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Experimental Comparison of PV-Smoothing Controllers

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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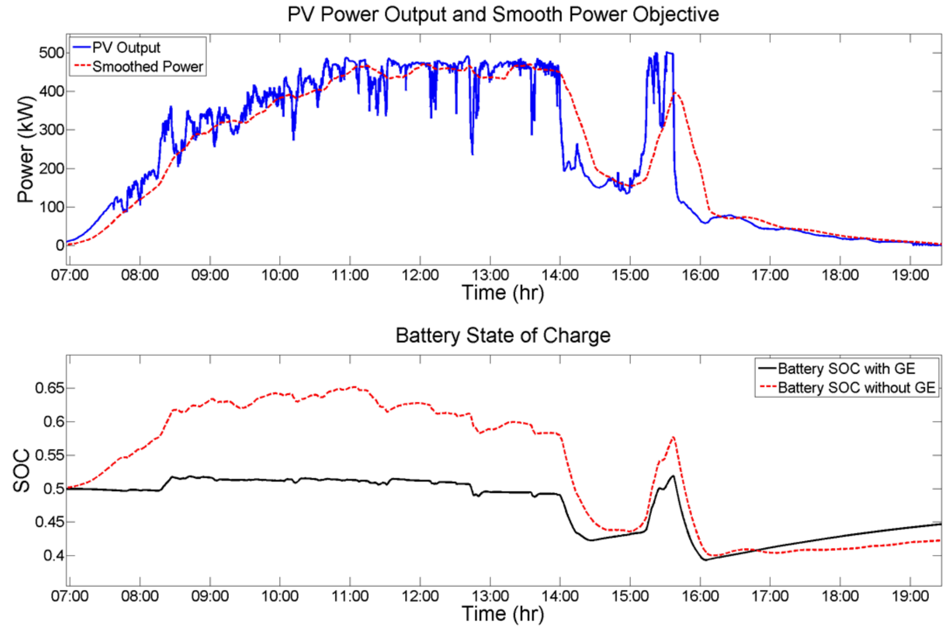
Research Objective

- 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, SHMZ, 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.

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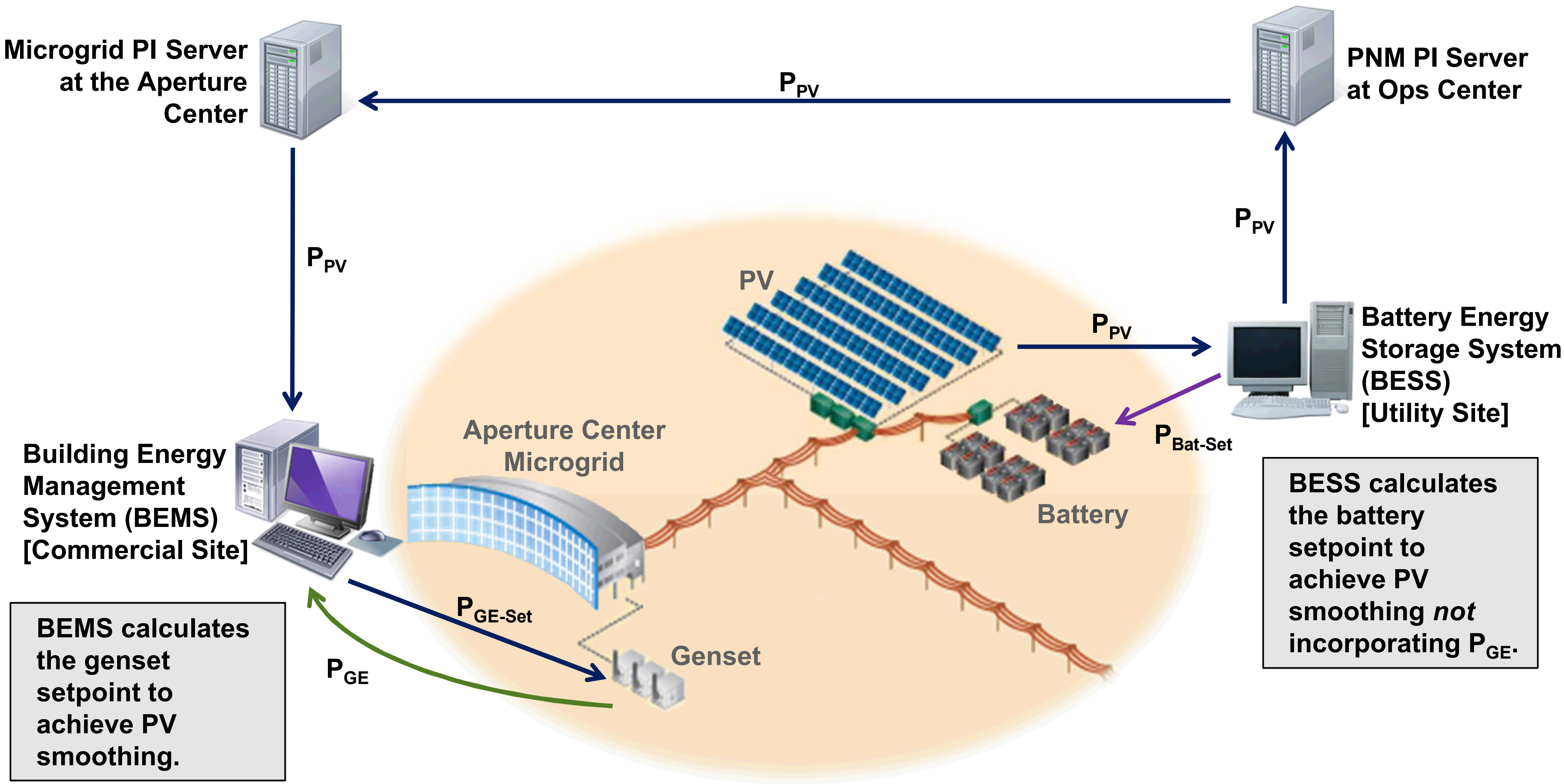
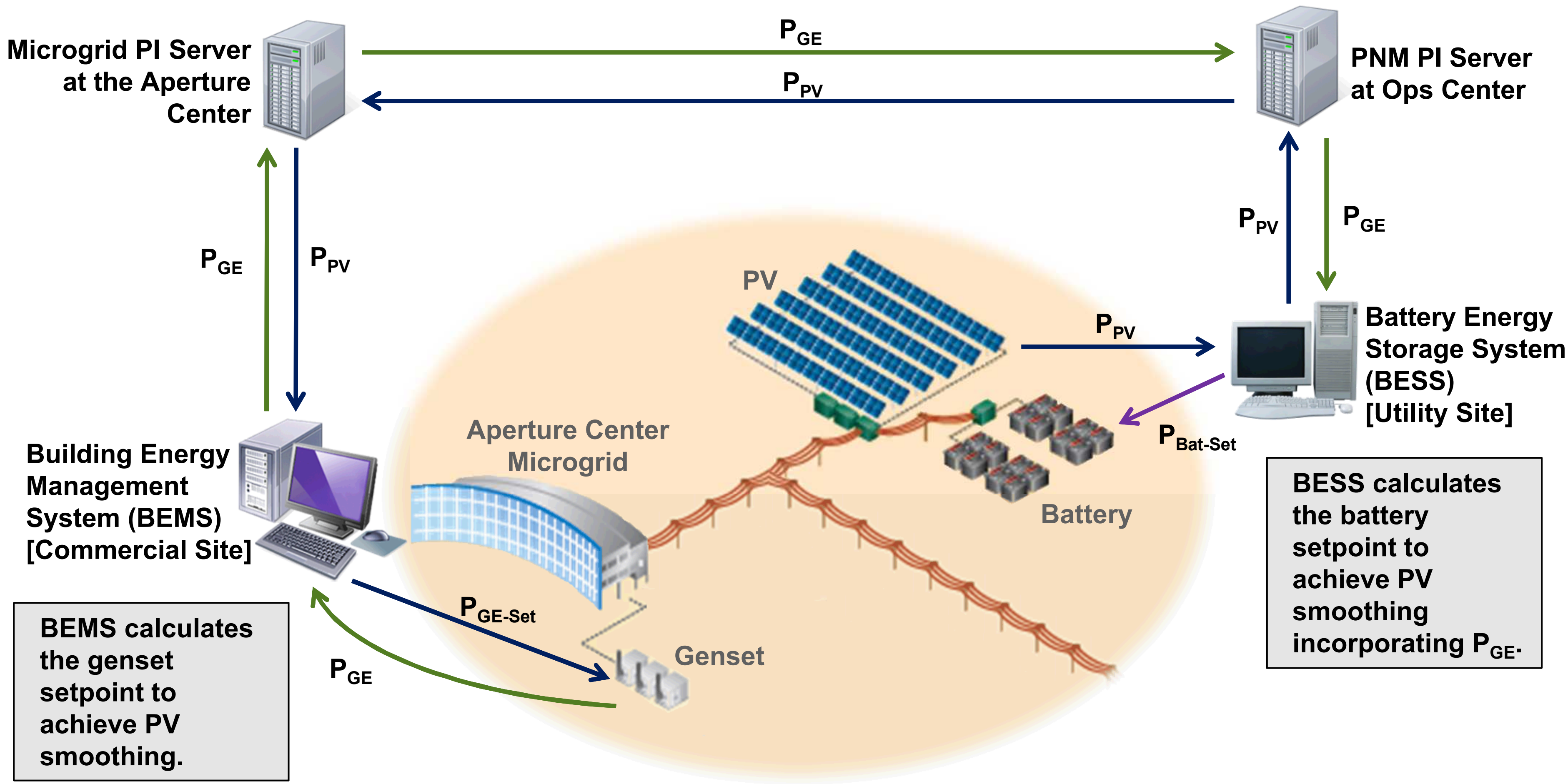
Albuquerque
I-25
Albuquerque Airport
Kirtland Air Force Base
PNM Prosperity Project
- 500 kW PV
- 500 kW, 500 kWh Smoothing Battery
I-25
~2 km
Mesa del Sol
NEDO Mesa del Sol Aperture Center
- 240 kW Natural Gas Engine-Generator

Uncoordinated, Distributed PV Smoothing



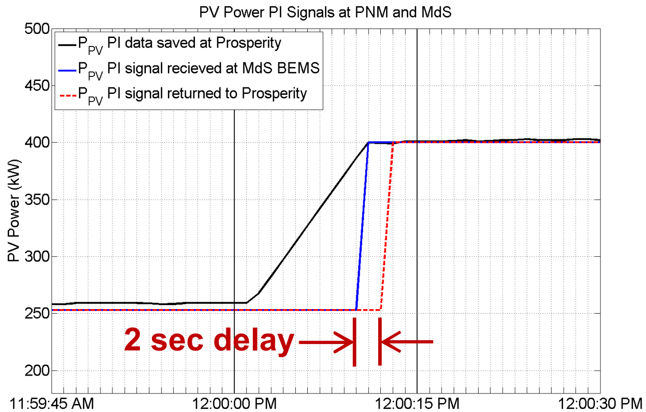
Coordinated, Distributed PV Smoothing



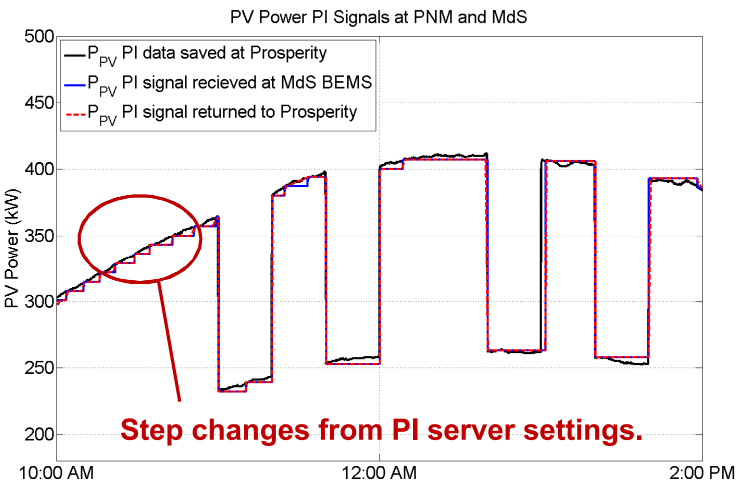
BEMS calculates the genset setpoint to achieve PV smoothing.

BESS calculates the battery setpoint to achieve PV smoothing incorporating P_{GE}.

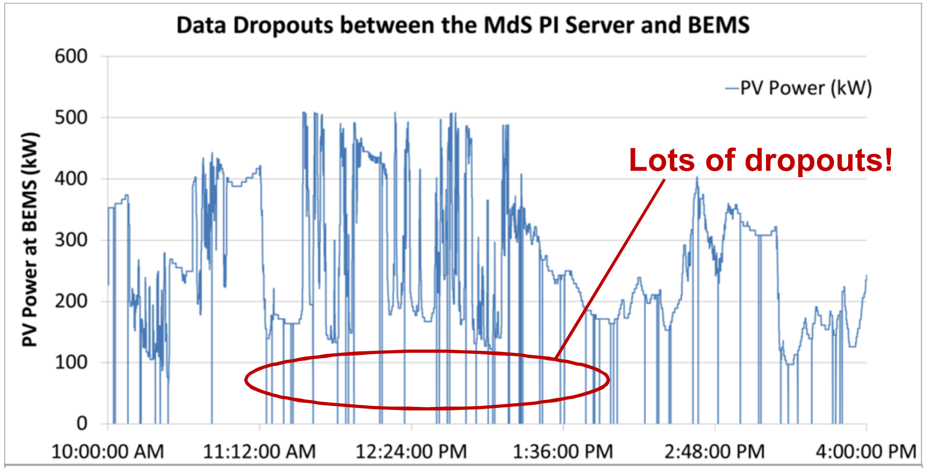
Challenges with the Demonstration

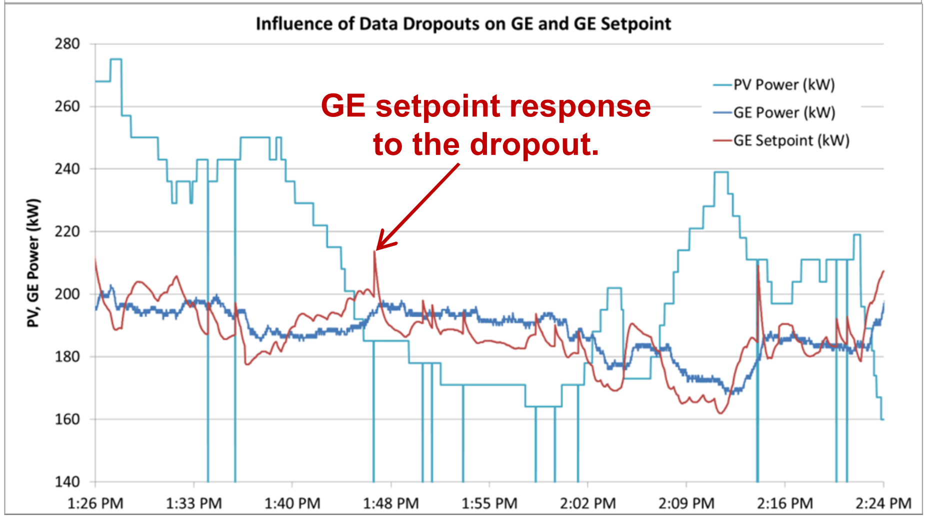


1-2 second communication latency in the PI-PI link.



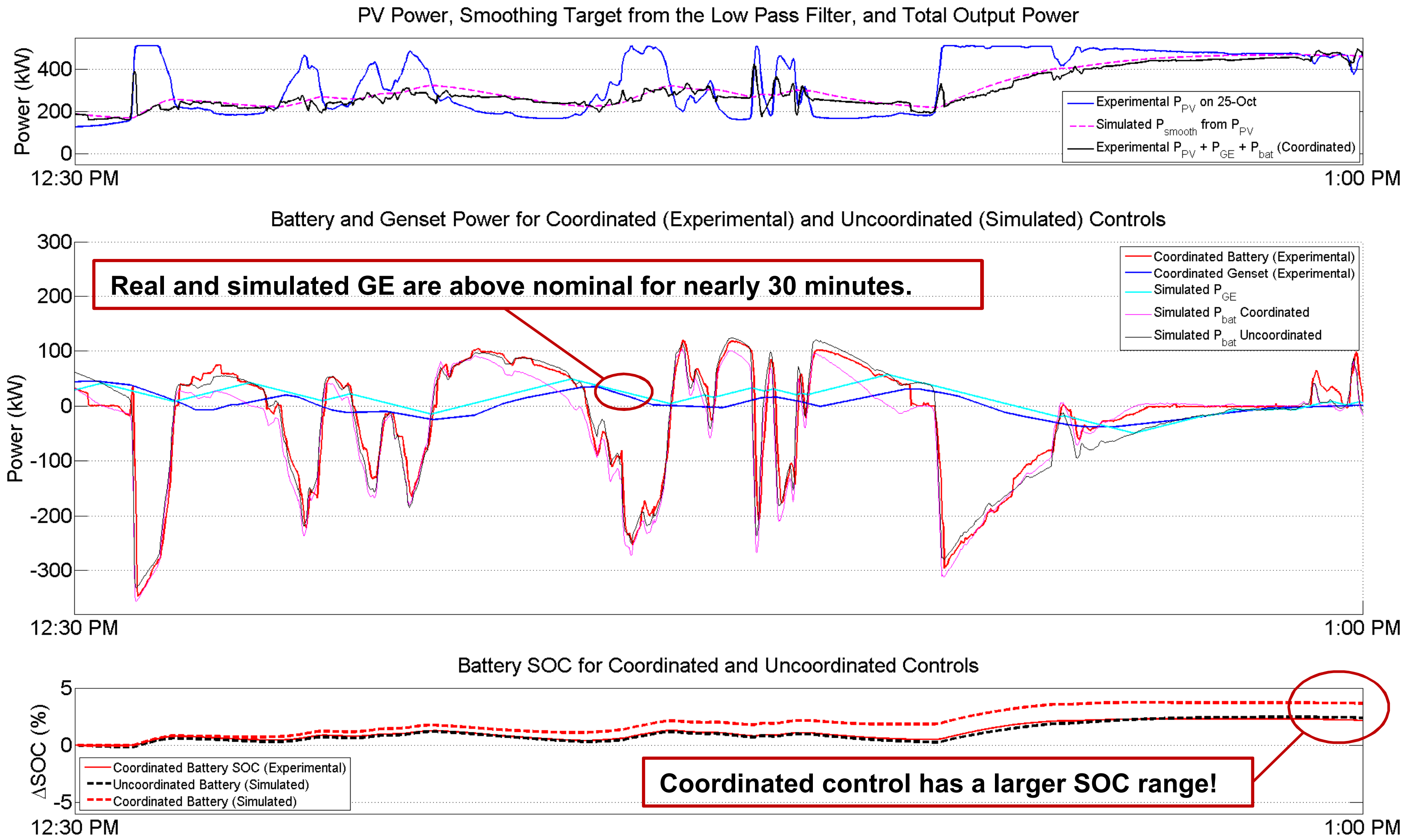
Data compression and exception rules at the MdS PI server caused the step changes in the BEMS P_{PV} profile.





P_{PV} communication errors between the MdS PI server and BEMS. The dropouts occur when P_{PV} = 0.

Smoothing PV on a high variability day

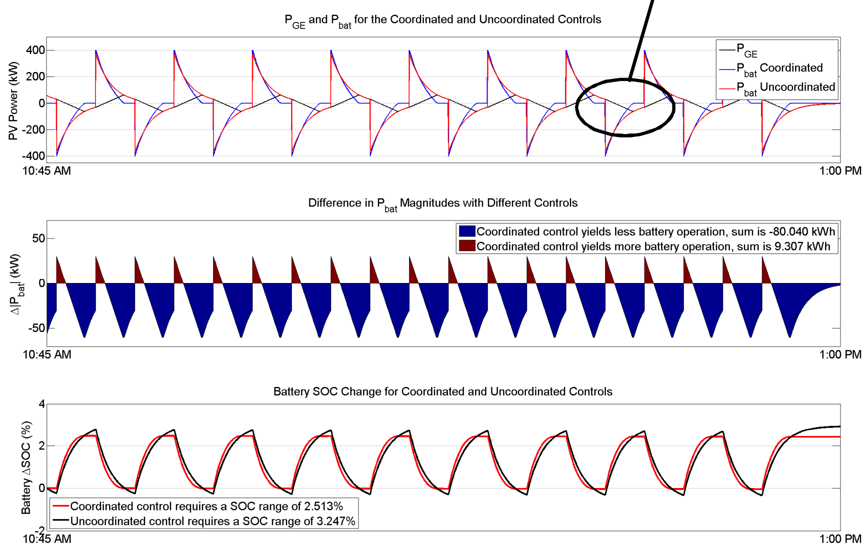


Battery SOC range study

- 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.

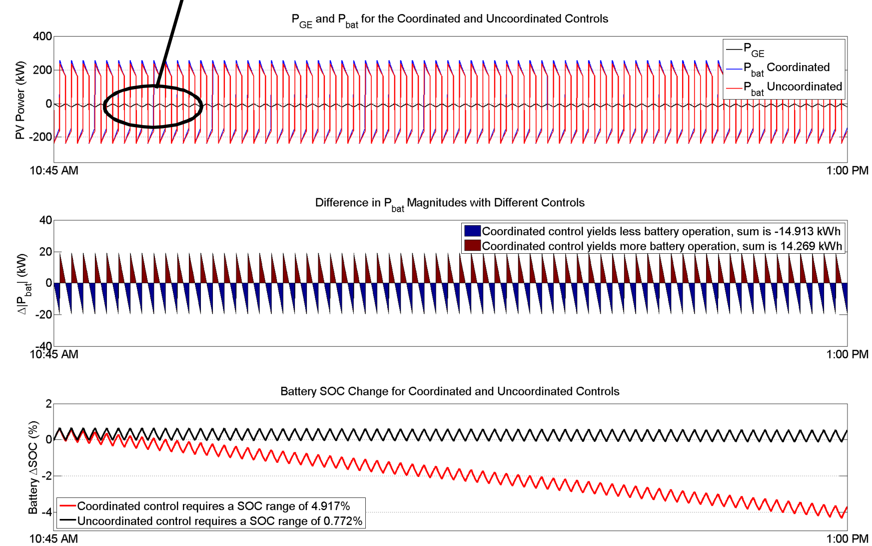
Two simulations with P_{PV} square waves.

GE reaches 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.



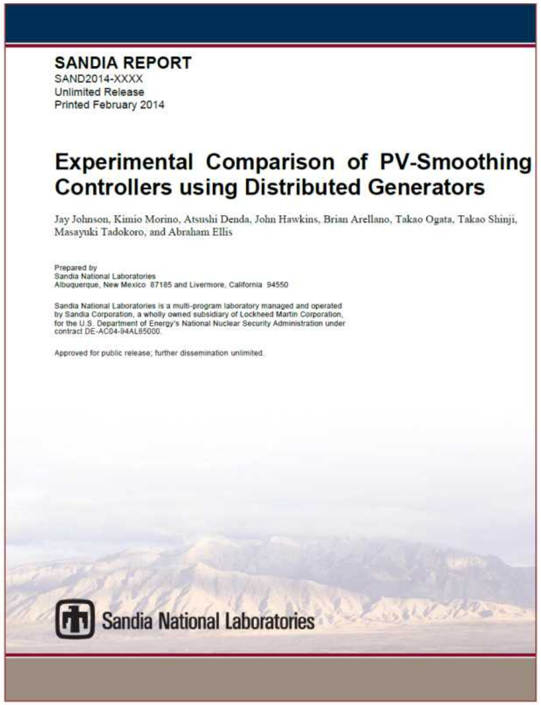
High frequency PV power doesn't allows the GE to reset and the coordinated battery SOC range is larger.

Conclusions, Impact, and Future Work

- The team successfully demonstrated a coordinated, distributed controller which reduces the variability of renewable energy resources with less battery energy throughput.
- In certain high variability situations, the coordinated control used more battery SOC range.
- The team found that PI systems are historians and not meant for real-time control with ~1 sec updates. They have slow update rates, communication latency, and bandwidth issues.
- *Thanks to all the partners who made this project successful!*

Full results and discussion in:

Jay Johnson, Kimio Morino, Atsushi Denda, John Hawkins, Brian Arellano, Takao Ogata, Takao Shinji, Masayuki Tadokoro, and Abraham Ellis, “Experimental Comparison of PV-Smoothing Controllers using Distributed Generators” Sandia Technical Report SAND2014-XXXX, Feb 2014.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Experimental Comparison of PV-Smoothing Controllers using Distributed Generators

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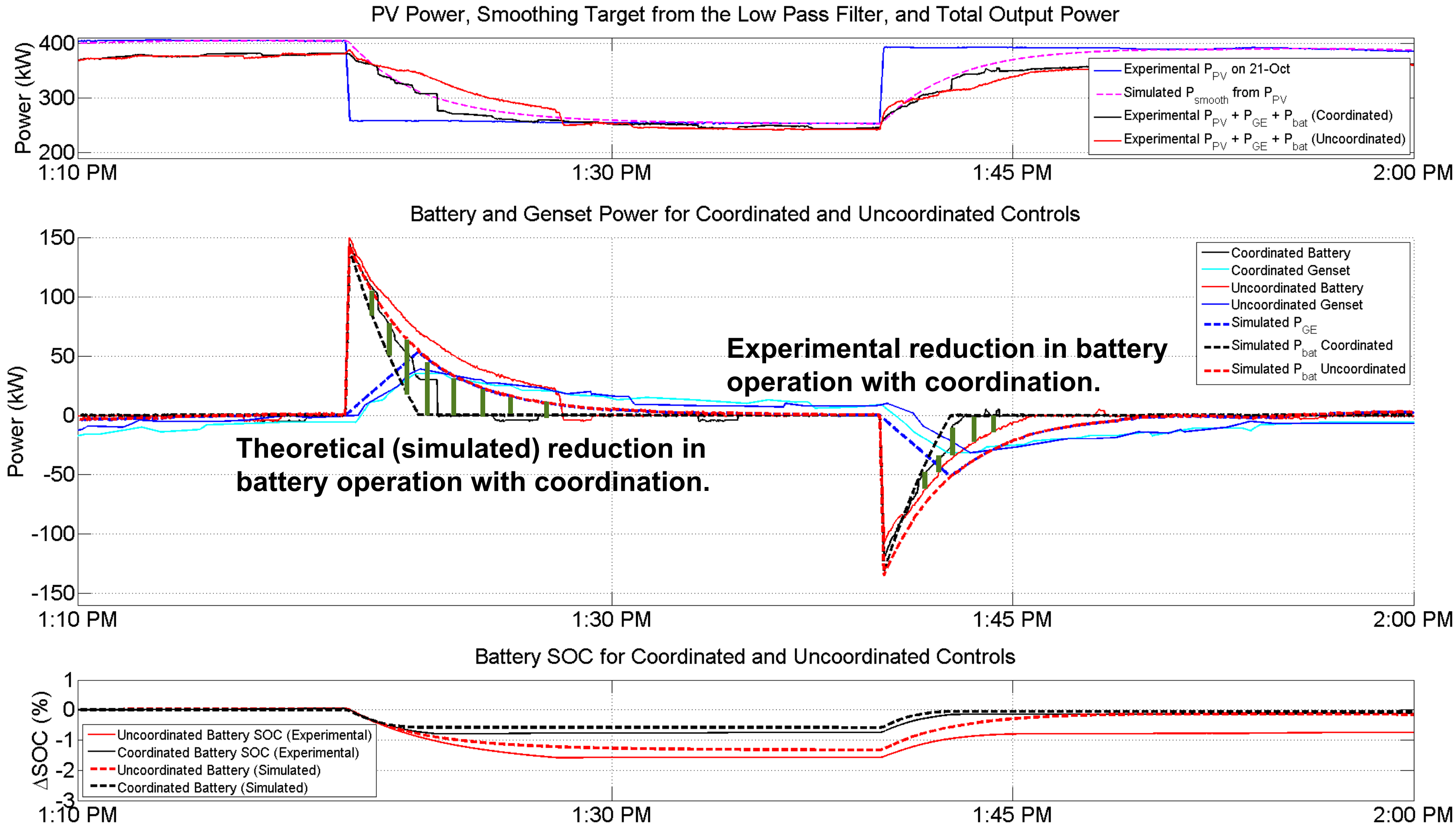
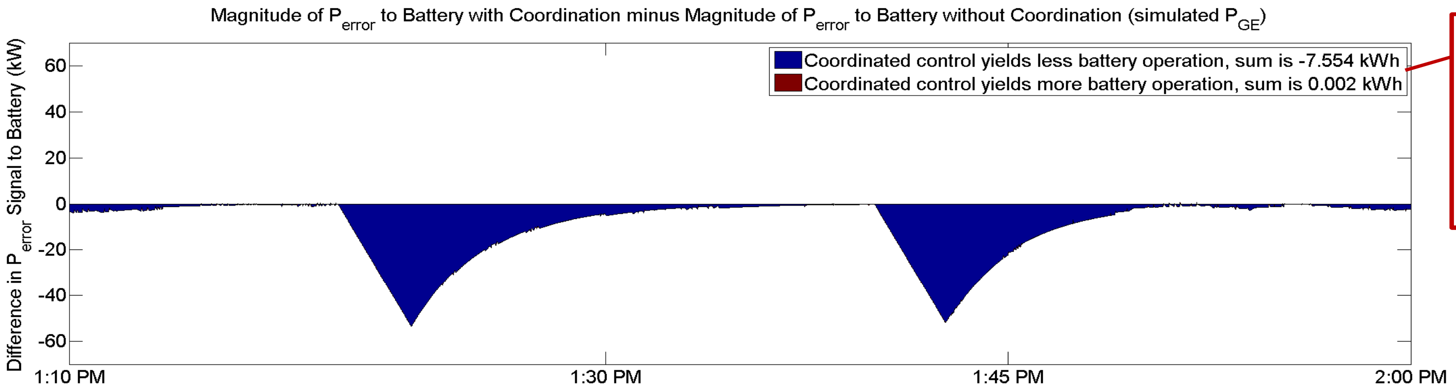
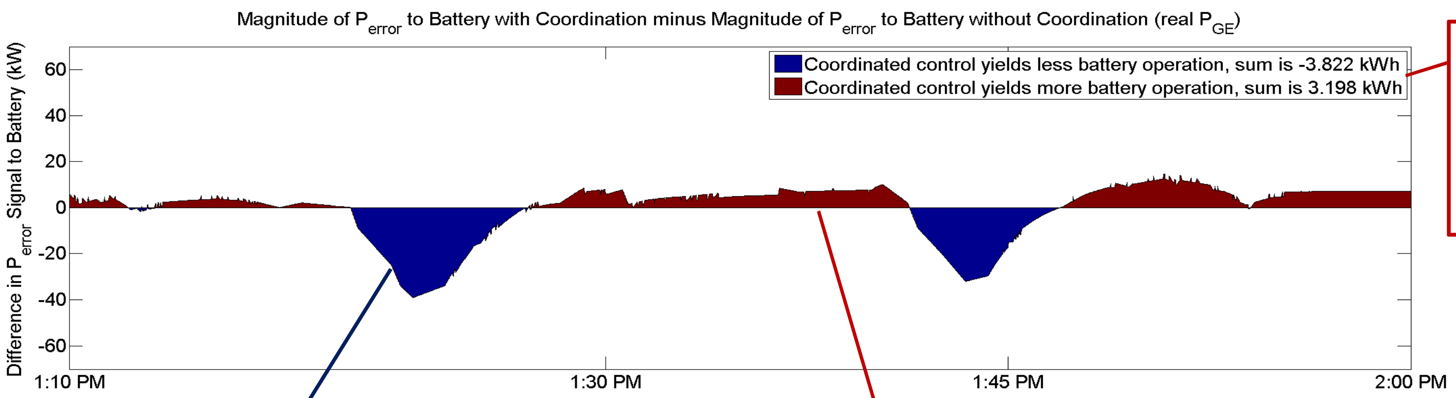
Coordinated vs Uncoordinated Controls



Battery Throughput Analysis



Simulation: Total energy throughput reduction from using the coordinated controller is 7.554 kWh



Experiment: Total energy throughput reduction from using the coordinated controller is 0.624 kWh

The blue area is where the coordinated battery is "working less" than the uncoordinated battery.

The red area means the coordinated battery is "working harder" than the uncoordinated battery.