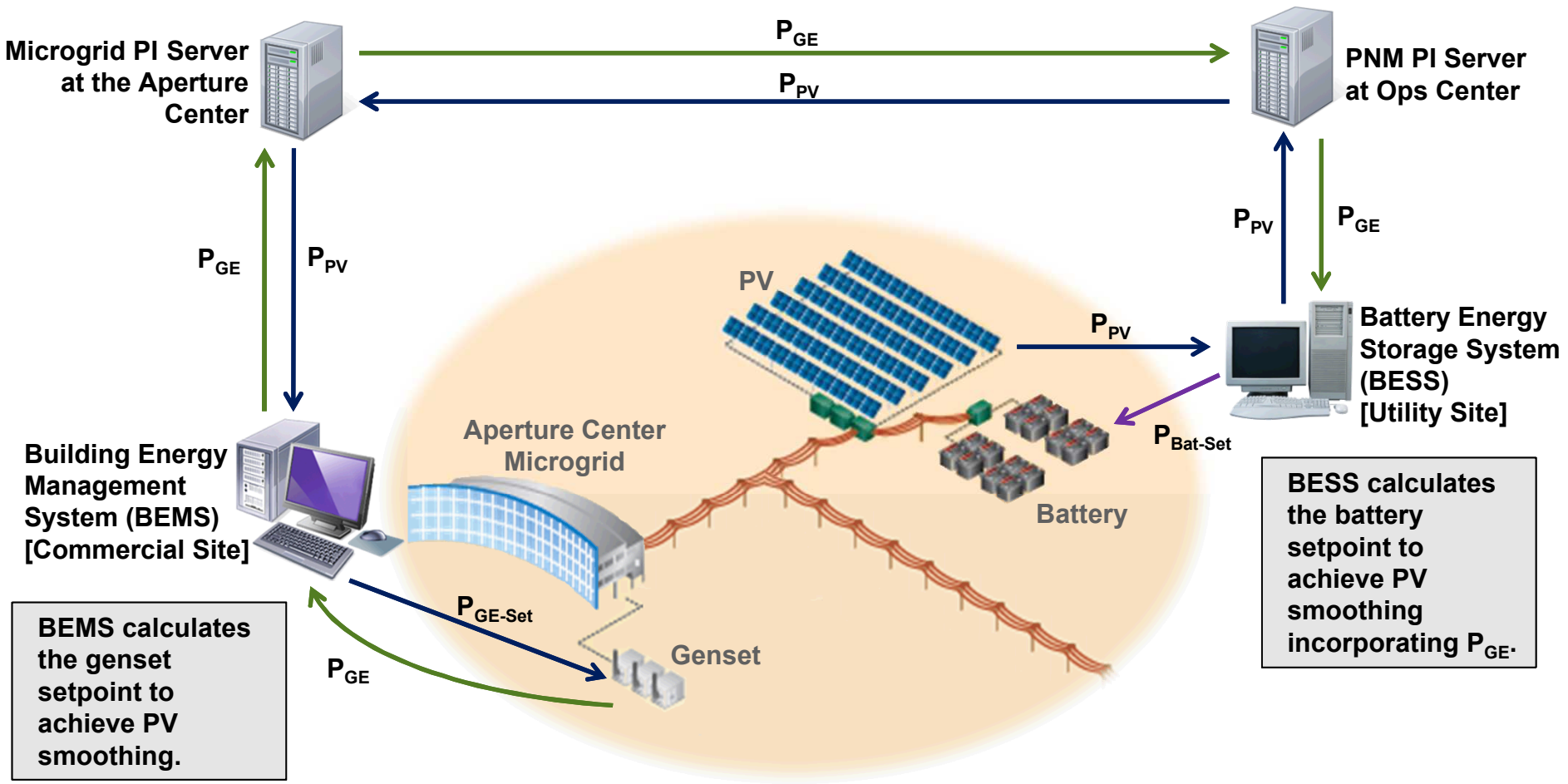

Albuquerque
I-25
Albuquerque Airport
Kirtland Air Force Base
I-25
~2 km
Mesa del Sol
PNM Prosperity Project
- 500 kW PV
- 500 kW, 500 kWh Smoothing Battery
NEDO Mesa del Sol Aperture Center
- 240 kW Natural Gas Engine-Generator

Uncoordinated, Distributed PV Smoothing



J. Johnson, K. Morino, A. Denda, J. Hawkins, B. Arellano, T. Ogata, T. Shinji, M. Tadokoro, and A. Ellis, "Experimental Comparison of PV-Smoothing Controllers using Distributed Generators" Sandia Technical Report SAND2014-1546, Feb 2014.

Coordinated, Distributed PV Smoothing



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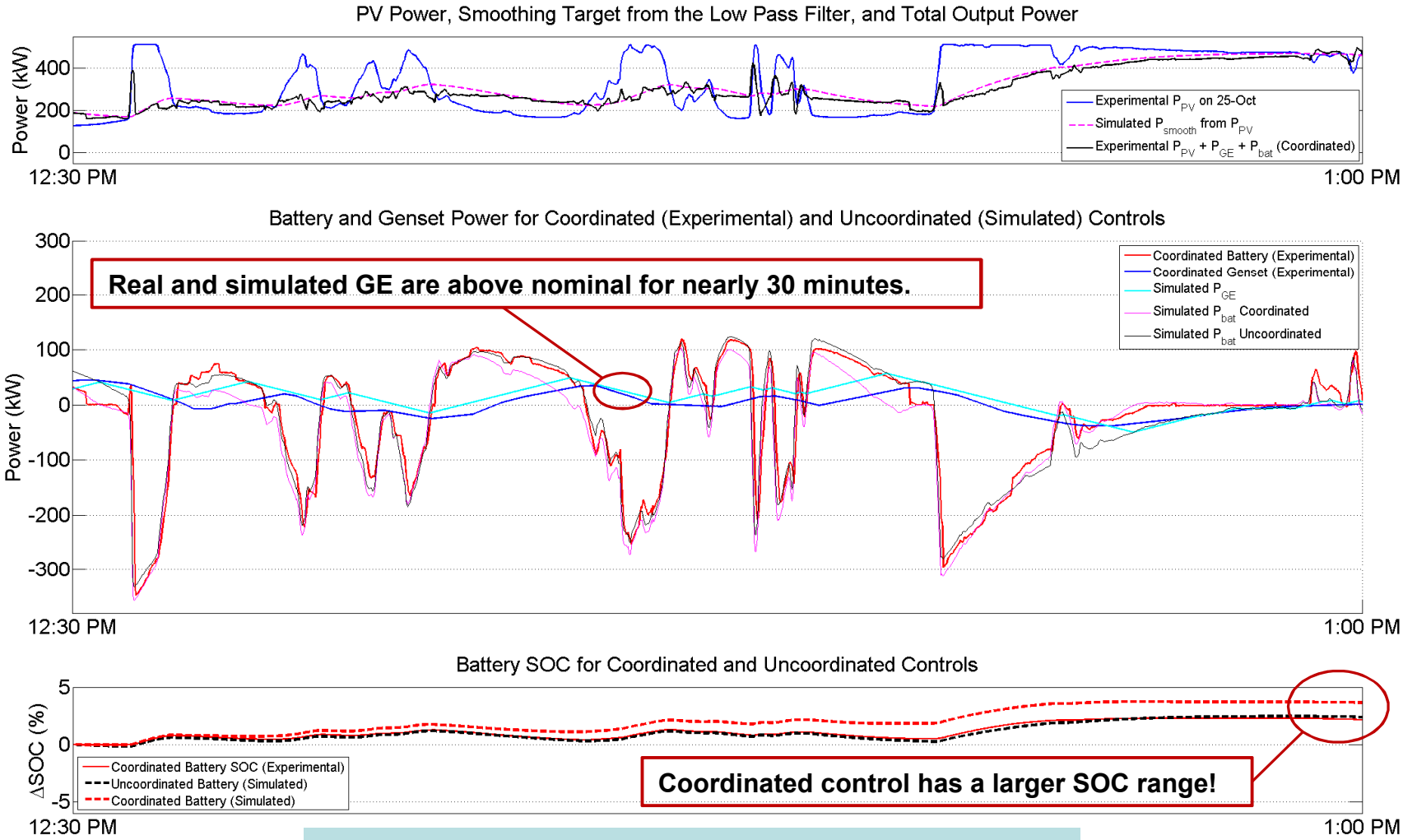
Smoothing PV on a high variability day



Control parameters need to be adjusted to allow genset to return to nominal power or the battery 'fights' the genset.

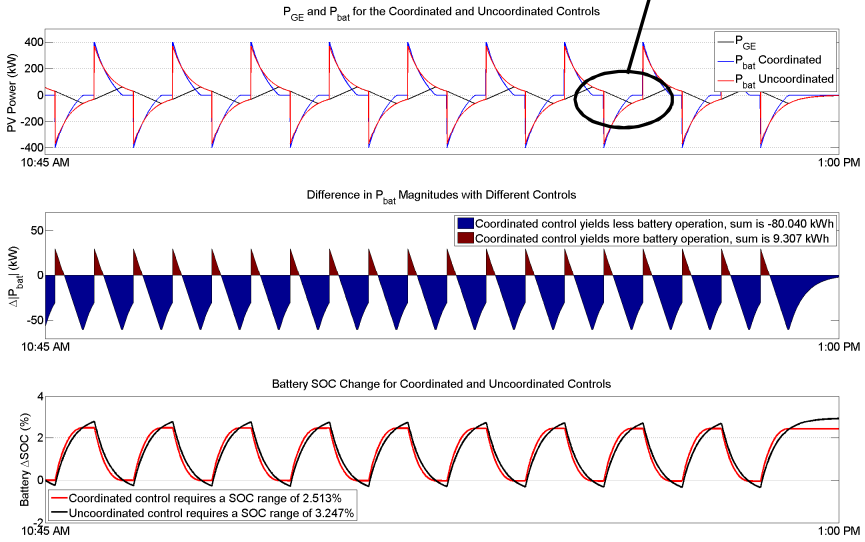
J. Johnson, K. Morino, A. Denda, J. Hawkins, B. Arellano, T. Ogata, T. Shinji, M. Tadokoro, and A. Ellis, "Experimental Comparison of PV-Smoothing Controllers using Distributed Generators" Sandia Technical Report SAND2014-1546, Feb 2014.

Battery SOC range study

- Higher frequency PV power output leads to SOC drift with the coordinated control. Therefore, **in certain cases the coordinated controller does not reduce the SOC range of the battery** as originally expected.

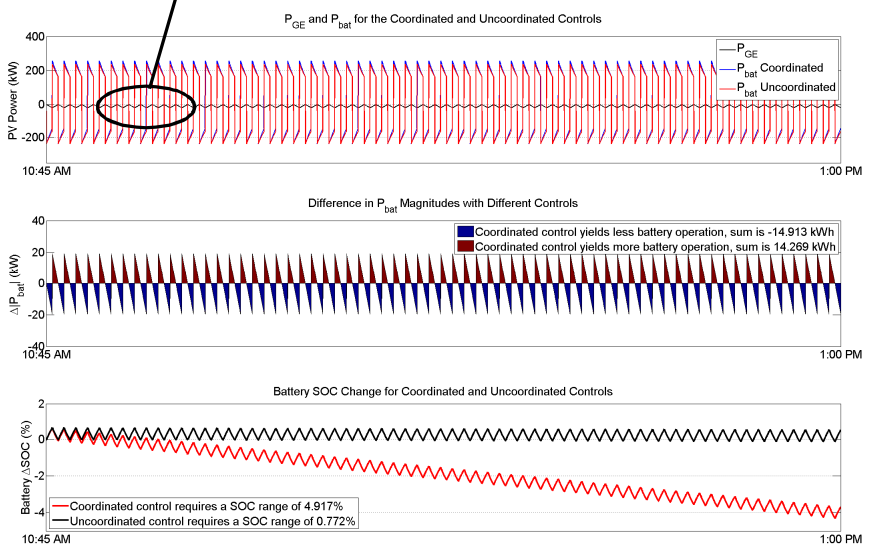
Two simulations with P_{PV} square waves.

GE crosses GE_{nom} each cycle.



Low frequency PV power allows the GE to reset and the coordinated battery SOC range is smaller.

GE stays below GE_{nom} so P_{bat} is always biased positive.



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Future Work: Virtual Power Plants!

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- VPPs are aggregations of DER assets controlled to provide identical (or superior) grid-support services compared to traditional generators.
  - Enables renewable energy, demand response, and energy storage to provide grid services
  - Improves grid reliability by providing additional operating reserves to utilities and ISO/RTOs
  - Removing renewable energy high-penetration barriers
- Goal: Develop a unified platform incorporating resource forecasting, standard communications, optimization, and control/dispatch to provide grid services with DERs.

Virtual power plant with communication network (EPRI)

>

Lake Side natural gas turbine power station in Vineyard, Utah. (Wikipedia Commons)

VPPs will provide a range of grid services

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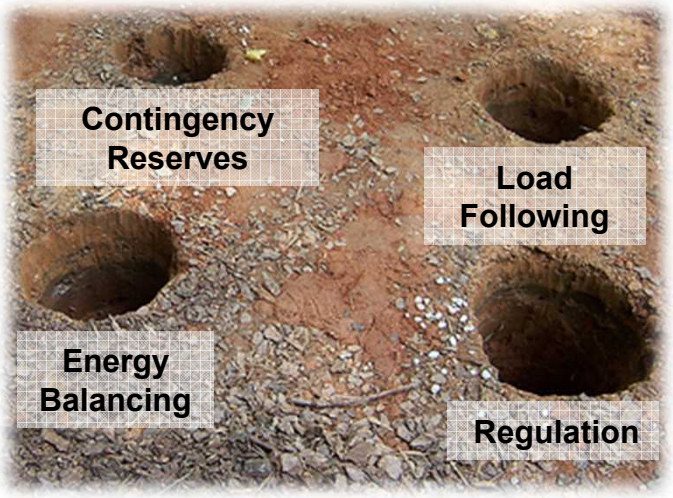
DER resources to fill in operational needs



Multi-domain Optimization
Objective: Minimize Utility Cost

A co-optimization must be completed to determine the service (or services) that the VPP will provide grid operators.

Domains:

- Regulation
- Following Reserve
- Energy Market
- Contingency Reserves*

* Current Research Focus

VPP Participation Updated as Needed

Optimization of DER Setpoints and Unit Commitment

Updates: 1 min | 10 min | 1 hour | As needed

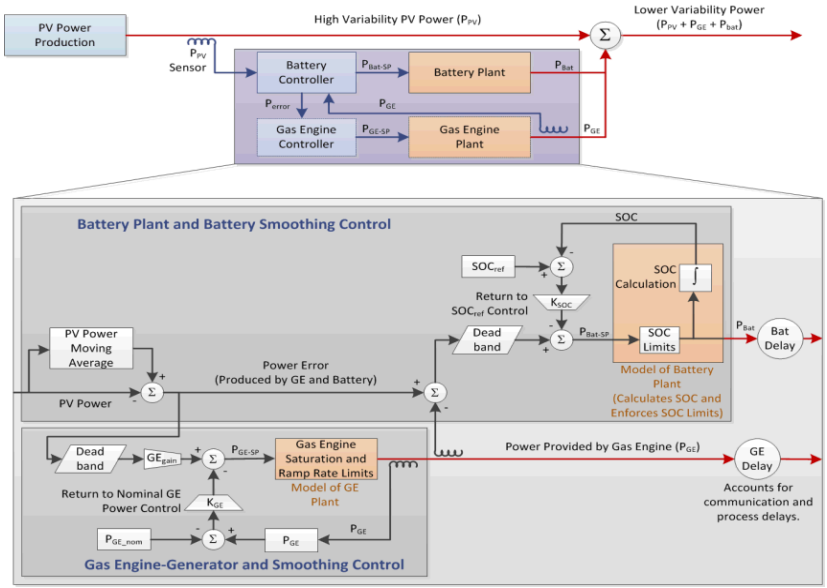
DER Feedback Control

Settling Time: <1 sec | 2 min | 15 min | As required

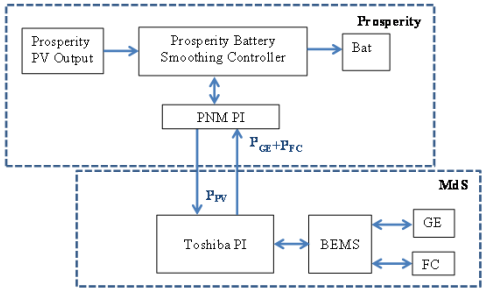
Cascading Control Concept (Past and Future)

Mesa del Sol/Prosperity coordinated control

- PV output smoothing completed with coordinating between Prosperity battery and MdS gas engine-generator
- PI-to-PI communications link between Prosperity and MdS.



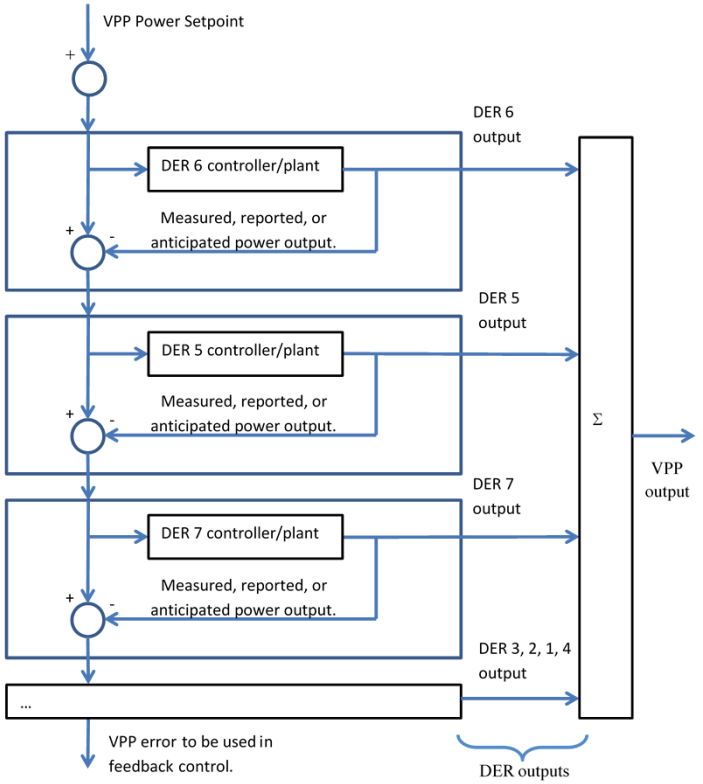
Coordinated Control



PI-to-PI Communications

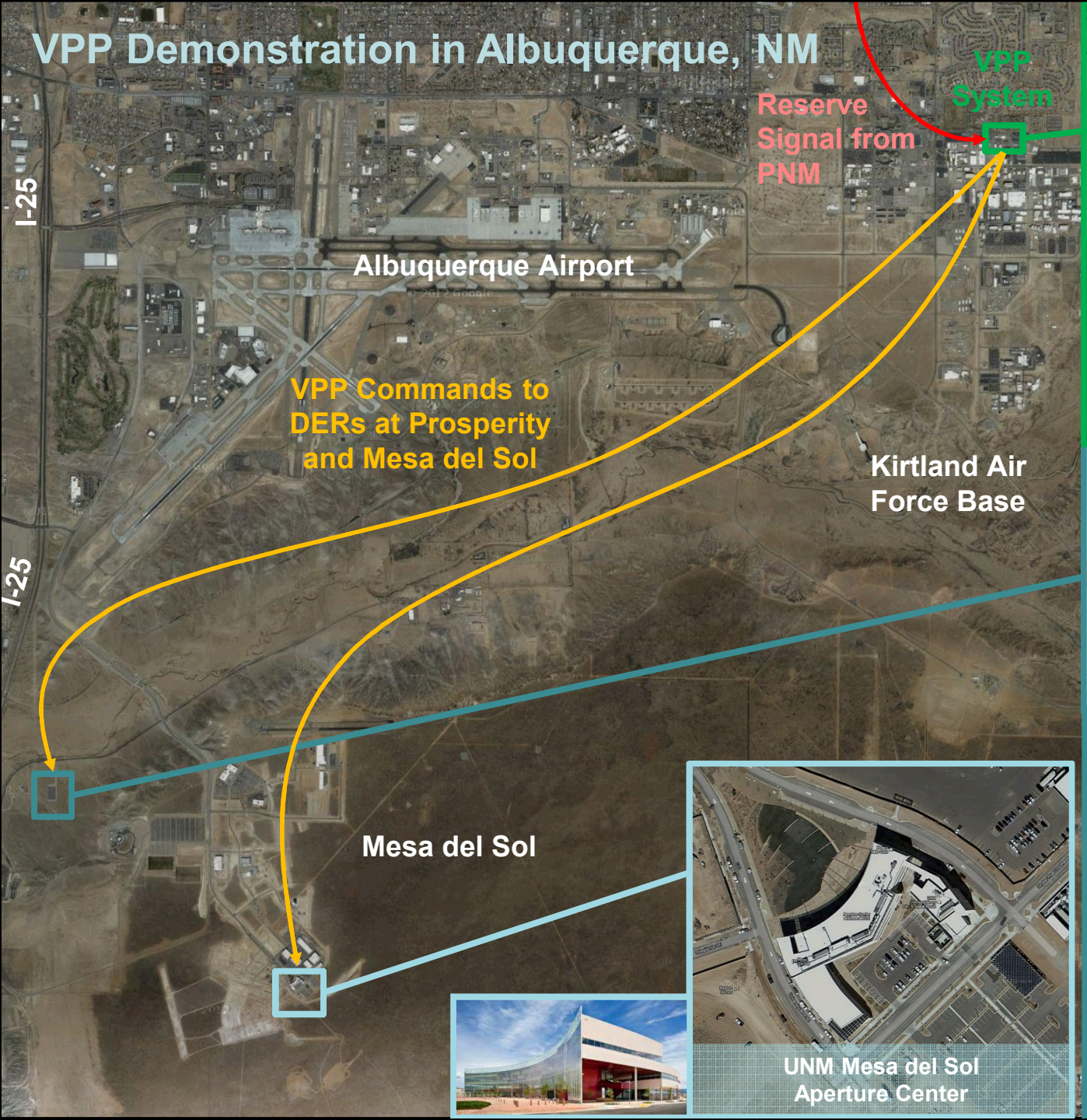
Virtual power plant control

- Use DERs from multiple locations in Albuquerque to meet power targets.
- DERs would be stacked based on response and/or communication speeds.

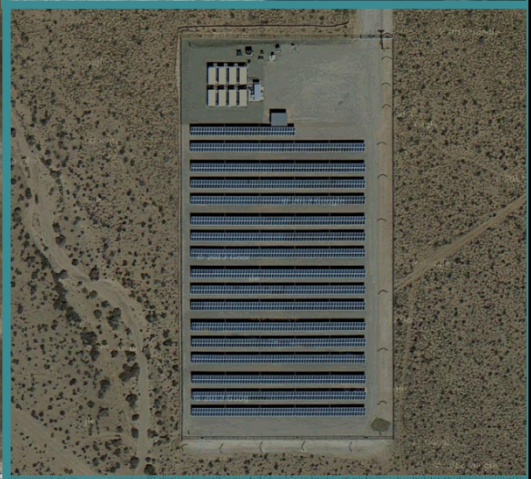


One form of cascading control that could be used in a VPP.

VPP Demonstration in Albuquerque, NM



Sandia's Distributed Energy Technologies Laboratory



PNM Prosperity Project

UNM Mesa del Sol Aperture Center

Conclusions

- The US-Japan team demonstrated a coordinated, distributed controller which reduces the variability of renewable energy resources with less battery operation.
  - Coordinated DER operations can be designed and optimized to meet an objective.

- Sandia is investigating Virtual Power Plants.
  - The control algorithm may be based on the previous work at MdS/Prosperity.
  - The VPP system is currently being designed and installed at Sandia National Labs, but the team hopes to do larger demonstrations with the MdS and Prosperity resources in the future.