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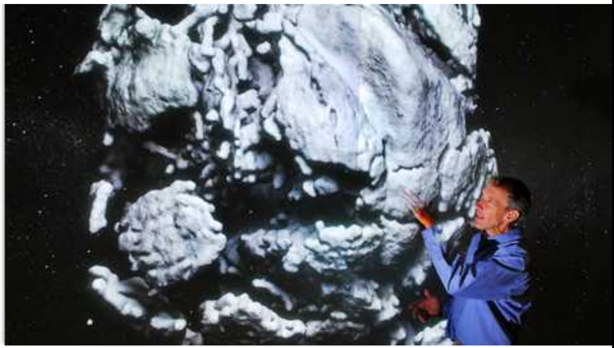

Sandia-Japan Collaboration Related to New Mexico Smart Grid Projects

Abraham Ellis

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Topics

- About New Mexico
- About Sandia National Laboratories
- Examples of Sandia-Japan collaboration
  - Anti-islanding Testing and Standardization Research
  - PV Output Variability Research
  - Demonstration of battery-based and distributed resource PV output
- Conclusion

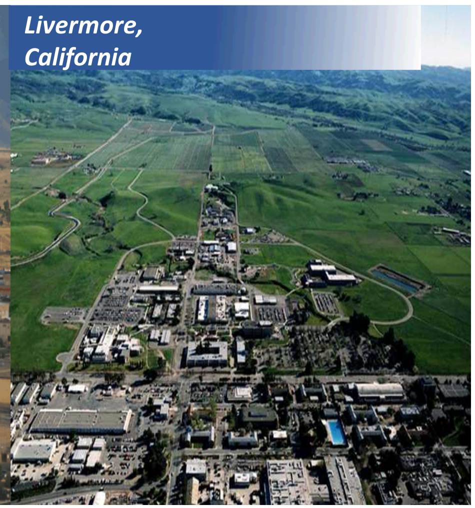
Where Is New Mexico?

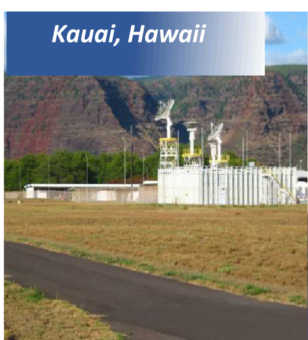
- 5^{th} largest US state
- Population is 2.1 million
- New Mexico is known for its beautiful landscape, rich culture, high tech industry, plentiful wind and solar resources

http://www.newmexico.org/

Sandia National Laboratories

- Multi-program US Department of Energy research and engineering laboratory
- Focusing on National Security, including energy
- Headquartered in Albuquerque, NM





Anti-Islanding Research

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- Anti-islanding (AI) is a topic of high importance in the US and Japan
  - Motivated by large-scale deployment of distributed PV and other DG
  - Both sides have extensive research and development experience in this area
- Goals:
  - Conduct AI testing of residential inverters
    - Single and multiple inverter cases
    - Testing in the Sandia and Japan laboratories
  - Compare test & analysis procedures
  - Validate detailed simulation models (US)
- Entities involved

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NPPT Northern Plains Power Technologies moving power forward

NEDO

KANDENKO

JET 一般財団法人 電気安全環境研究所 Japan Electrical Safety & Environment Technology Laboratories

Comparison of AI Test Methods

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- Test methods and performance requirements are very different

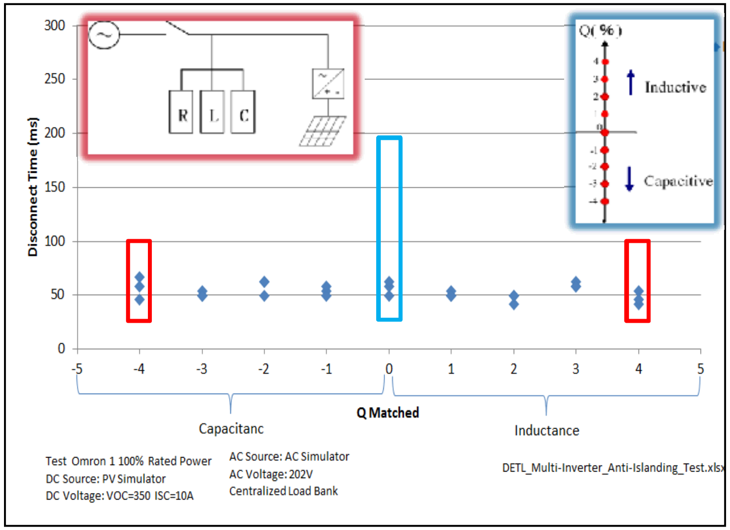
	US (UL-1741)	Japan (JETGR0003-4-1.0)
Key Equipment	• Grid connection • PV simulator • Adjustable load	• Grid connection • PV simulator • Adjustable RLC load and induction motor
Test conditions	• ∆P: 0 • ∆Q: 0, +/-1%, +/-2%, +/-3%, +/-4%	• ∆P: 0, +/-5%,+/-10% • ∆Q: 0, +/-5%,+/-10%
Load in test island	• RLC with quality factor (QF)=1.0 • QF = R × Sqrt (C/L)	• Induction motor (150W load while running) • RLC circuit to adjust net P,Q load • No QF specified (typically, QF<<1.0)
Number of tests for <u>single</u> inverter	• 2 tests at ∆Q=0 • 1 test at other ∆Q mismatch levels • Repeat at 100%, 66%, and 33% • Total tests: **30**	• 2 tests for each (∆P, ∆Q) combination • DG at 100% output • Total tests: **50**
Multiple inverter test	• No requirement for multiple inverter testing	• Multiple inverters with the same AI functionality (up to 10): test only at worst run-on-time condition (15 times)
AI algorithm requirement	• Not specified • External detect/trip allowed	• Specified (since 2011) • External detect/trip allowed
Test pass criteria	• 2-second disconnect	• 0.2-second disconnect

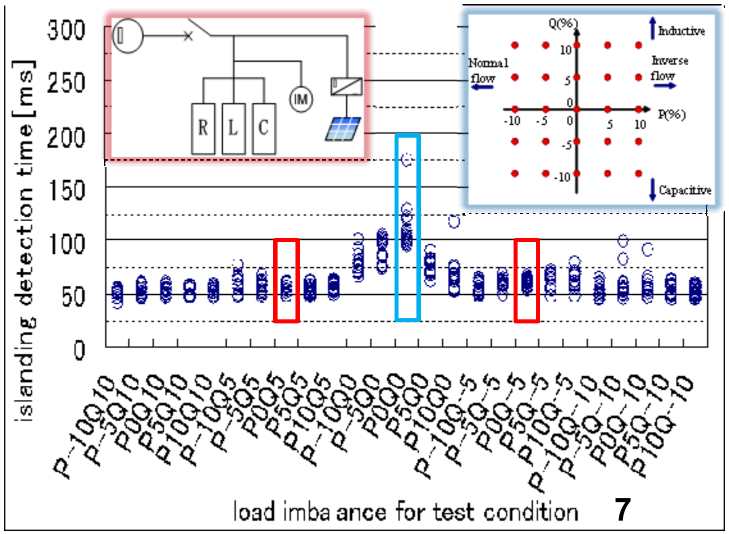
Anti-Islanding Research – Results

- Testing by Kandenko/JET
  - 1, 2, 4, 6, 8 Japan-A inverters
  - 1, 2, 4, 6, 8 Japan-B inverters
  - Combination of up to 8 inverters
- Testing by Sandia
  - 1, 2, 4 US-A inverters
  - 1,2 Japan-A inverters
  - Combination of 10 inverter from 5 different manufacturers
- In terms of run-on-times, test results using the JET and UL methods compare well
  - Differences can be explained by high Q factor versus motor load (JER)
- Planning several publications
  - Two joint technical publications in planned for 2013 (CIGRE and IEEE)

Same hardware – allows for direct comparison of methods

Test results for Japan-A residential PV Inverter
Condition: 100% of rated power





PV Variability Analysis

- PV output variability from large plants and multiple systems over a large areas (e.g., high density residential) is not well understood
  - Models needed to understand system impacts and mitigation strategies
  - Access to high resolution, high quality data is difficult
- Sandia-Japan collaboration
  - Analyze data from residential deployment case to compare variability of irradiance and total output
  - Validate Sandia/UCSD models that use point irradiance to model total plant output
  - High quality data provided by NEDO/Kandenko from recent Ota City demonstration project
- Entities involved

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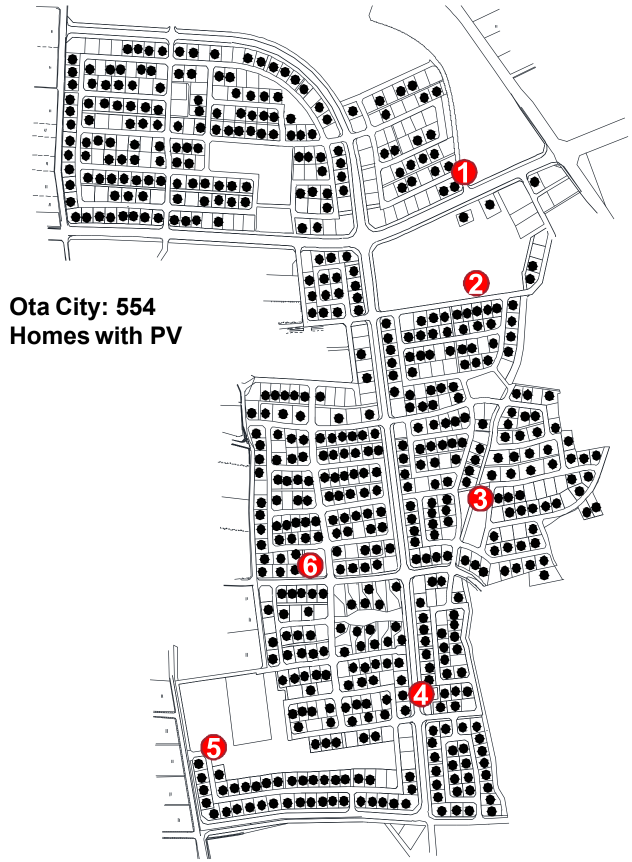

PV Variability Analysis

- Data set consists of
  - PV output and load for 554 houses
  - Irradiance at 6 locations
  - 1-sec data, Feb./2006 – Dec./2007
- Sandia analysis
  - Compared Ramp Rates (RRs) at timescales of 1-sec to 10-min
  - Used wavelet decomposition to show reduction in variability at various timescales
  - Follow-up work: Refine and validate models and computer tools that generate estimated PV output data using measured irradiance at one point

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- **Variability can be measured in different ways**
- **Statistical analysis of normalized Ramp Rate (nRR) gives some useful information**
- **Maximum nRR may be of interest, but 99th percentile of nRR is better to filter out noise**

- **Magnitude of nRR depends on the time scale**
- **In Ota City, for all time scales, maximum nRR decreases rapidly for the first 10 randomly selected homes, stable after that**

Wavelet Decomposition Technique

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GHI sensor = 1 house

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Little reduction in *fpi* at long timescales: little geographic smoothing

Strong reduction in *fpi* at short timescales: lots of geographic smoothing

Fluctuation power index = average magnitude of wavelet modes.

References:

Wavelet Variability Model (WVM)

- Follow-up research: Sandia/University of California San Diego developing tools to simulate PV output variability using WVM
  - Single large plants, plant fleet (including residential)

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Ota City

Simulated wavelet modes (magenta) derived from GHI wavelet modes (black) by scaling based on simulated VR

Compare well with wavelet modes of the actual power output (blue) of all of Ota City

Ref:

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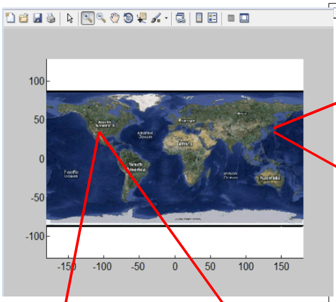
Ota City



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Copper Mountain (50 MW)

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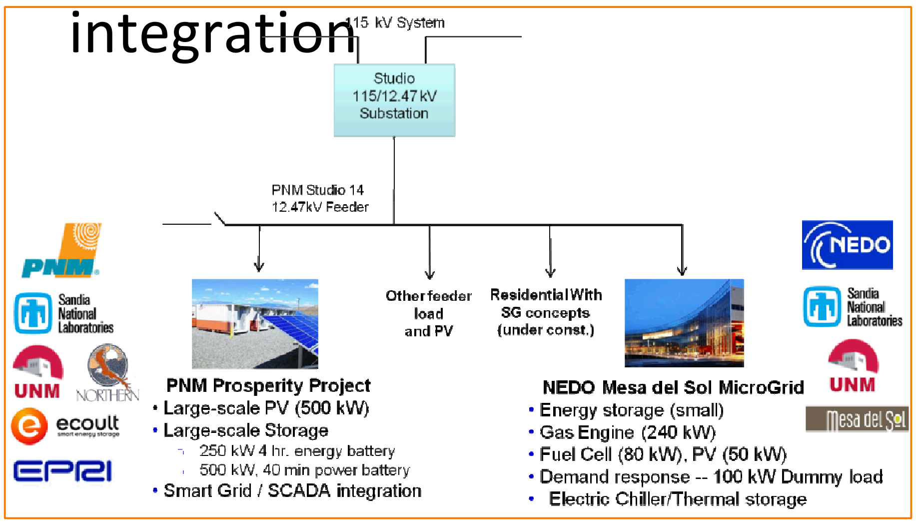
Scale comparison

References:

Background on Research Project

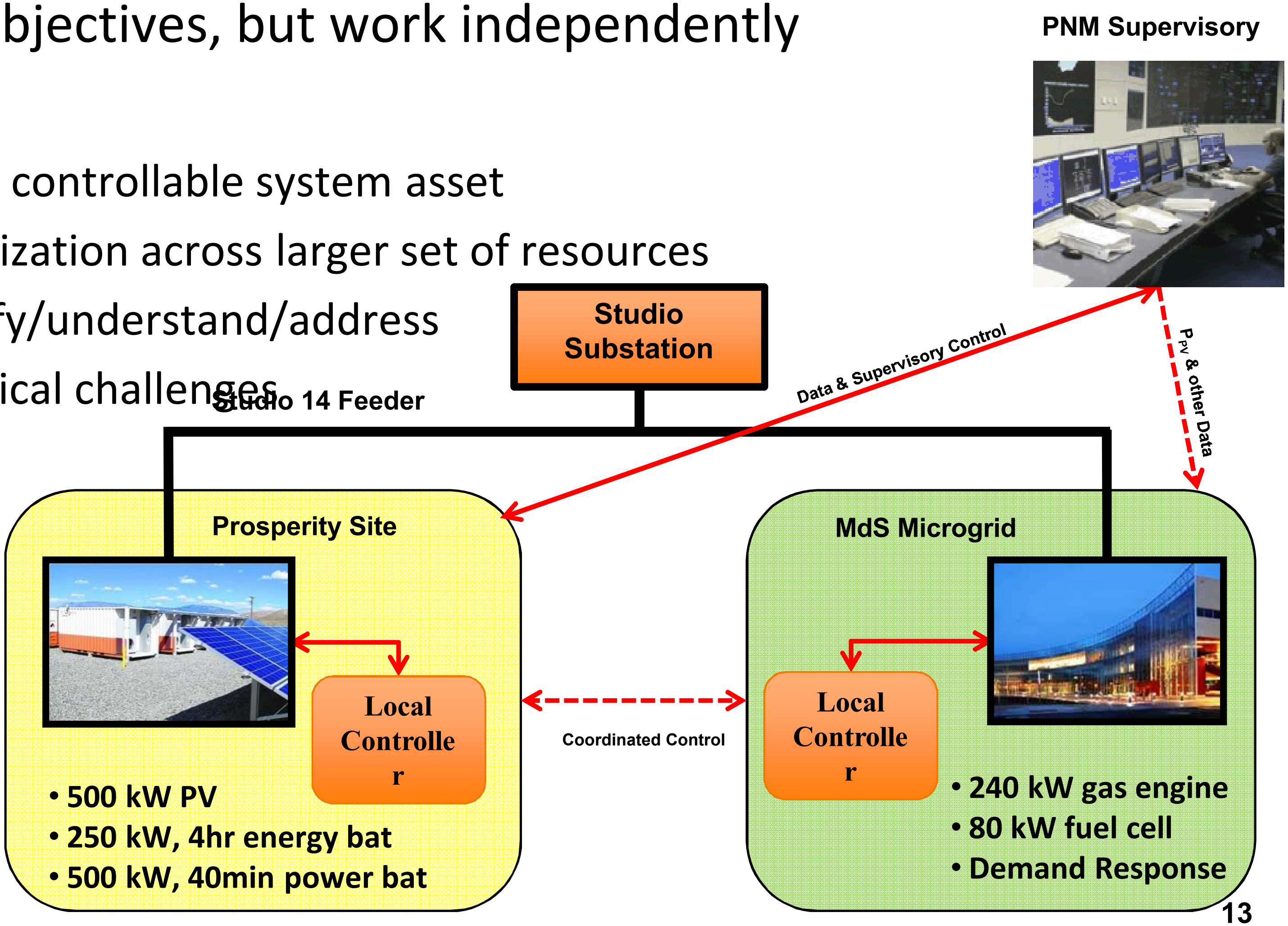
- Demonstrate coordinated operation of the PNM Prosperity and Mesa Del Sol (MdS) projects
  - PV output smoothing using MdS Gas Engine and Prosperity battery
  - Controls optimization and plan for future field demonstration
- Part of a larger PNM vision of renewables and smart grid integration



- Project partners: Sandia PNM, UNM, MdS, Tokyo Gas, Shimizu

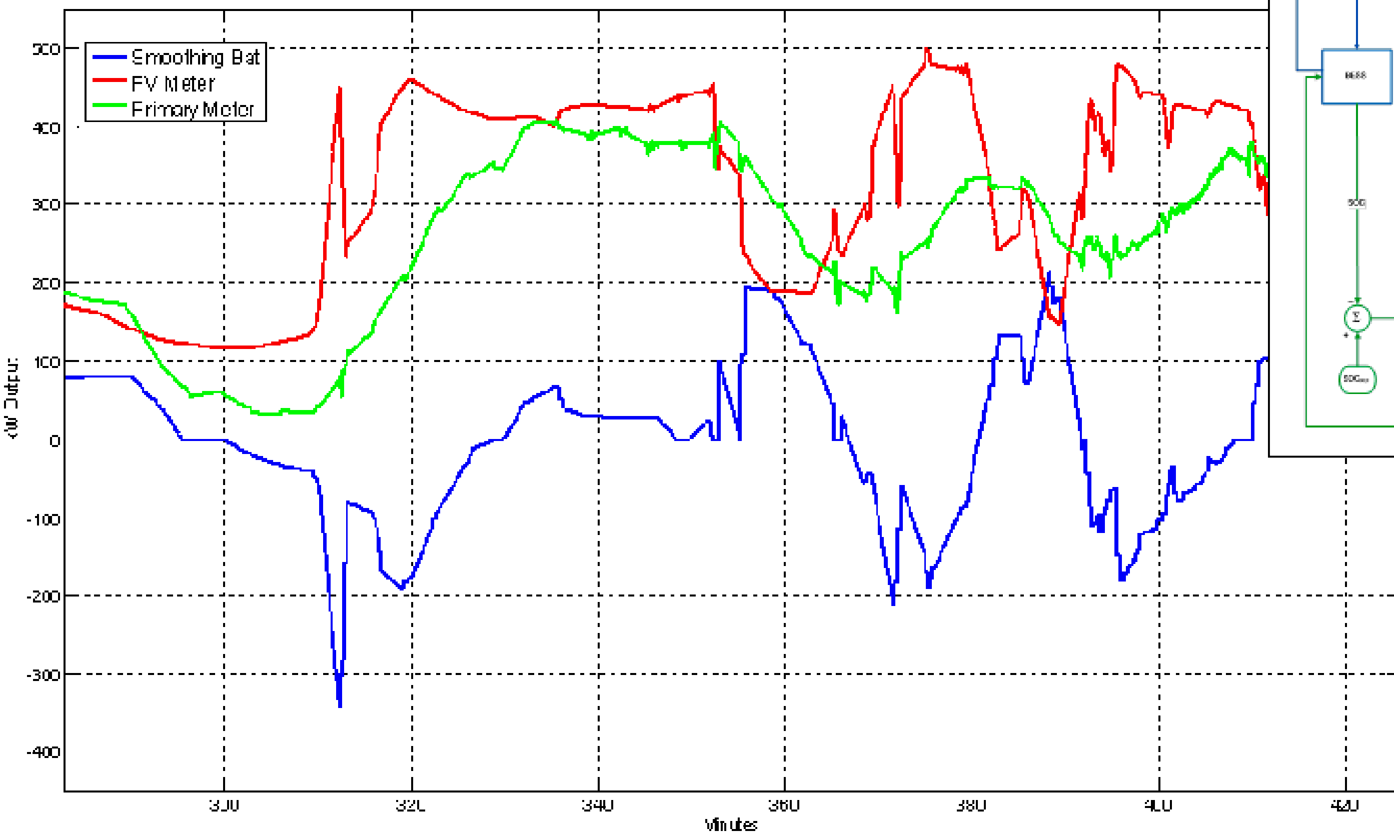
Coordinated Controls

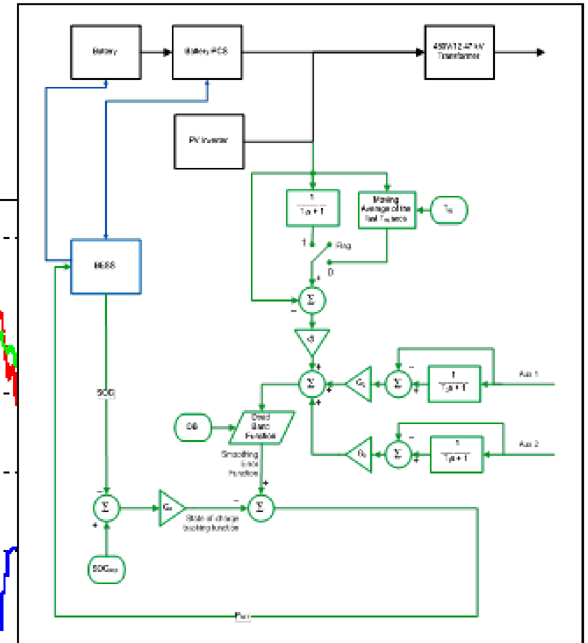
- Presently, the Prosperity and MdS controllers have similar objectives, but work independently
- Why?
  - Larger controllable system asset
  - Optimization across larger set of resources
  - Identify/understand/address technical challenges



PNM Battery-Based Smoothing Control

- Sandia work builds on on-going control design and demonstration at PNM's Prosperity Site
  - Similar to project in LAC

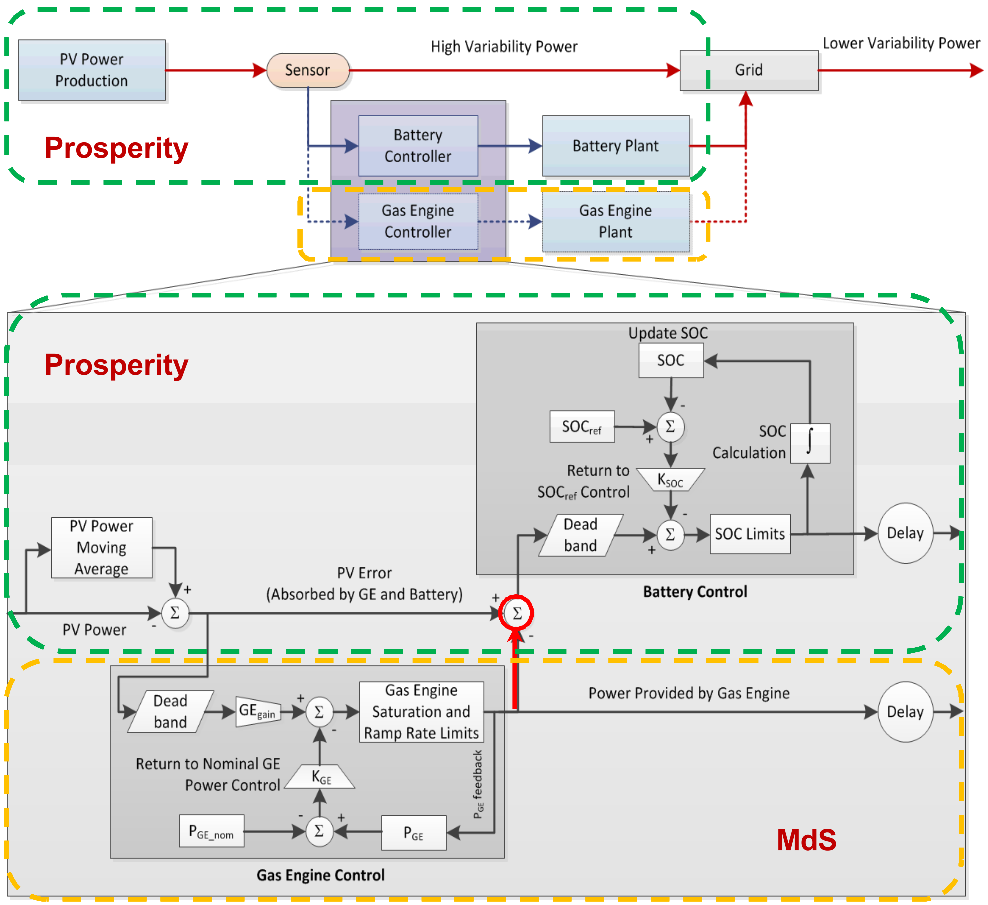




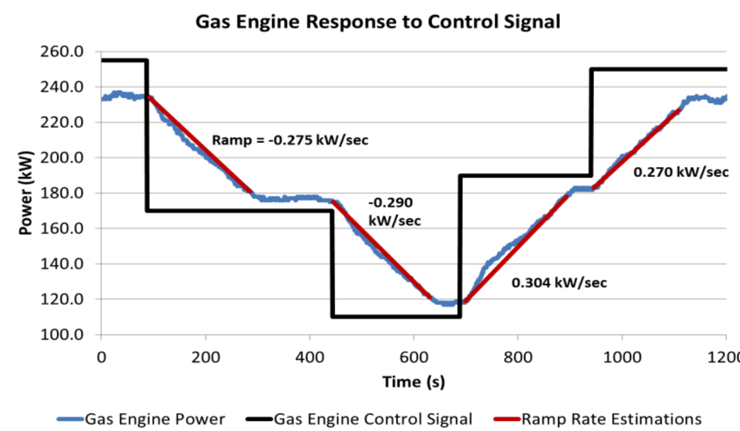
References:

Control Design

- Baseline: assume that Battery controller is aware of MdS DG output
- Summation to be implemented at the Prosperity (SOC is proprietary)



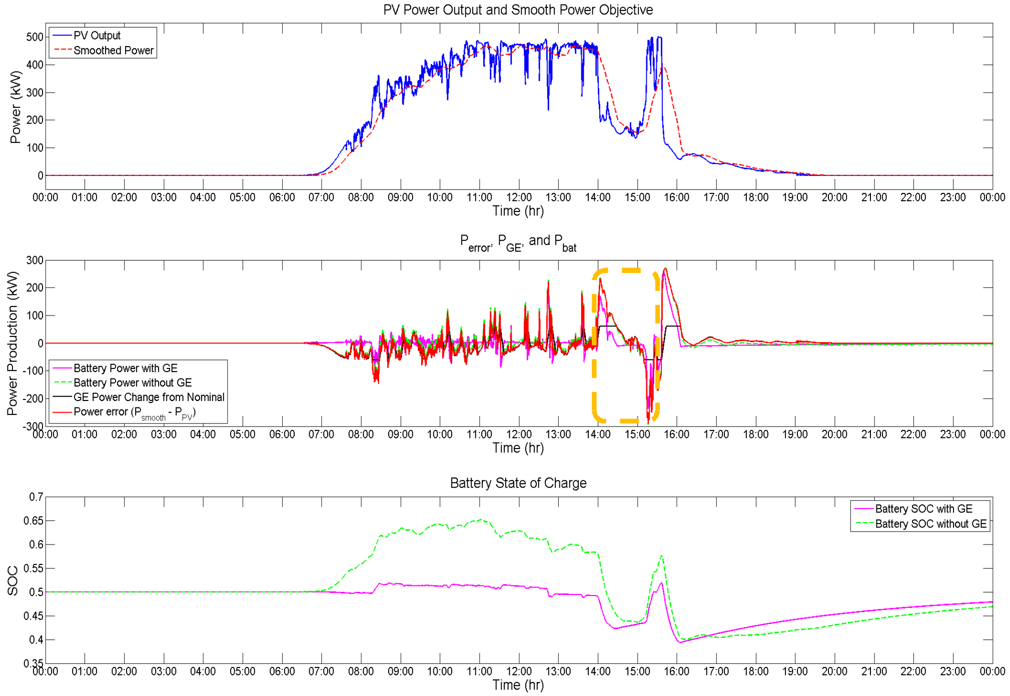
Parameter	Default Value	Range of Values
GE_{gain}	1	0-1
T_w	300 s	300-1800 s
K_{SOC}	100	10-1000
K_{GE}	$0.2*GE_{RRSat}$	$0.05*GE_{RRSat}$- $0.5*GE_{RRSat}$
GE Delay	0 s	0-5 s

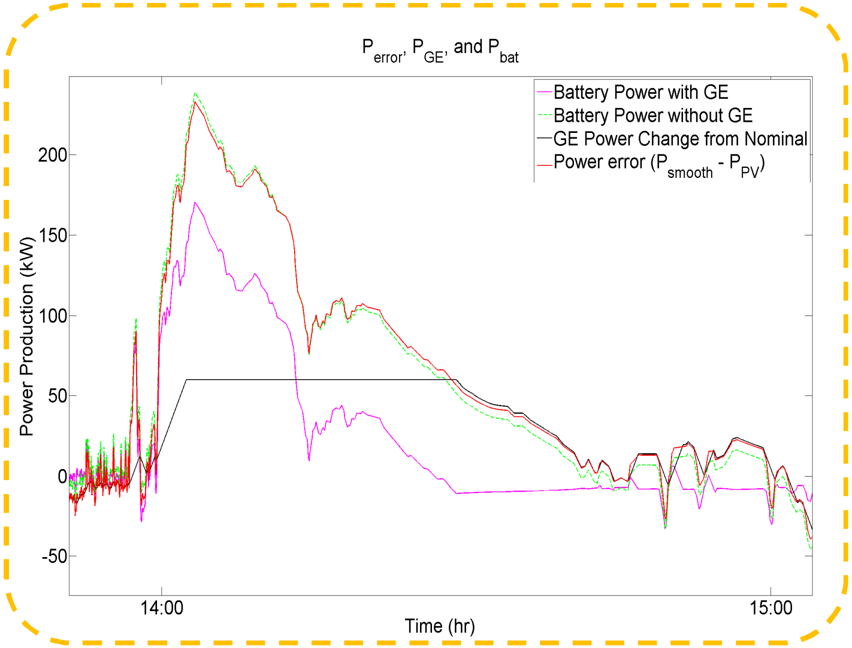


Representation of MdS gas engine. Fuel cell not modeled explicitly— equivalent to increasing GE ramp rate by 20%

Simulation Example (with Comm.)

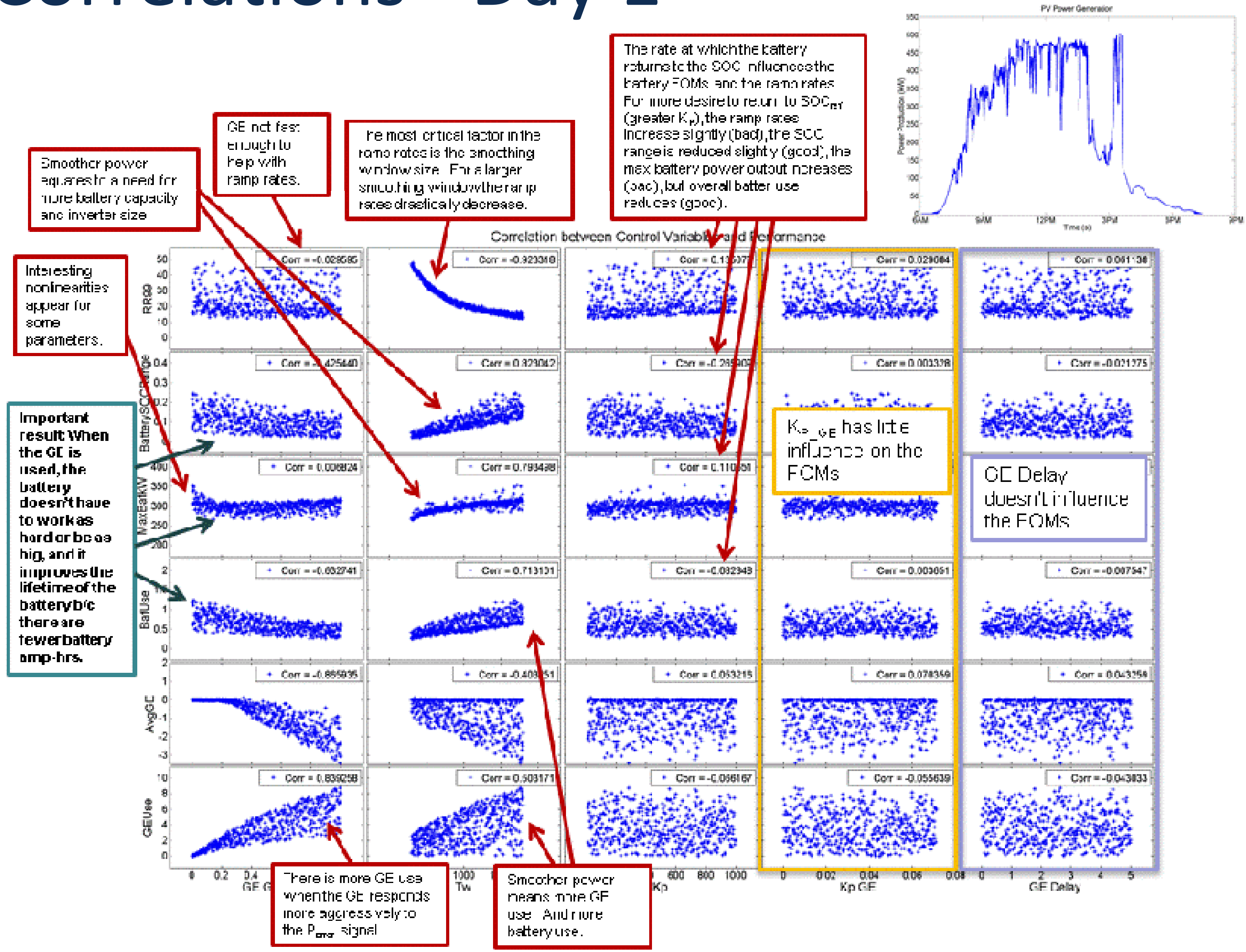
- Same smoothing performance with and without the gas engine
  - With the gas engine, battery SOC swing and maximum PCS power are smaller
  - Because the gas engine very is slow, battery must cover fast PV ramps
  - Gas engine saturates during sustained PV ramps





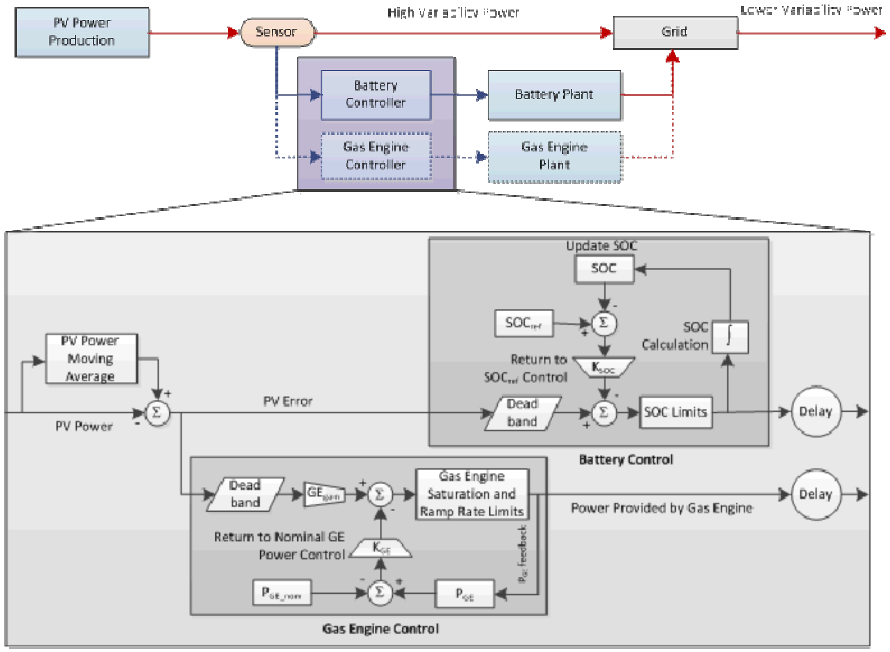
NOTE: For ease of comparison, gas engine is plotted as delta from target level (180 kW)

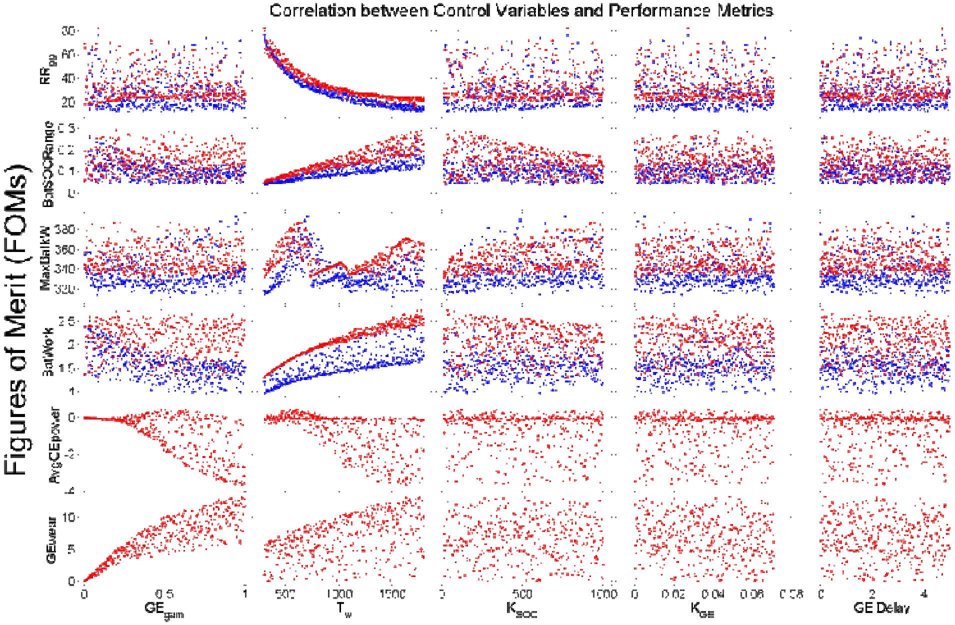
Correlations - Day 1



Control Without Communications

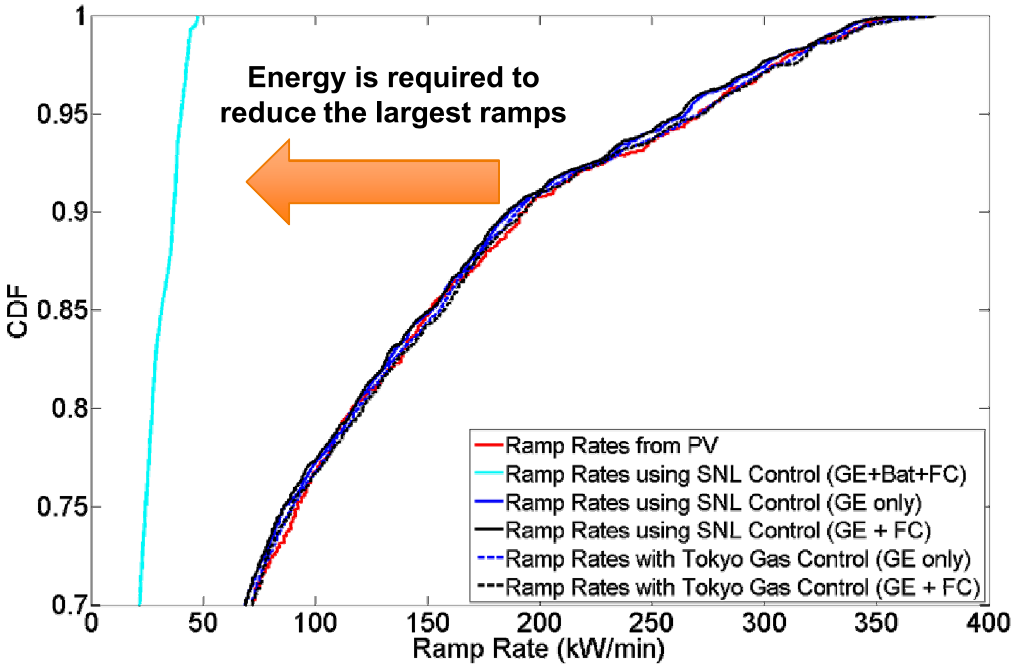
- Performance is not as good with respect to all FoM
  - GE_{gain} and T_w still have the largest effect
- Communications also enables wider range of DER dispatch (e.g., feeder peak load saving or transmission reliability support)





Validation of Simulation and Field Test

- Tokyo Gas field tests compare well with Sandia model
  - Confirmed benefit in terms of battery SOC range and PCS size reduction
  - However, the gas engine and fuel cell do not significantly reduce PV ramp rates (too slow—see figure below)
  - The battery provides the bulk of the ramp reduction benefit



References:

Conclusions

- Successful collaboration on several important R&D topics
  - PV Output Variability
  - Anti-islanding
  - PV Output smoothing using Smart Grid approach
- Planned follow-up research