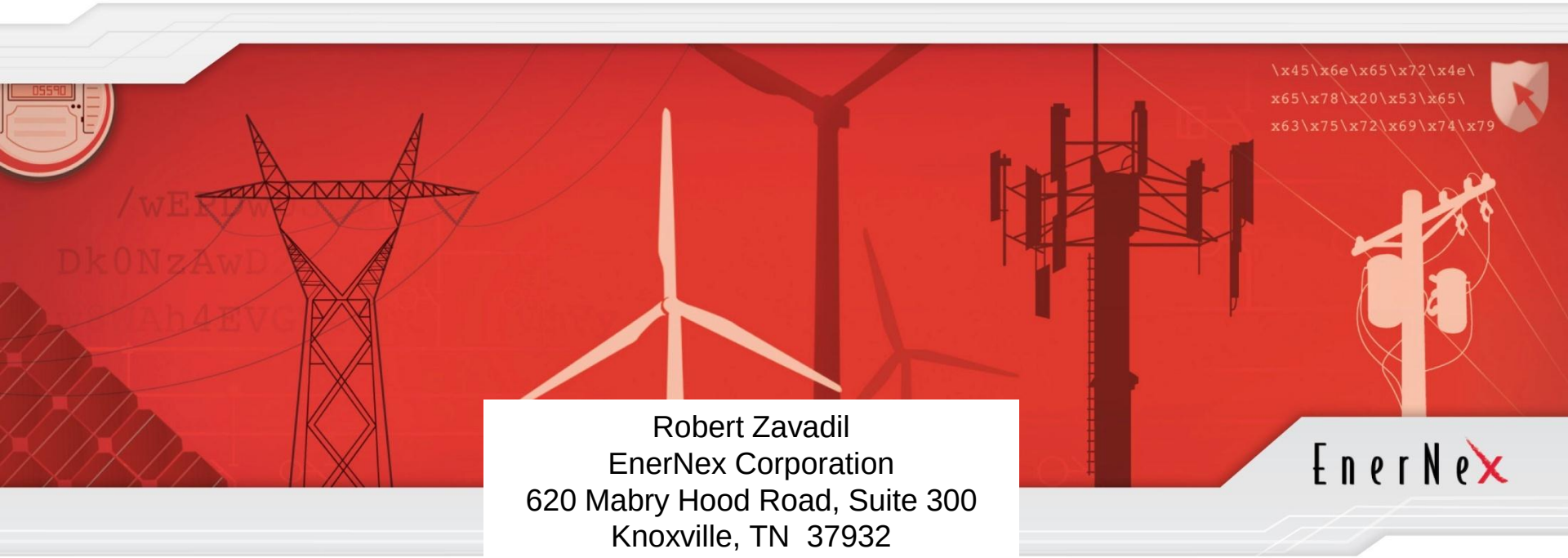
Kauai Island Utility Coop
PV Integration Study



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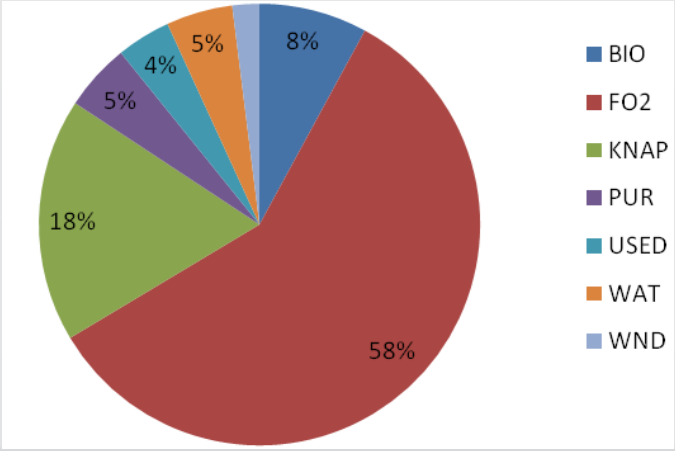
Study Background

- Sandia-supported project for Kauai Island Utility Cooperative (KIUC)
- Assess "integration impacts" of moderate amount of solar PV on small island power system
  - ~80 MW peak load
  - Up to 15 MW PV
  - 100+ MW conventional capacity

	Installed PV Capacity (MW)		
Location	Scenario 1	Scenario 2	Scenario 3
Site 1	3	3	3
Site 2	1	1	3
Site 3	1	1	3
Site 4	-	3	3
Site 5	-	1	1
Site 6	-	1	1
Site 7	-	-	1
Total	**5**	**10**	**15**

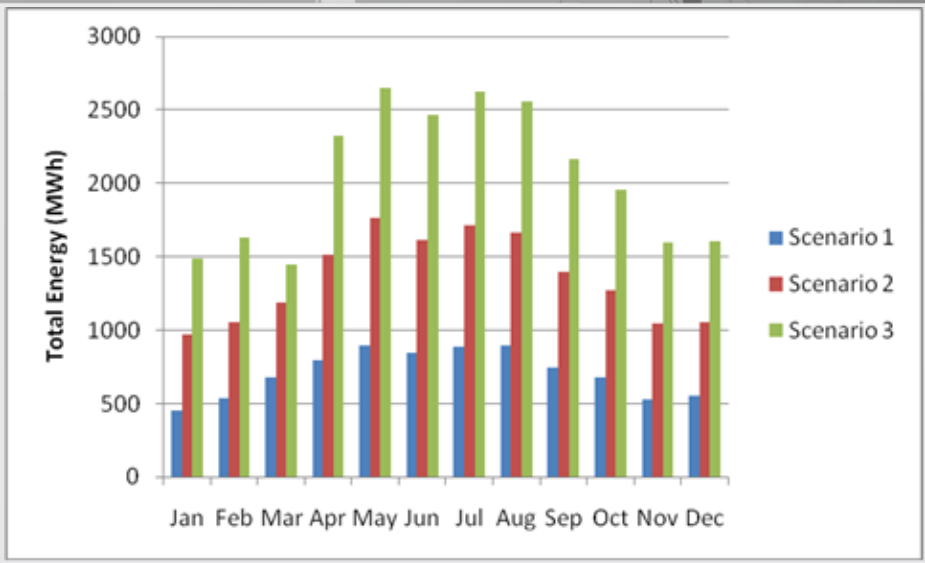


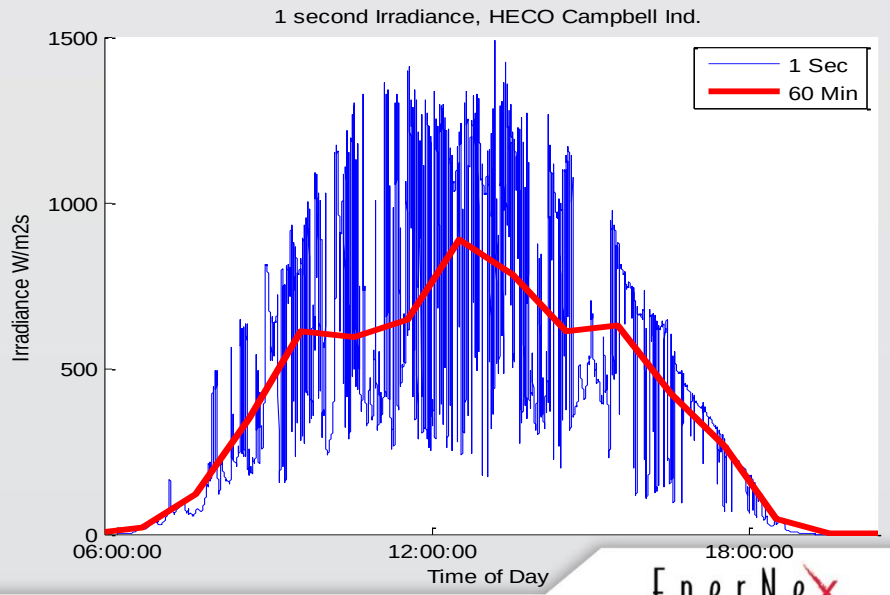
Issues and Challenges

- "Integration Impacts" quite different for small isolated power system
  - Greater emphasis on short-term phenomena, e.g. regulation/frequency control
  - Little resource diversity
    - System control accomplished with one or two designated units
    - Solar resources exposed to similar sky conditions
- Challenges for this study
  - Analytical:
    - Methods utilized for mainland/large system studies not adequate
    - Need increased temporal resolution – fast variations in RE output are important
    - Frequency control is the measure of impacts
  - Data
    - High resolution, long term PV production data critical
    - Not generally available
    - "Patchwork" of data from various Hawaii sources used

Characterizing PV Variability

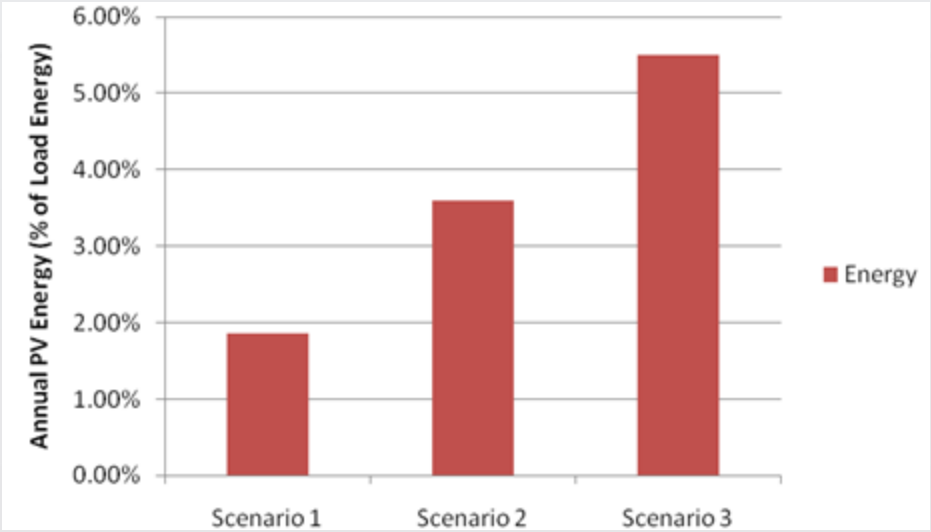
- Focus on:
  - Seasonal
  - Hourly
  - Sub-hourly, to highest resolution available
- Also necessary to capture scenario differences
  - Smoothing due to spatial diversity
  - Proper scaling of all sub-hourly production changes
- Available data was limiting factor
- Multiple monitoring sites from across Hawaii examined to guide profile construction

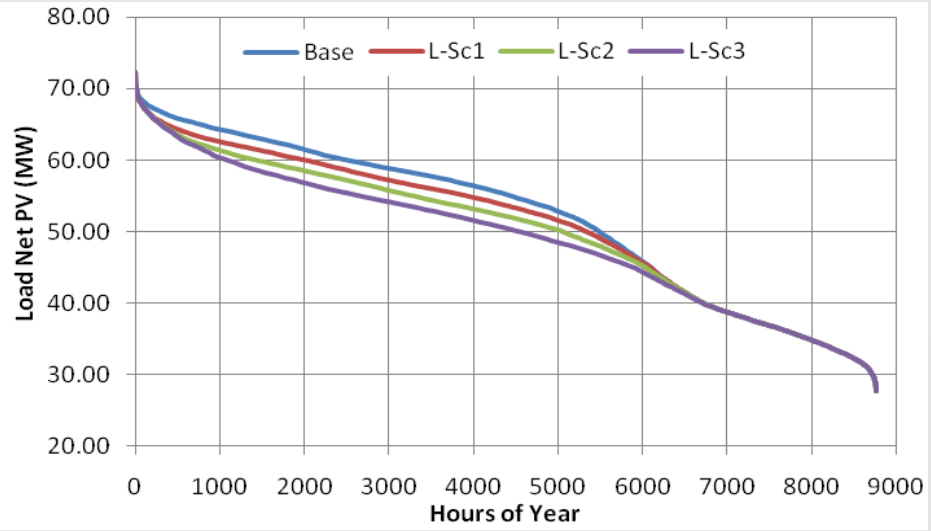


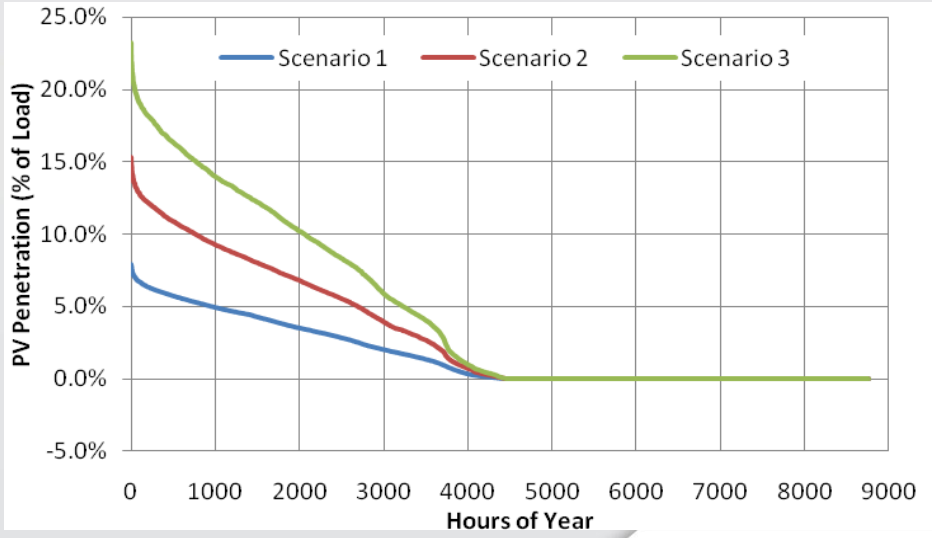


Scenario Characteristics

- Up to about 6% of annual energy
- Penetration relative to load is significant for moderate number of hours in larger scenarios

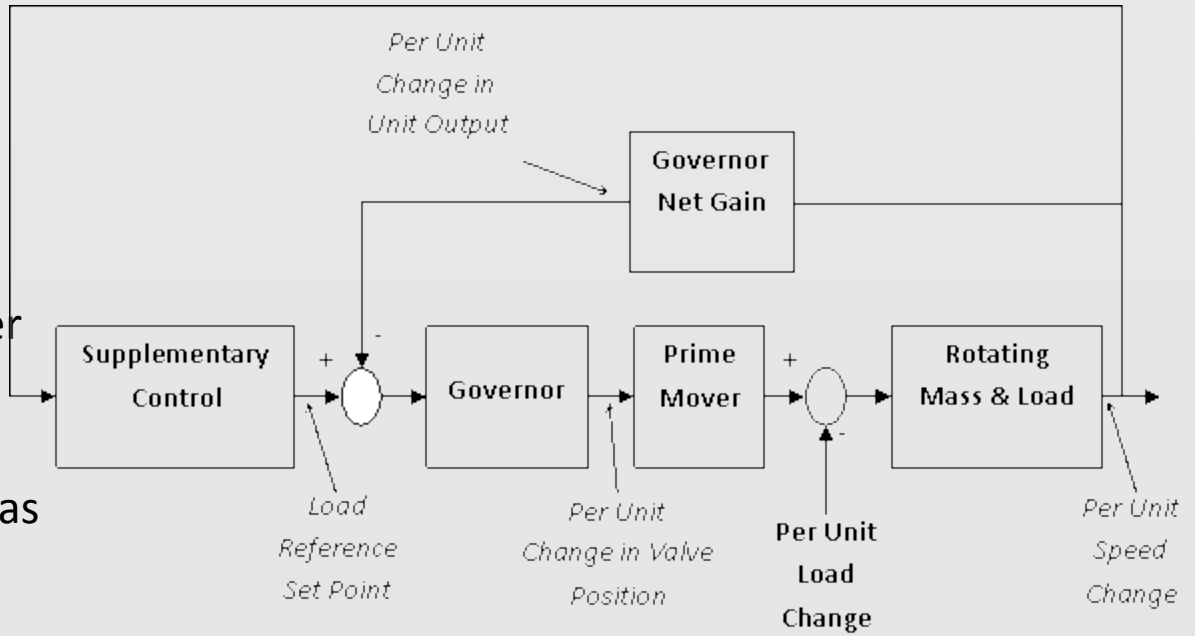






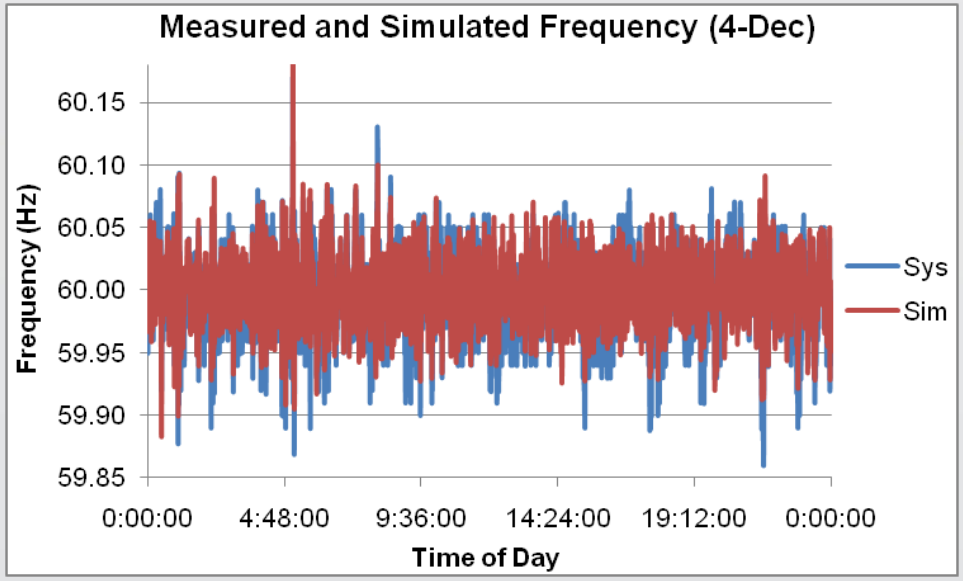
Frequency as an Integration Metric

- Load/generation imbalances manifested directly as frequency deviations
- No "hard limit" for allowable frequency variations
  - Smaller systems – wider frequency deviation band
  - Assumed that desire was to maintain historical frequency control performance
- Translation of imbalance into frequency requires "dynamic" model



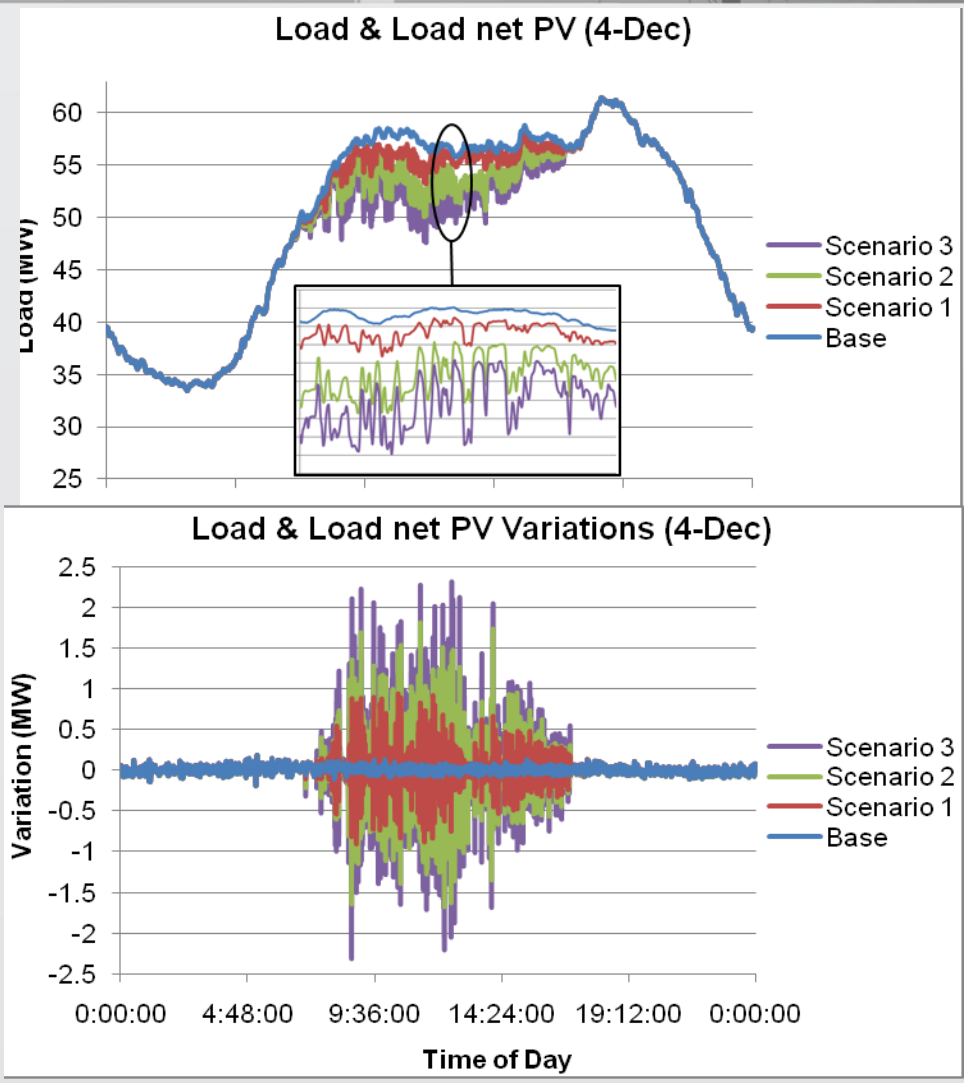
Calibrating the model

- Use high resolution load, generation, and frequency data (selected periods available)
- Calibrate dynamic model parameters to reproduce frequency control performance
- Statistical comparison



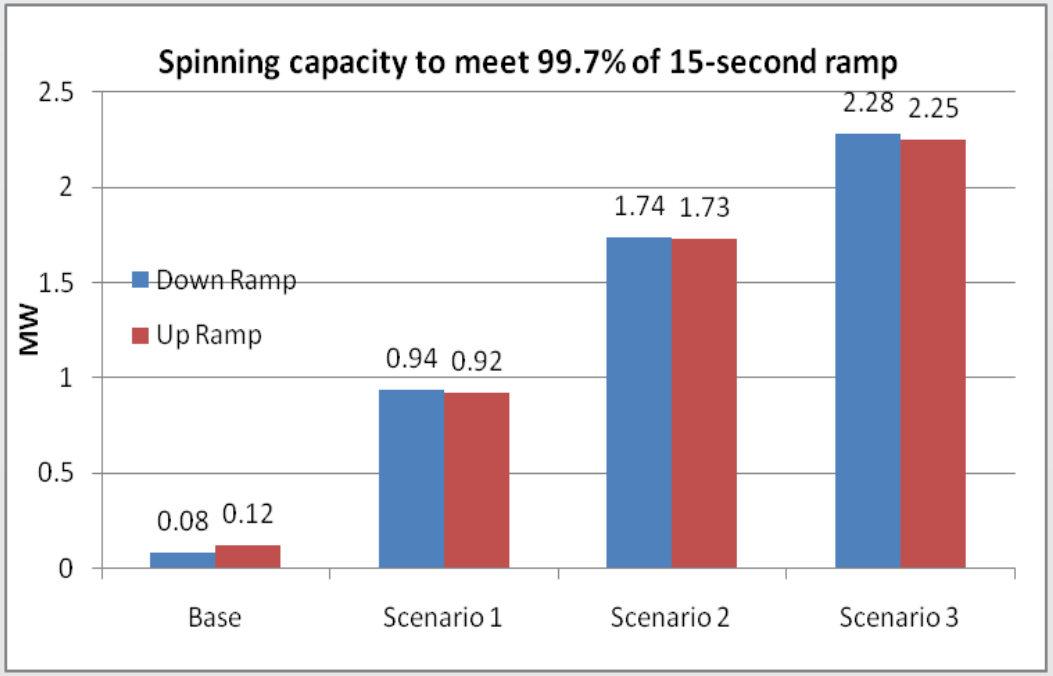
Assessing PV variability impacts

- Net load variations fed into dynamic model
- Model parameters (primarily regulation range) adjusted until statistics of frequency control match load-only case
- New parameters capture increase control requirement



Results

- Amount of spinning reserve for frequency control increases with PV penetration
- Effects are confined to
  - Fastest variations; little to no impact on slower ramping requirements
  - Possible “contingency” events



Range of monthly maximum load changes for study period in 2011	PV Penetration							
	Base Case		Scenario 1		Scenario 2		Scenario 3	
	From	To	From	To	From	To	From	To
Regulating (MW/15sec)	0.10	0.34	0.95	1.69	1.66	2.90	2.25	4.35
Load-Following (MW/h)	7.45	10.79	7.30	10.72	7.23	10.65	7.07	10.53

Looking back, and forward…

- Study retrospective
  - Unique characteristics of KIUC system necessitated different study approach
  - Solar PV profile, variability data is a critical need, in general
  - Adequate data would allow more comprehensive examination of “tail” events, impacts on system operating cost
- Opportunities for facilitating PV integration into KIUC system
  - More detailed KIUC dynamic model would be helpful – allow for specific controls tuning and changes in operational practices (or application of storage resources) as PV penetration grows
  - Enhanced solar data will provide more solid foundation for technical analysis

Looking Real:
KIUC to Develop Kauai's Largest Solar Project

Līhu'e, Kaua'i, Hawai'i – October 6, 2011 - Kaua'i Island Utility Cooperative (KIUC) is pursuing the development of an approximately 10 megawatt photovoltaic (PV) project. Upon completion the project will be the largest PV facility in Hawai'i and the largest on the island of Kaua'i by almost two times.

The cooperative will immediately begin efforts to obtain approval from the U.S. Department of Agriculture's Rural Utilities Service (RUS) to reallocate up to $68 million of previously approved loan funds to construct an integrated PV and Battery Energy Storage System project on Kaua'i. The funds were originally approved for a 10 megawatt combustion turbine generator often referred to as "Gen X" or "CT2."

To qualify for federal tax incentives under the Stimulus Bill and Hawai'i state tax incentives, KIUC's board of directors last week approved the formation of a new for-profit subsidiary, KIUC Renewable Solutions One, LLC. The for-profit subsidiary is necessary because KIUC as a tax-exempt cooperative does not qualify for the federal or state incentives. KIUC expects that up to 50 percent of the cost of the PV portion of the facility will be paid for by the incentives. The subsidiary company will be 100 percent owned and controlled by the cooperative.

"KIUC is following a model employed by other electric cooperatives, to use a subsidiary to qualify for tax incentives only available to for-profit companies. We will combine the tax credits, our own low cost financing, and the declining cost of solar photovoltaic systems to produce energy at significantly less than the cost of power generated from oil. The cost for a KIUC owned PV facility will also be lower than the recently signed Power Purchase Agreement contracts due to our lower overall cost of capital," said KIUC president David Bissell.

A majority of KIUC's generation today still comes from fossil fuels, but the co-op has actively expanded its portfolio of renewable technologies. KIUC now has 17 megawatts of solar PV and biomass-fired generation projects under Power Purchase Agreements. Approximately 35 megawatts of low-impact hydropower projects are being studied, but KIUC has not determined whether additional clean, renewable hydropower can be feasibly developed on Kaua'i.

A Request for Proposal to contractors to build the PV facility was released this week. "We are on a very short timeline to qualify for the federal incentives," said **Brad Rockwell, KIUC manager of production. "With this facility we would have about 20 megawatts of solar PV on our system, and that is why we are integrating the Battery Energy Storage System to handle that level of intermittent resource and still have excellent reliability," he added.**

"KIUC would have more solar PV concentration than any utility in the U.S. if this project can be successfully developed," added Bissell.

"The benefits are significant," said KIUC board chairman Phil Tacbian. "By using the RUS approved funds for solar development, the cooperative effectively shelves the combustion turbine plant and moves closer to giving our members the clean, renewable energy they have asked for."

The combustion turbine was originally hoped to be fueled by renewable bio-diesel, but that technology has not developed quickly enough to realistically use the RUS funds in the approved timeframe. A biomass-fired boiler at the Port Allen Generating Station was studied earlier this year, but its cost would appear to be less attractive than a solar PV facility according to KIUC's engineering analysis.

"With wind power not feasible due to endangered species concerns, combining solar PV with the Battery Energy Storage System moves us closer to the board's strategic goal of 50 percent renewable by 2023. If we are able to develop additional low-impact, clean hydropower later this decade, we will get there ahead of schedule," added Tacbian.

Kaua'i Island Utility Cooperative (KIUC) is a not-for-profit generation, transmission and distribution cooperative owned and controlled by the members it serves. Headquartered in Lhu'e, Kaua'i, Hawai'i, the cooperative currently serves more than 32,000 electric accounts throughout Kaua'i. Committed to reinventing how Kaua'i is powered, KIUC is aggressively pursuing diversification of its energy portfolio to include a growing percentage of hydropower, photovoltaic, bio-fuel, and biomass. For more information on Kaua'i Island Utility Cooperative, visit www.kiuc.coop. For more information on PV and renewable energy, visit www.kiucrenewablesolutions.coop