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PV Smoothing Demonstration using a Coordinated Battery and Genset

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Jay Johnson

Photovoltaic and Distributed Systems Integration, Sandia National Laboratories

Outline

- Research Objective
- Challenges – Geographical Separation and Communications
- Coordinated and Uncoordinated Control Systems
- Model Validation Options
- Results from Demonstration
- Research Impact
- Conclusions

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

Special Thanks to: 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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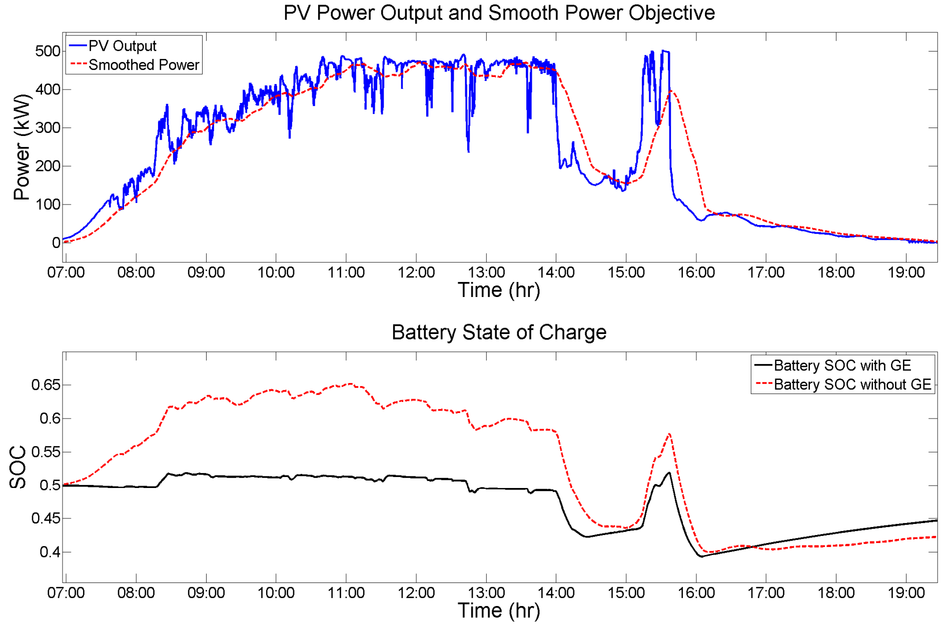
Research Objective

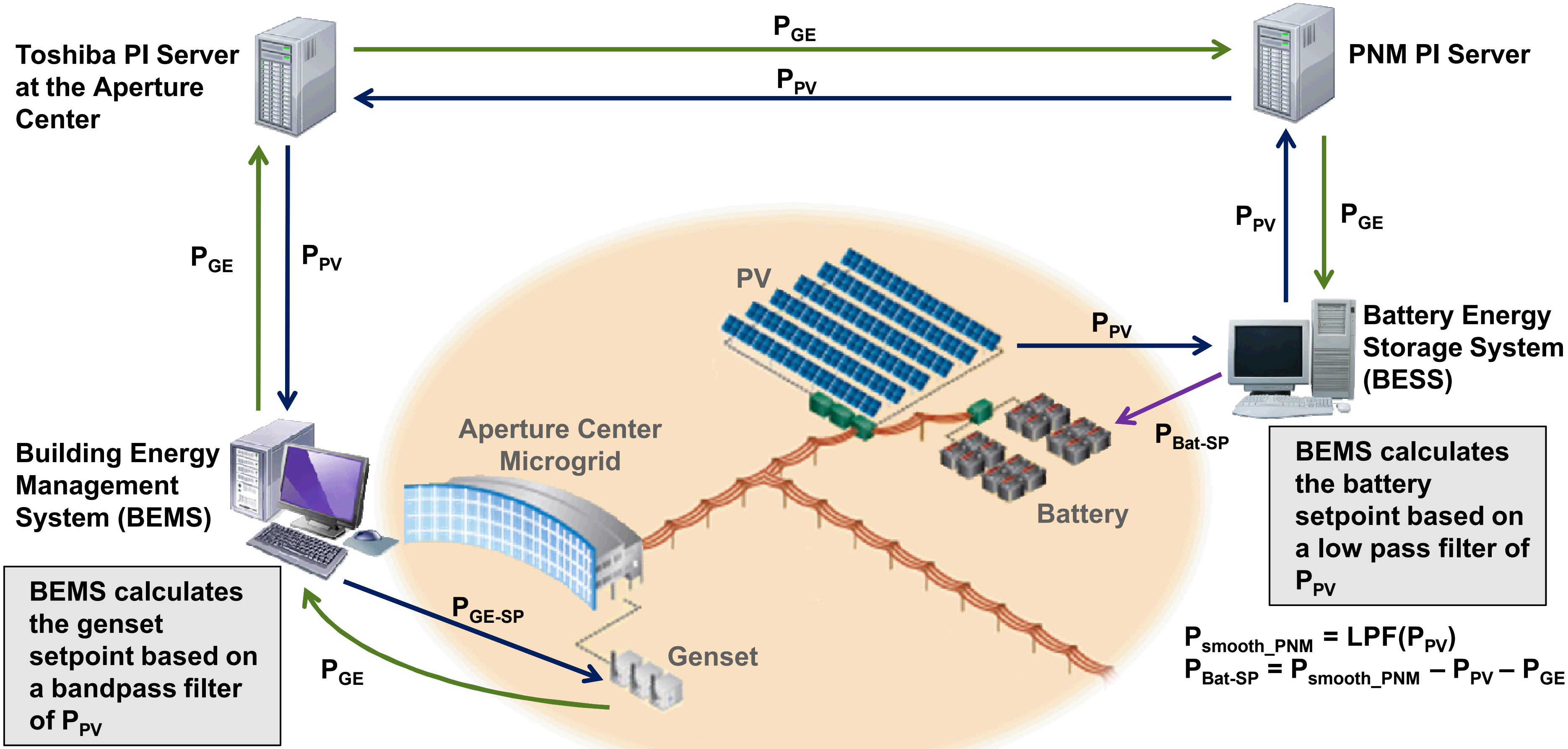
- Objective: Reduce costs of battery-based PV-smoothing systems by novel control schemes.
- Approach: Smoothing PV power with a coordinated battery and inexpensive gas genset reduces the required battery capacity and associated costs.



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


Albuquerque
I-25
Albuquerque Airport
Kirtland Air Force Base
I-25
~2 km
Mesa del Sol
PNM Prosperity Project
- 500 kW PV
- 500 kW, 330 kWh Smoothing Battery
NEDO Mesa del Sol Aperture Center
- 240 kW Natural Gas Engine-Generator

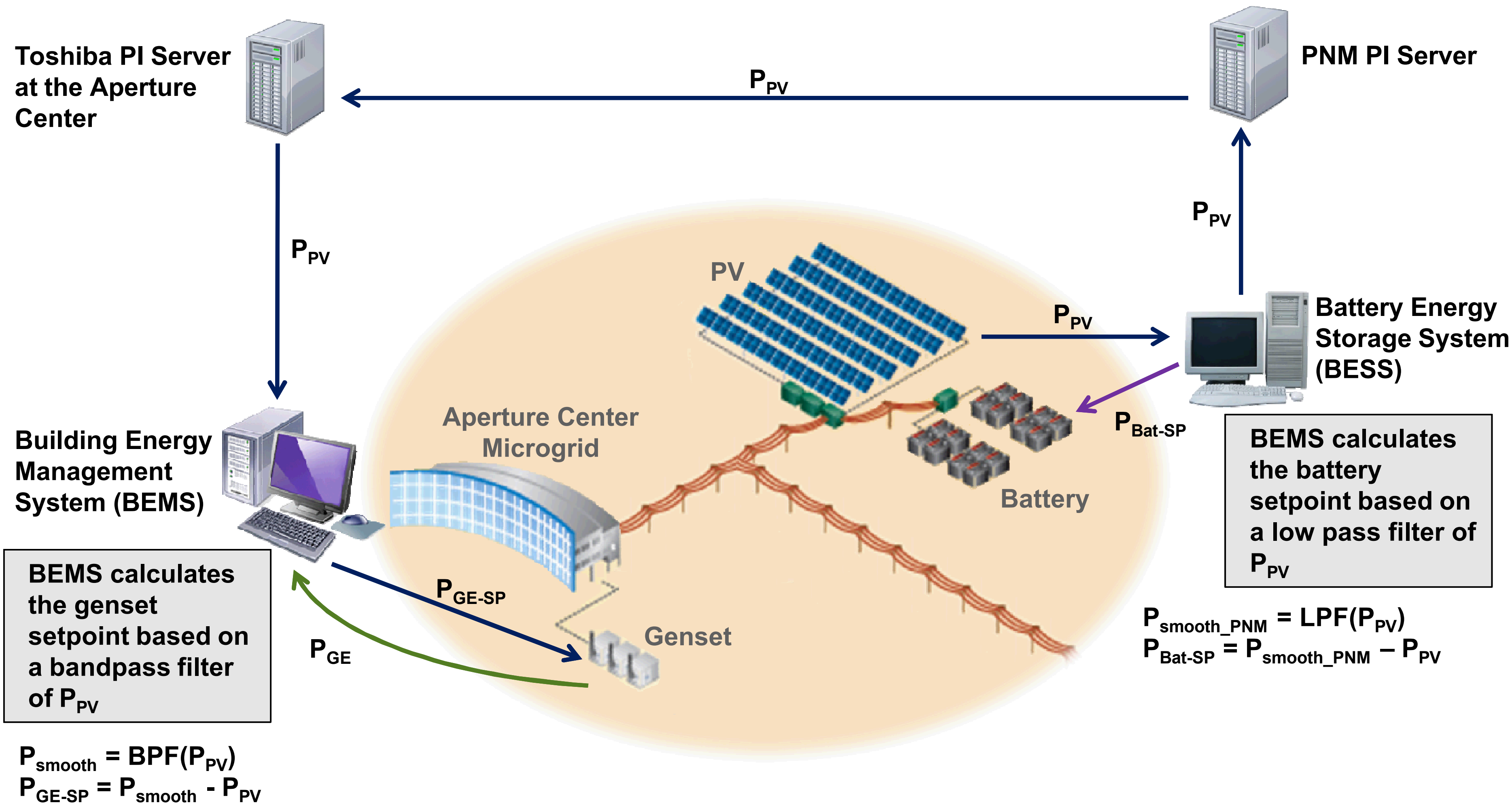
Coordinated, Distributed PV Smoothing



$$P_{smooth} = BPF(P_{PV})$$
$$P_{GE\text{-}SP} = P_{smooth} - P_{PV}$$

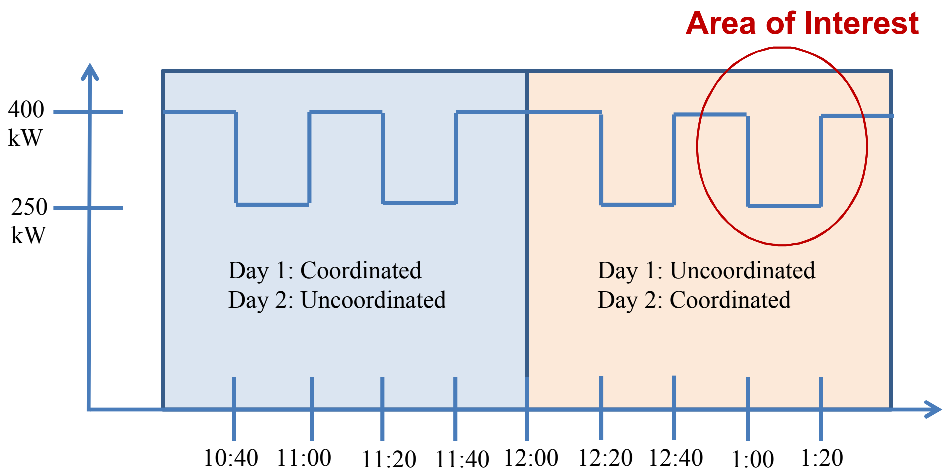
$$P_{smooth\_PNM} = LPF(P_{PV})$$
$$P_{Bat\text{-}SP} = P_{smooth\_PNM} - P_{PV} - P_{GE}$$

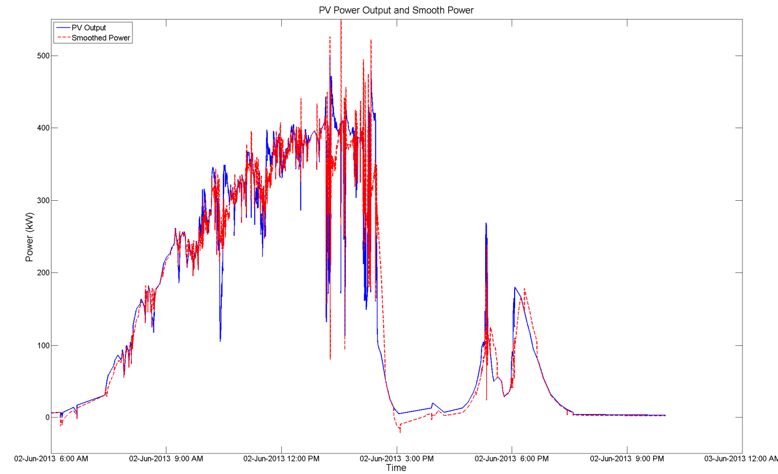
Uncoordinated, Distributed PV Smoothing



Model Verification

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

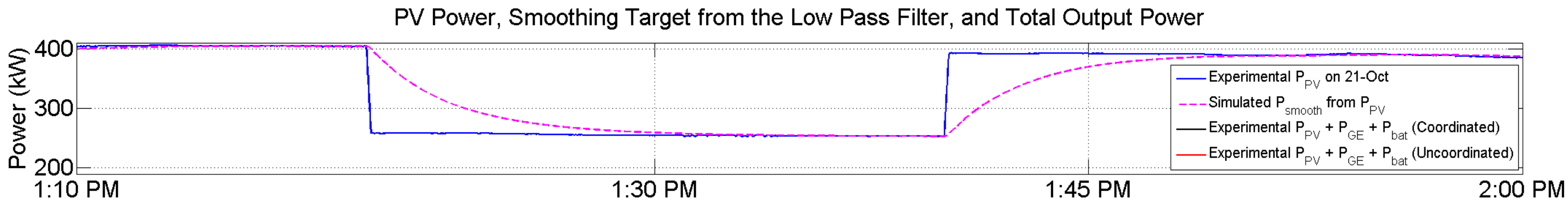




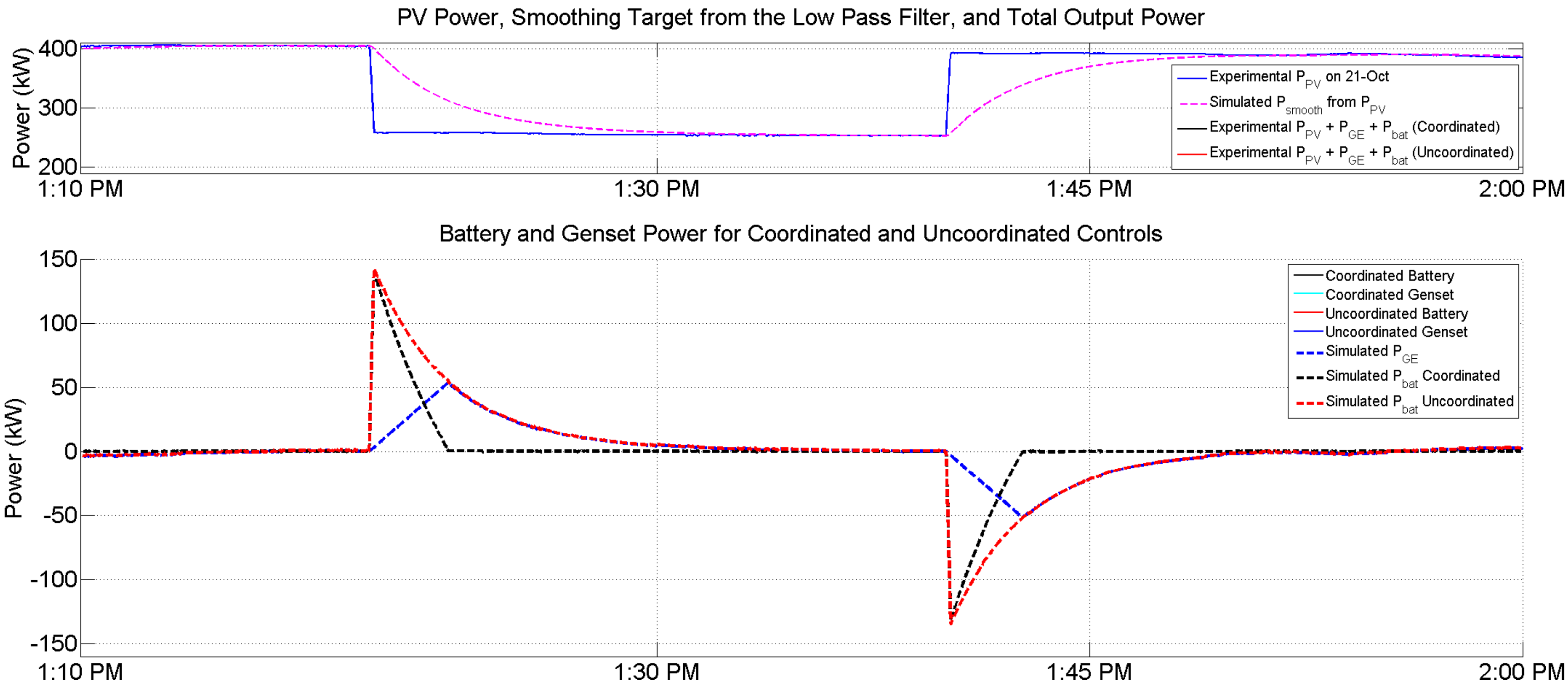
Test 1: Creating highly-repeatable, artificial PV variability by switching off a portion of the PV system during a day without clouds.

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.

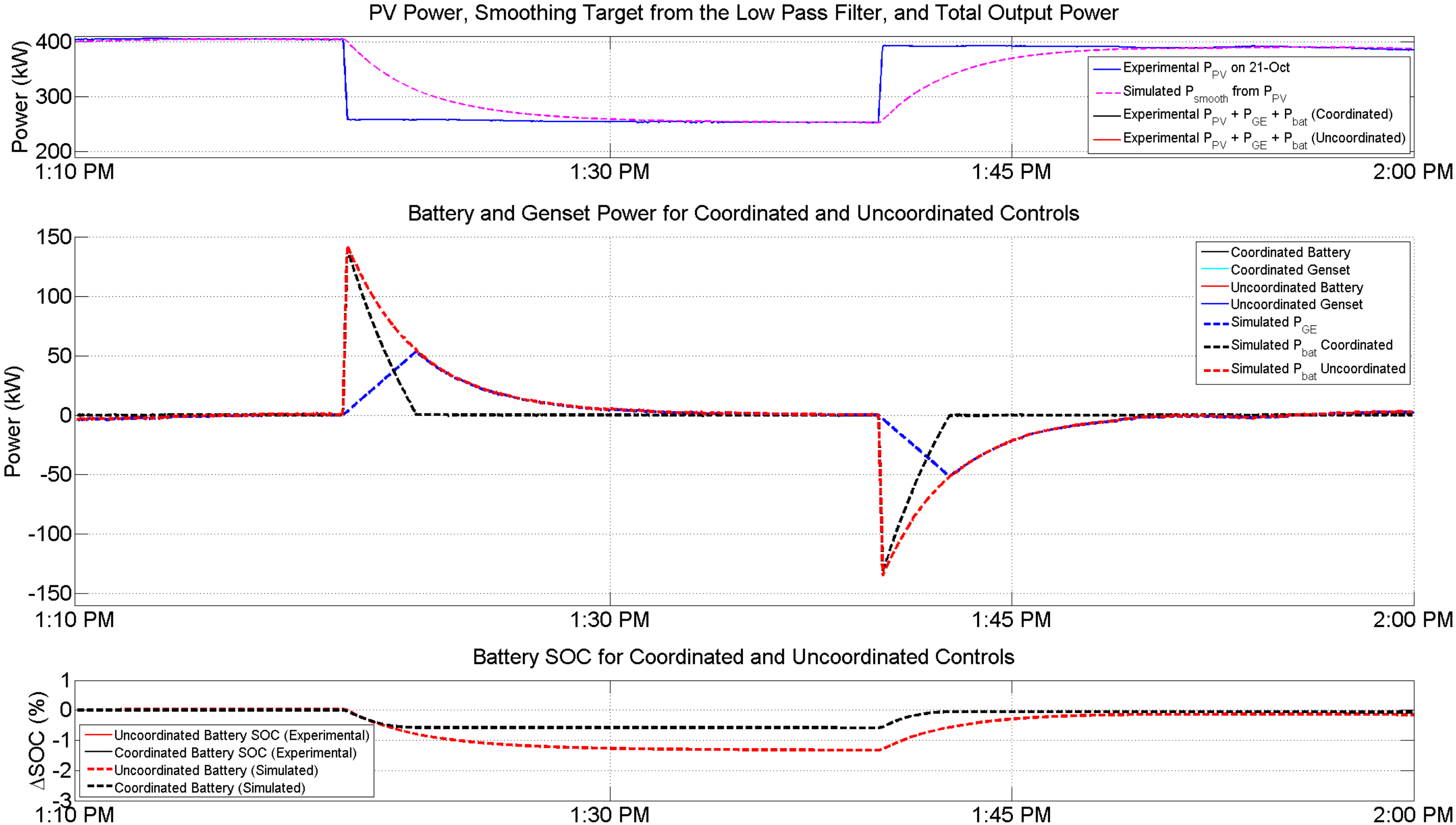
Coordinated vs Uncoordinated Controls



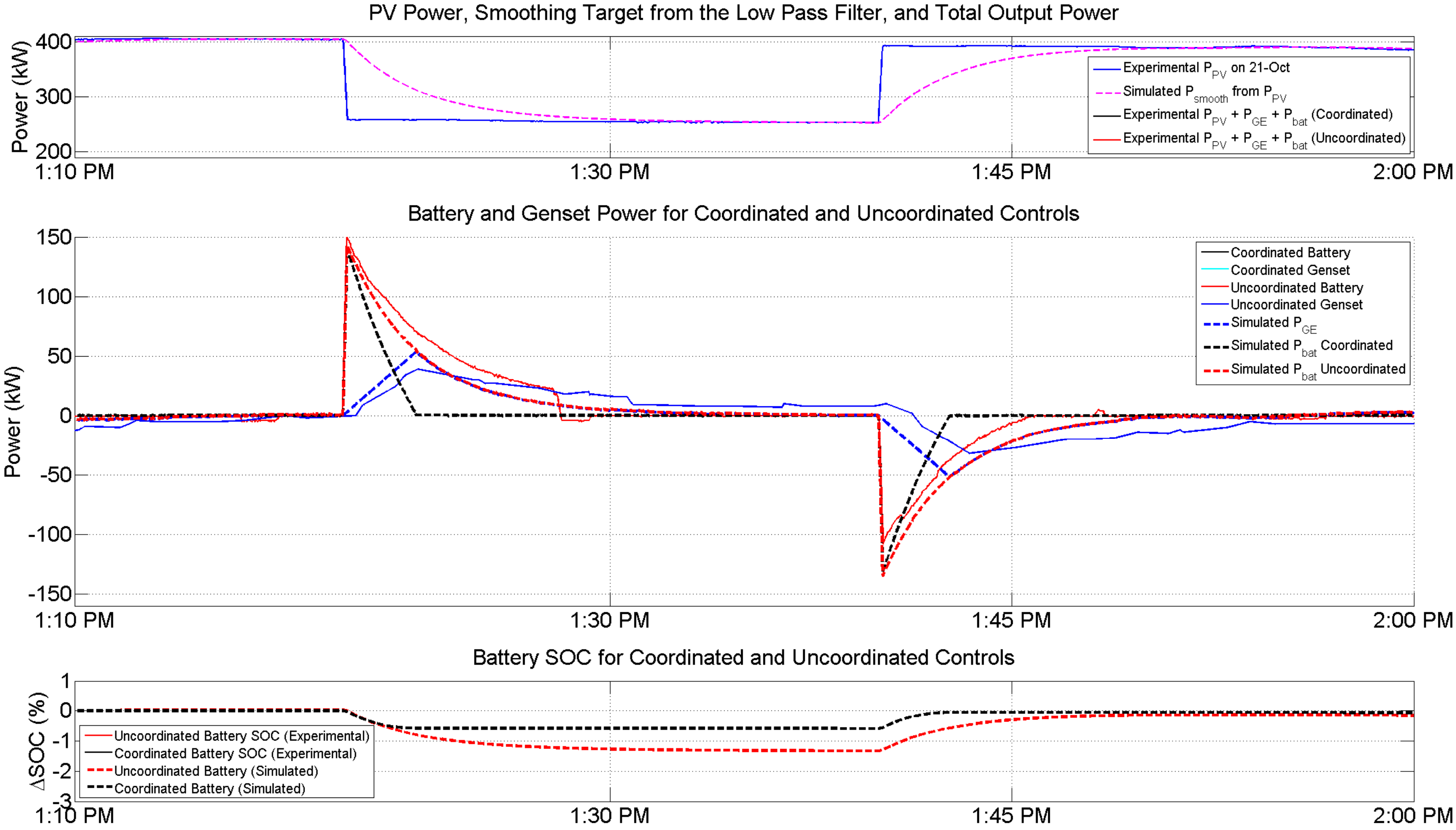
Coordinated vs Uncoordinated Controls



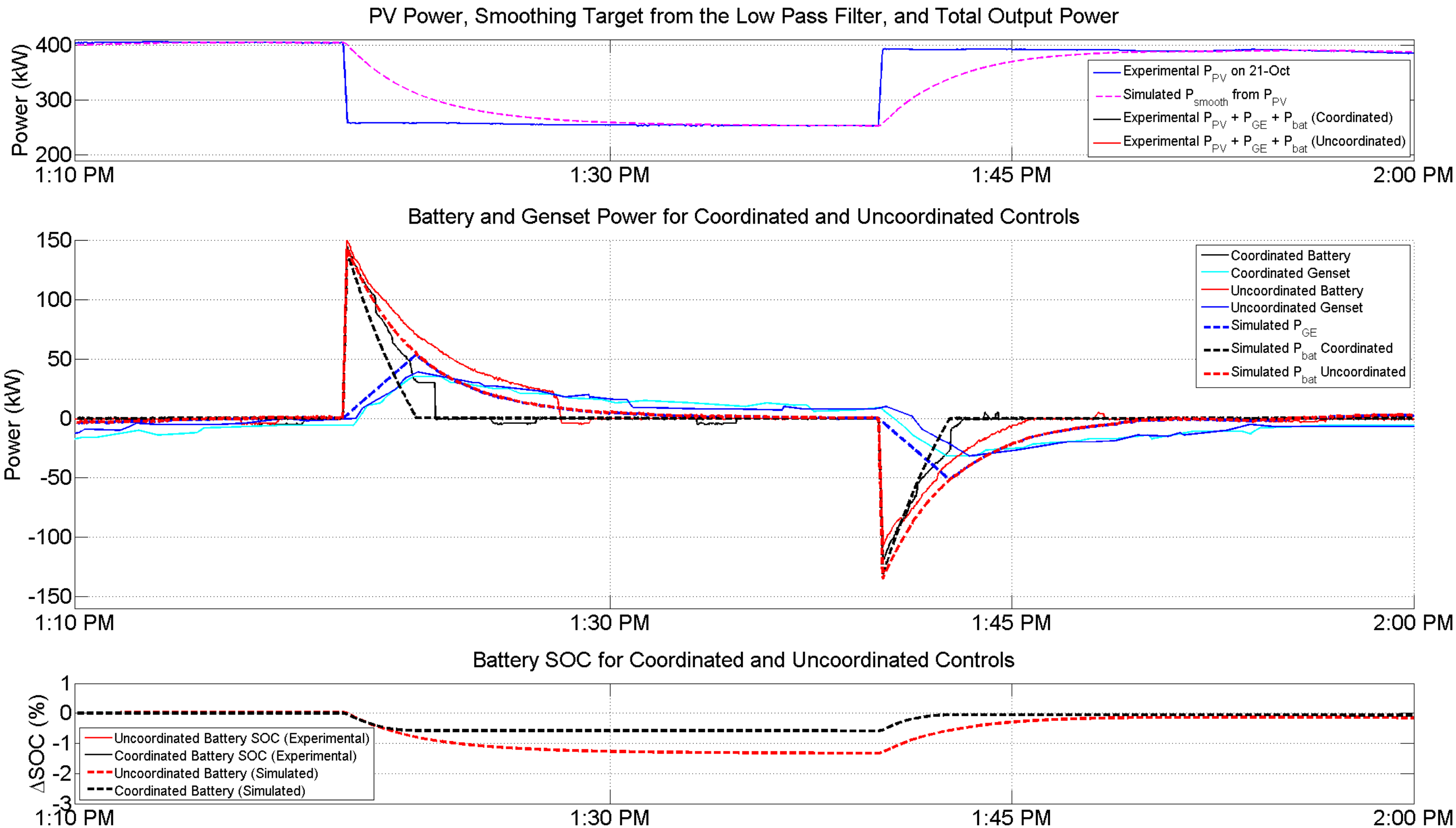
Coordinated vs Uncoordinated Controls



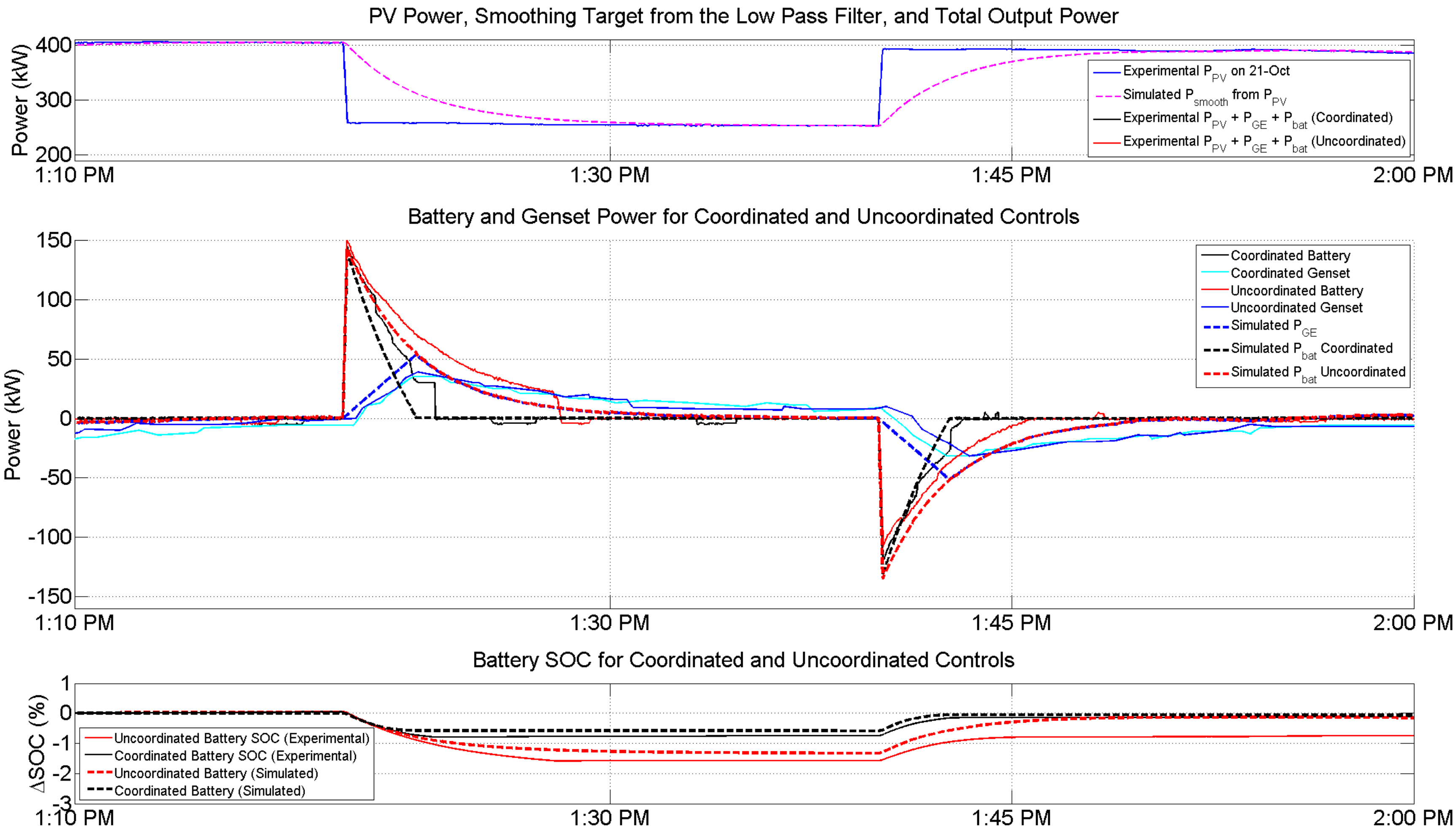
Coordinated vs Uncoordinated Controls



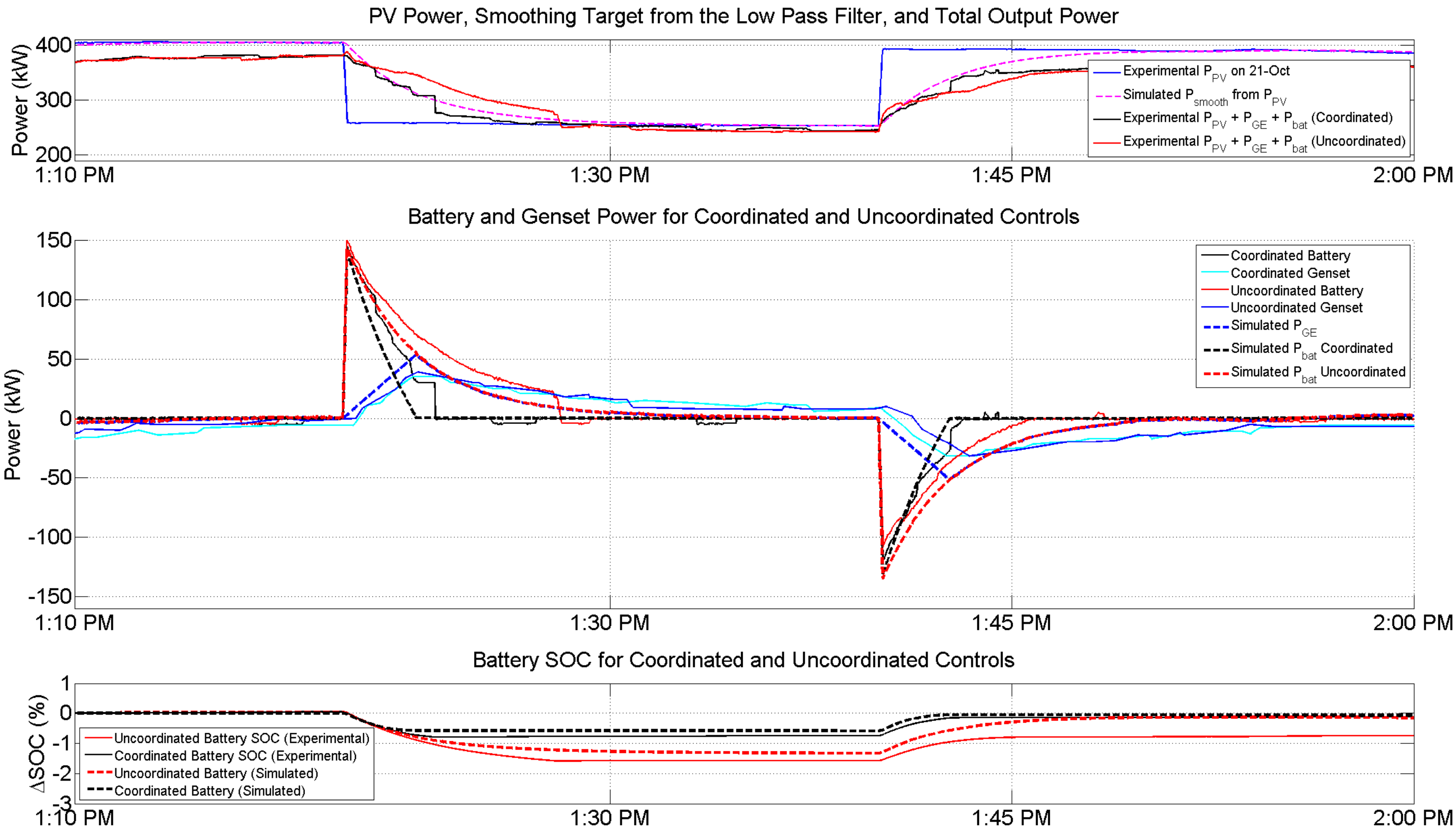
Coordinated vs Uncoordinated Controls



Coordinated vs Uncoordinated Controls



Coordinated vs Uncoordinated Controls

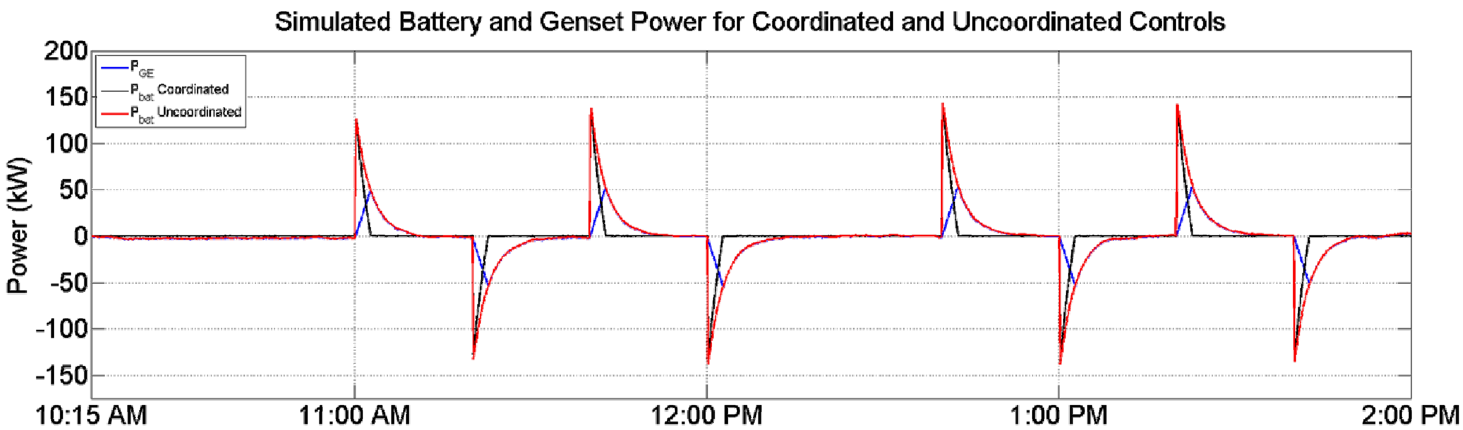


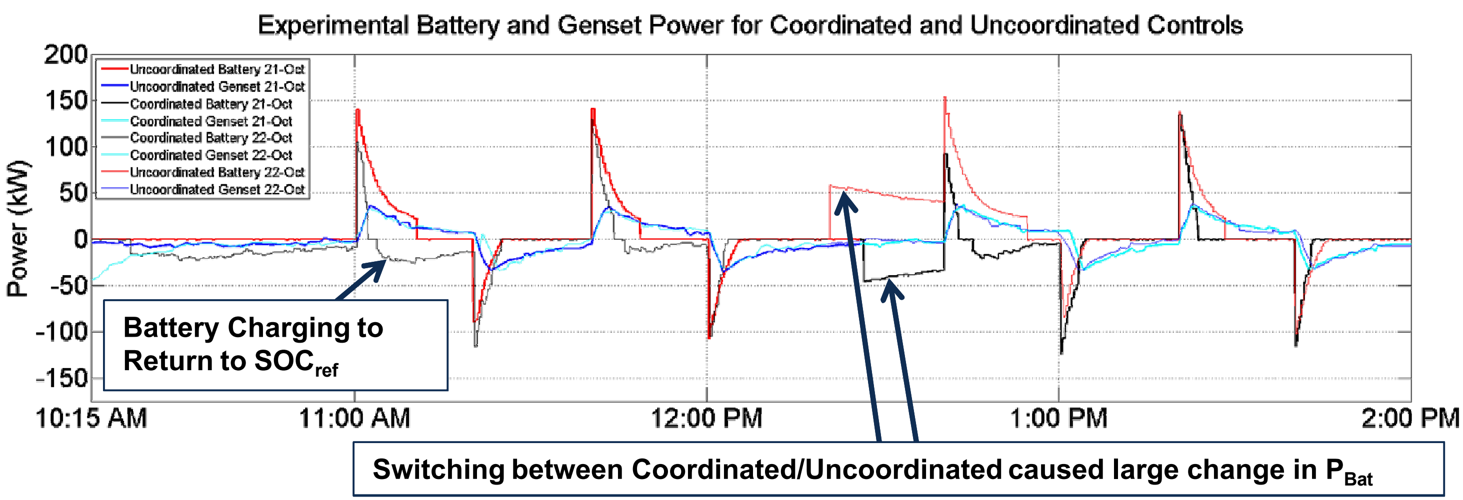
Conclusions, Impact, and Future Work

- The team demonstrated Sandia's coordinated, distributed, PV-smoothing controller reduces the variability of renewable energy resources for less capital cost (smaller batteries).
  - This technology allows higher penetrations of PV and wind on electricity grids, especially constrained microgrids.
- The cascading, battery-based control algorithm could be applied to absorb P_{error} signals:
  - Area Control Error (ACE) for utility-scale power systems
  - The difference in $P_{supplied}$ and P_{demand} in microgrids
- This program has strong and continued support from utility and industry partners!
  - We look forward to additional full-scale demonstrations of controls for renewable energy integration and microgrid operations.

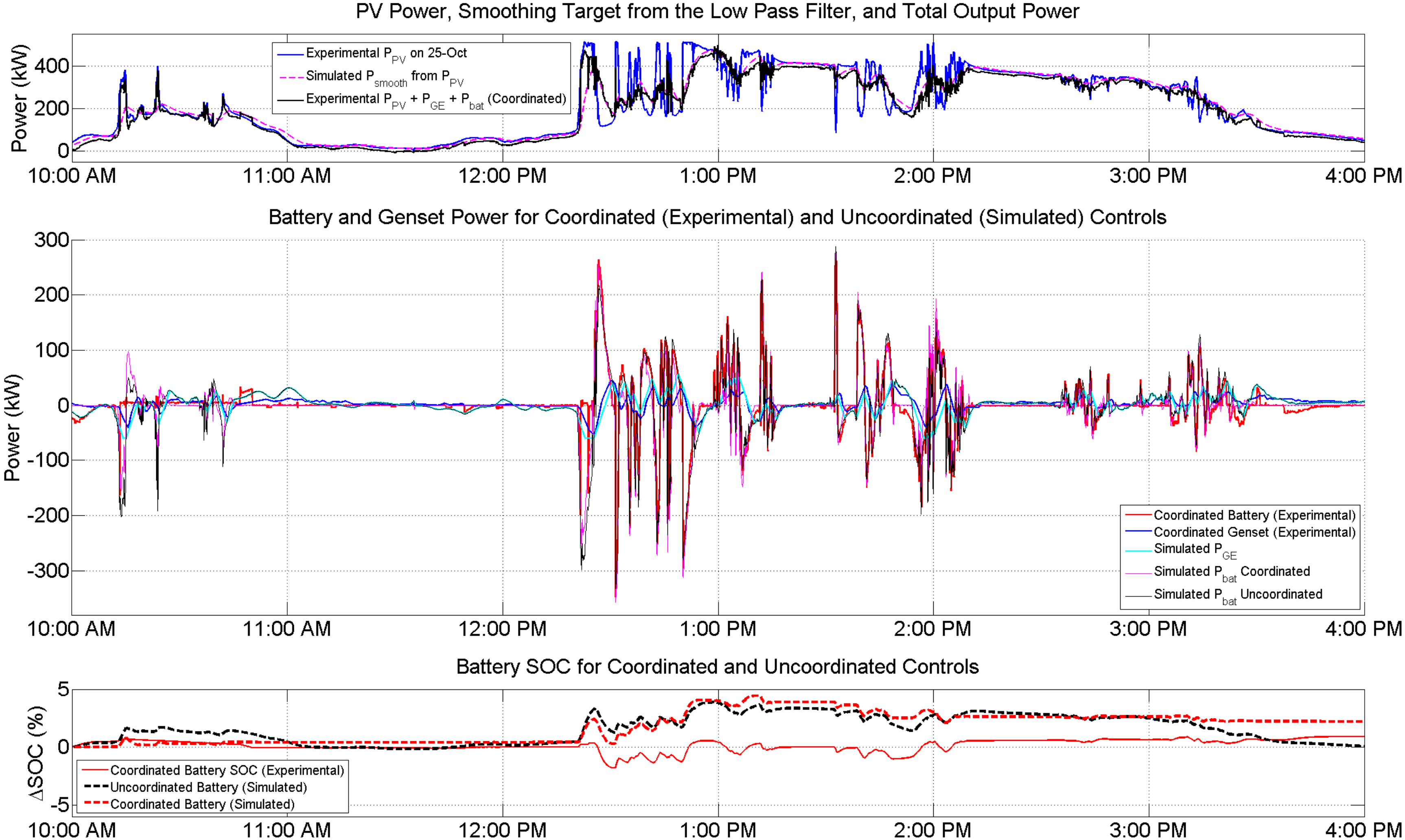
Coordinated vs Uncoordinated Controls

Experimental results show variability due to battery return signals and communication errors/latency.

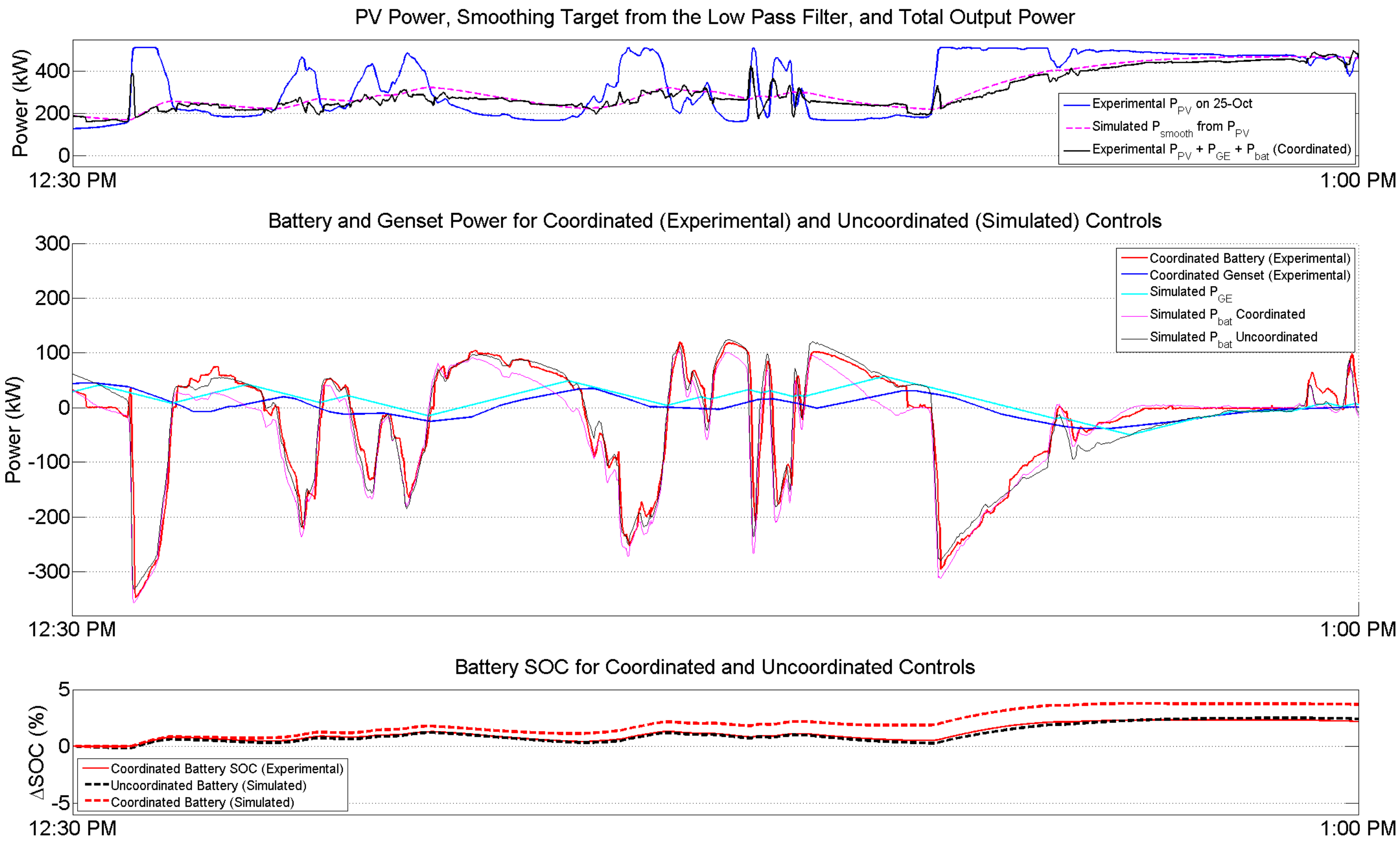




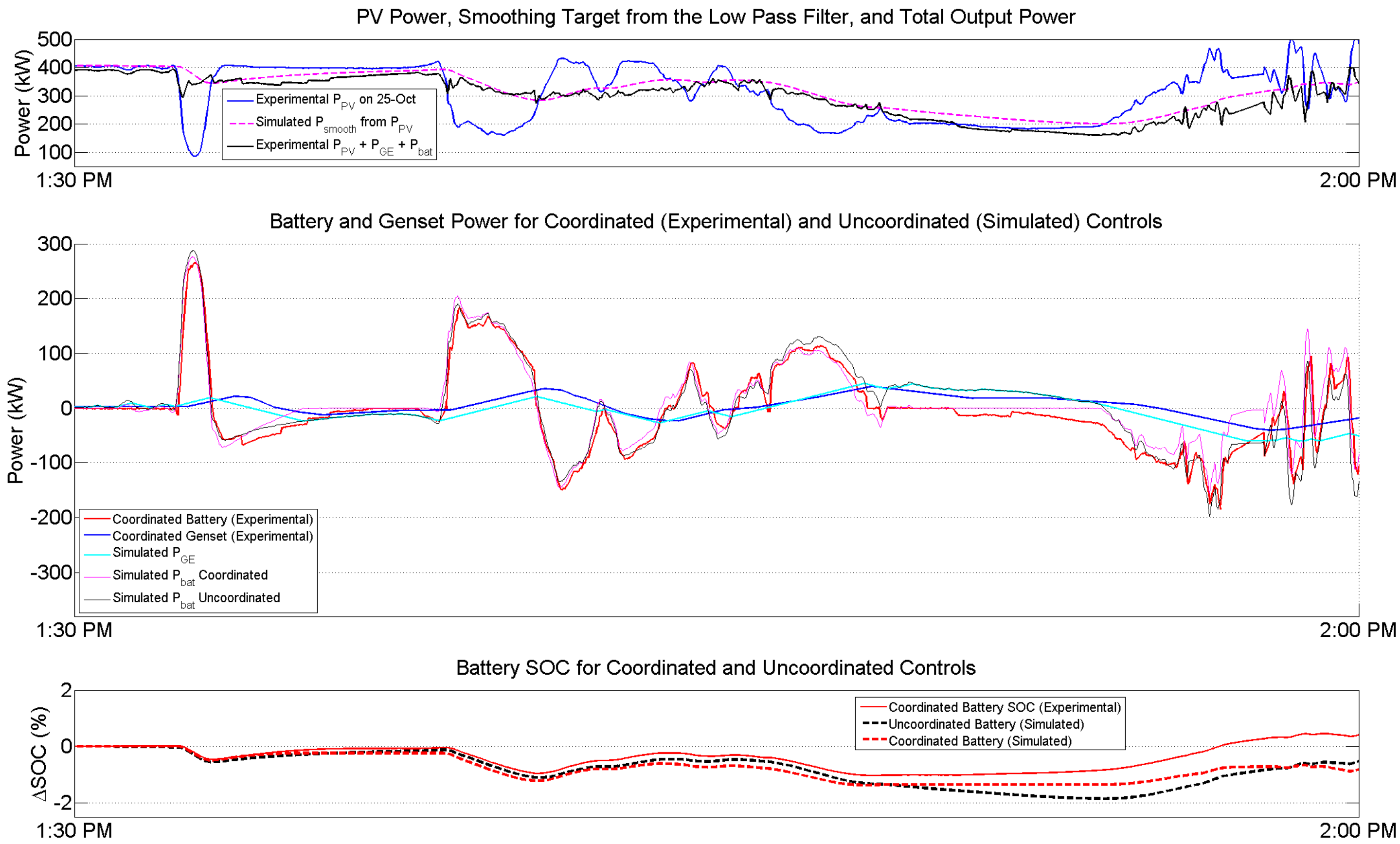
Coordinated Control with PV Variability



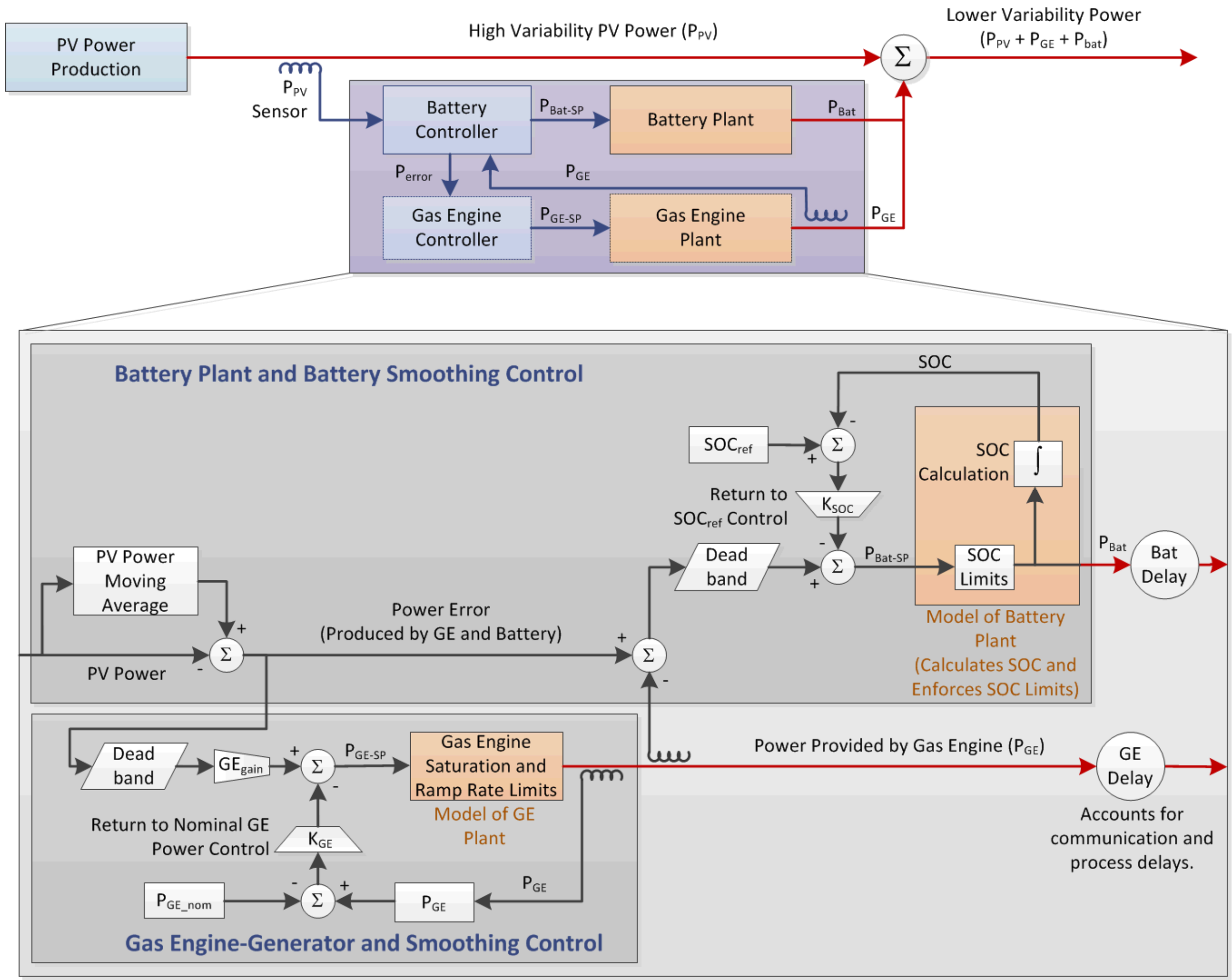
Genset making the battery work harder



Genset helping the battery work less



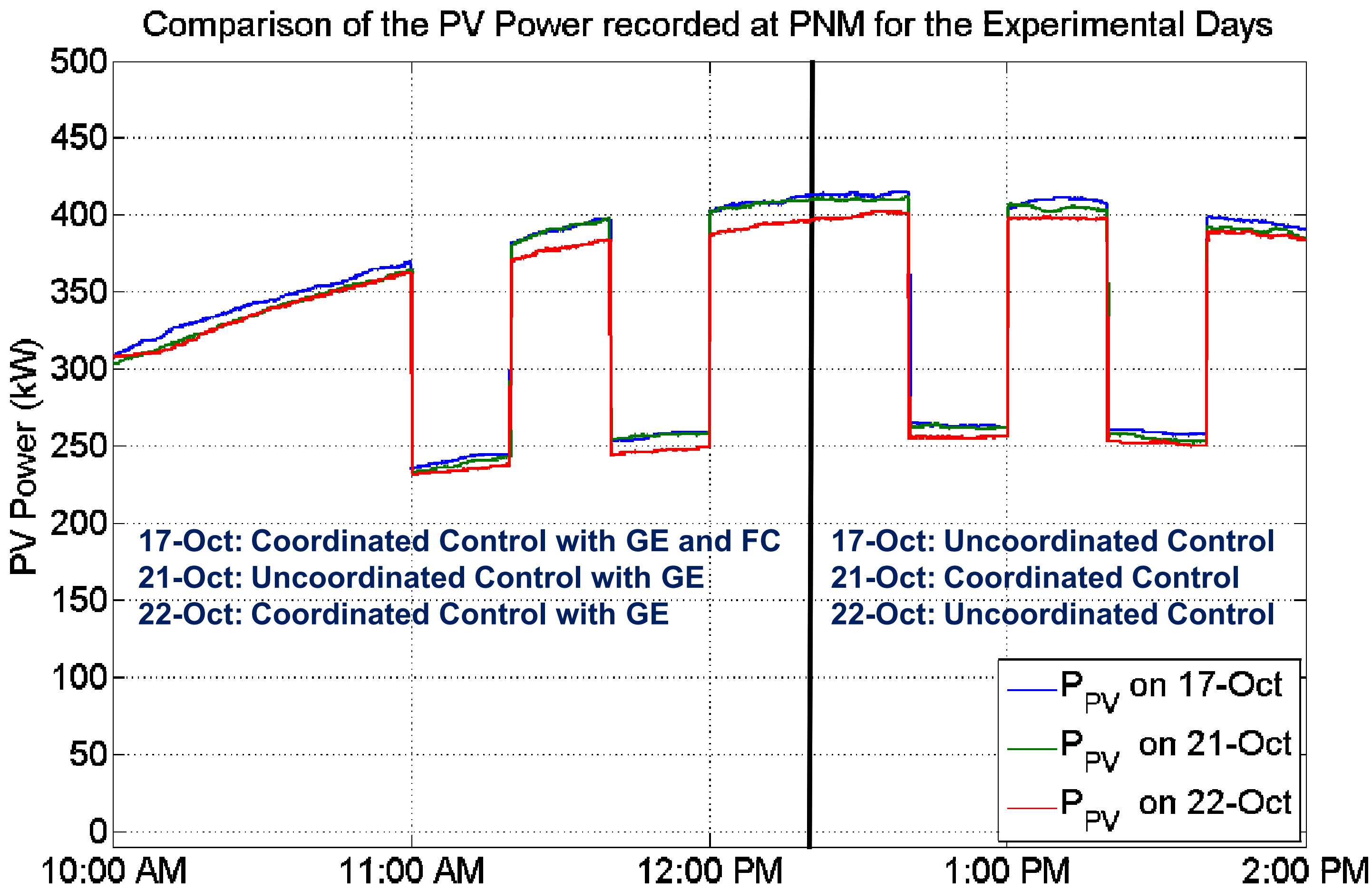
Battery-Genset Coordinated Control Model



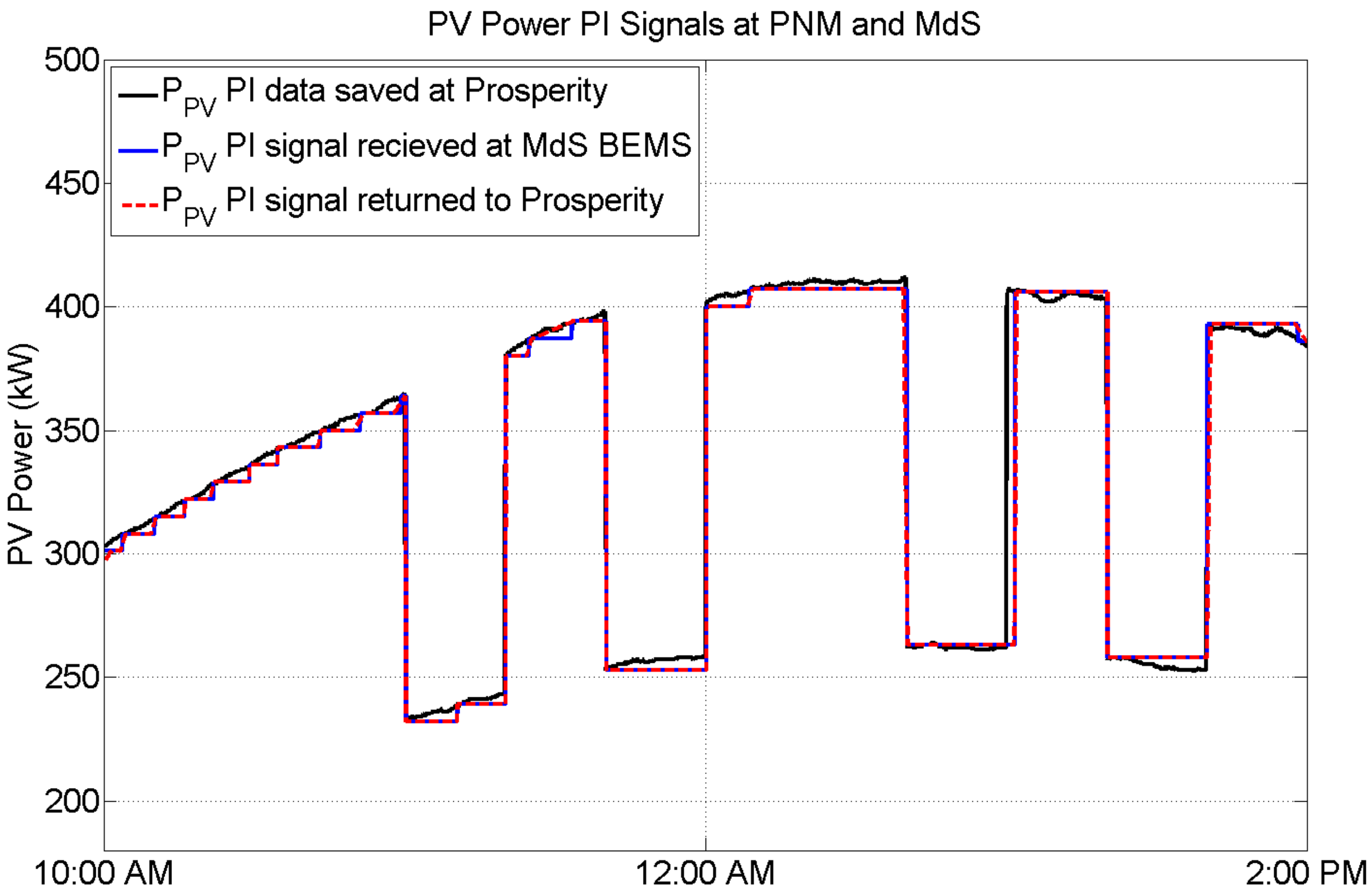
Control Algorithm Design

- Existing controls
  - Local PV smoothing control implemented at Prosperity
- Extended objective: Demonstrate by simulation coordinated operation of Prosperity battery and MdS gas engine to smooth PV plant output
  - P_{bat} and P_{GE} are controlled to minimize $P_{smooth} – P_{pv}$
  - P_{smooth} is computed by applying a moving average of P_{pv}
  - Simple proportional control with deadband, rate limits, and saturation
- Sub-objectives
  - Maintain battery SOC within a prescribed range
  - GE output and battery SOC should recover to a *target level* to avoid saturation (for example, battery SOC = 0.5±0.2 per unit; GE output is 180±60 kW)
  - Optimize according to several possible figures of merit (for example, battery SOC swings or amount of ampere-hour processed)

PV Power for the Test Days



Latency Verification



Communication Delays