Energy Storage Deployments in Hawaii

GridSTART
Hawai'i Natural Energy Institute | University of Hawai'i
Grid System Technologies Advanced Research Team

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UNIVERSITY of HAWAI'I
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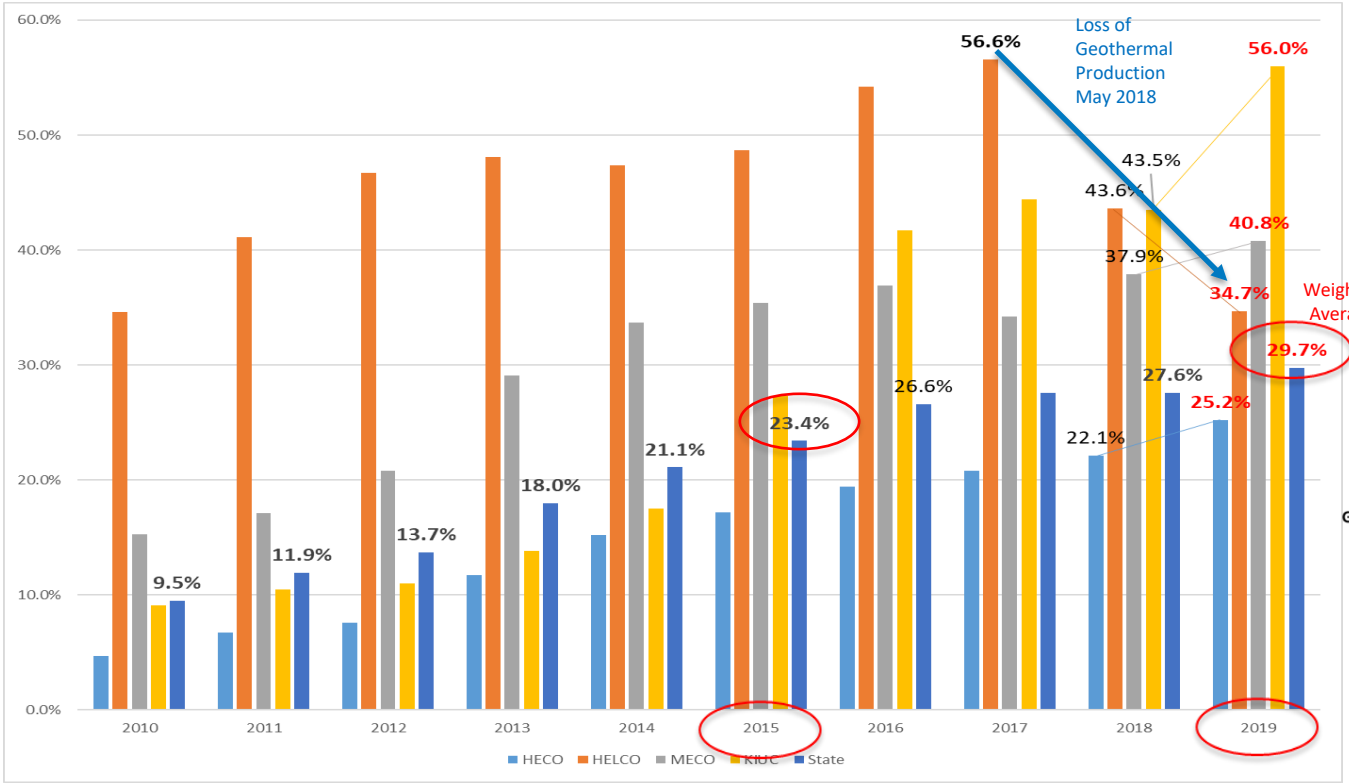
Energy Storage: What, When, Why, Where and How?

Alaska Wind-Diesel Workshop
January 13, 2021

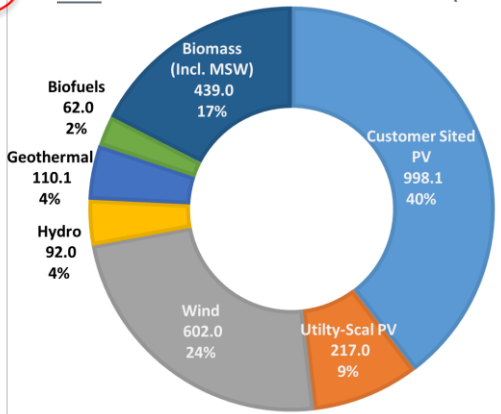
Progress Exceeds Hawaii RPS Goals



Hawaii RPS Goals

2015 - 15%
2020 - 30%
2030 - 40%
2040 - 70%
2045 - 100%

2018 STATE RENEWABLE ENERGY GENERATION (GWHS)



Source: Hawaiian Electric and Kaua'i Island Utility Cooperative RPS Reports

Distributed PV Circuit Penetrations in Hawaii

Maui Electric

Maui System Peak: 202 MW

119 MW PV / 72 MW Wind

Installed PV & Wind:

95% of Sys. Peak

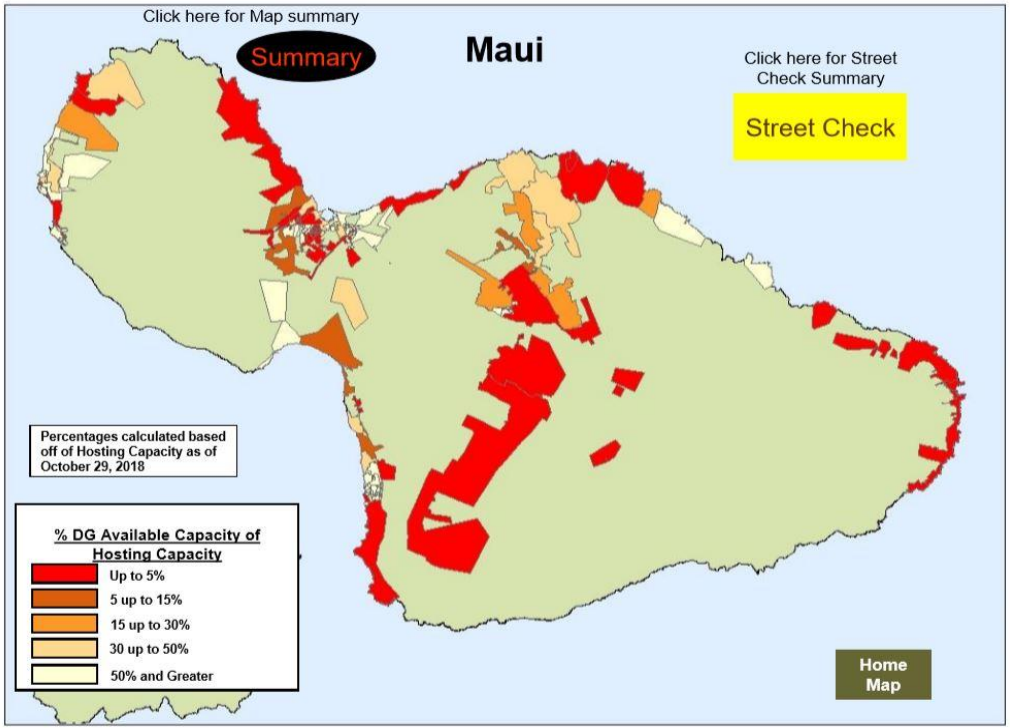
DG PV capacity = 56% peak load

13% Energy

Wind capacity = 36% peak load

21% Energy

Reverse power flow exists on the vast *majority* of distribution circuits today



PV penetration on some circuits exceed 300% Daytime Minimum Load (DML)

Hawaii Distributed PV Programs Shifting to Storage

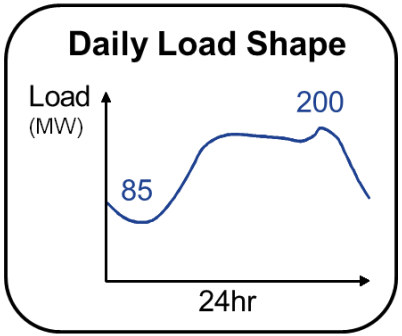
Program	Grid Export Rate*	Battery Storage Required?	Grid Export Window	Controllable?	Wireless Availability Required?
Customer Grid-Supply Plus	10 cents/kWh	No	Daylight	Yes	Yes
Smart Export	15 cents/kWh	Yes	4 p.m. to 9 a.m.	No	Yes
Customer Self-Supply	N/A	No, but usually installed	N/A	N/A	No
SIA	N/A	No	N/A	No	No

Smart Export customers with a renewable system (typically rooftop PV) **and battery energy storage system** have the option to export energy to the grid from 4 p.m. – 9 a.m. Systems must include grid support technology to manage grid reliability and system performance.

Maui Island

Leading the way in combined Solar and Wind integration

68,000 Customers



Wind - 72 MW
PV - 205 MW
277 MW

113 MW **Existing** Distributed PV
17 MW Approved Distributed PV
75 MW PPA Awarded PV+BESS
205 MW Total

Installed PV & Wind @ 137% of System Peak Demand

Solutions to Increase Wind Energy Delivered on Maui

Facility	Percent of available energy delivered (% before / % after)	% increase in delivered energy
Plant 1	97% / 99%	2%
Plant 2	72% / 84%	17%
Plant 3	27% / 45%	**68%**

BESS Function

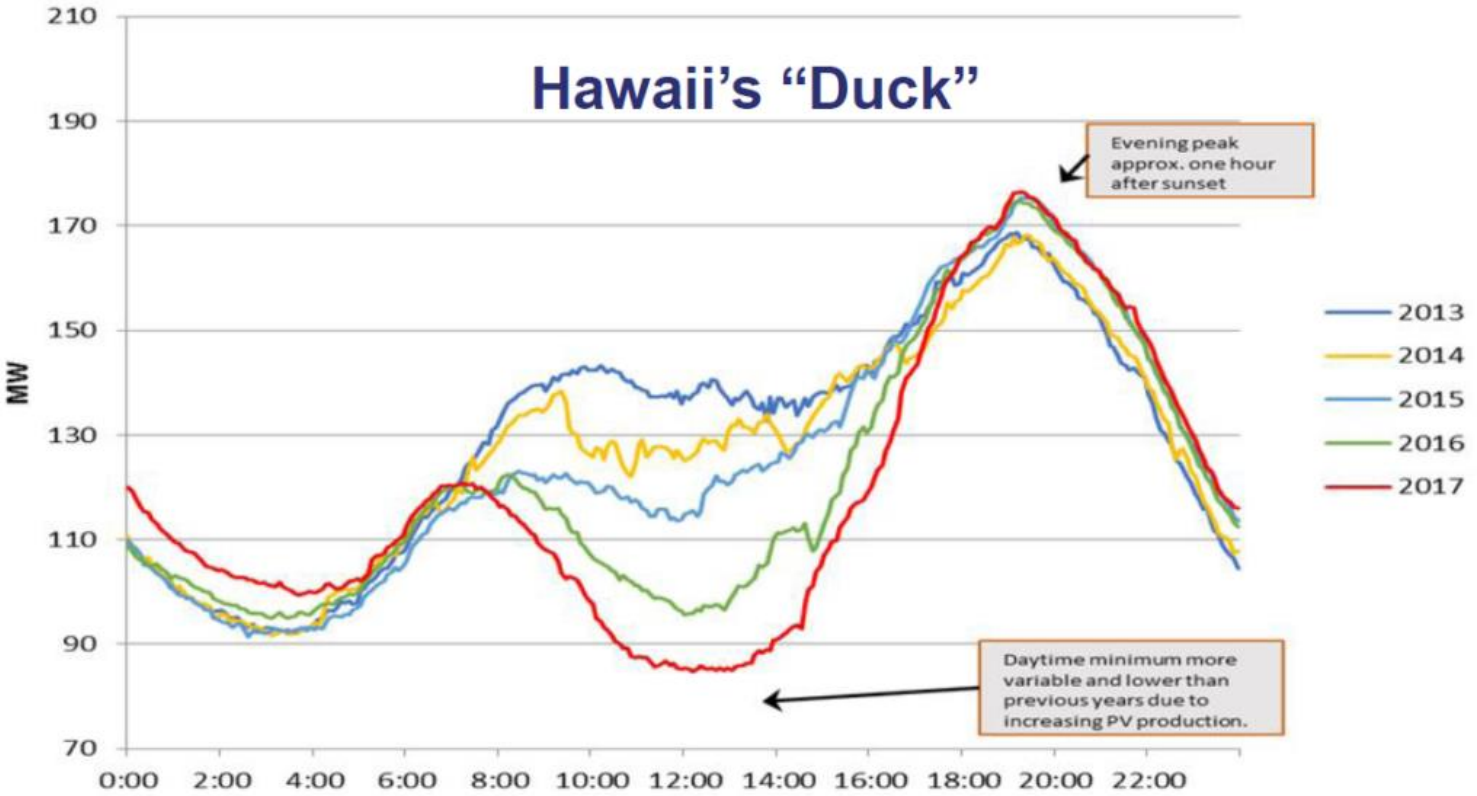
- 10MW / 20MWh
- Manual and AGC Dispatch
- Aggressive frequency Response
- Ramp Rate Limit within a limited SOC Range

MECO Operations

- Include 10MW of BESS in Up Reserve
- Reduce Down Reserve of M14 & M16 by 1.5MW
- Reduced Operation of K1 and K2
- 50MW Up-Reserve Limit

Result: Reasonably priced bankable wind projects

Net Load Curve



"Hawaiian Electric Announces 'Mind-Blowing' Solar-Plus- Storage Contracts"

Source: Jan. 4, 2019, Greentech Media

"It's hard to overstate the scale of this announcement," said Dan Finn-Foley, a senior energy storage analyst at Wood Mackenzie Power & Renewables.

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

NEWS RELEASE

FOR IMMEDIATE RELEASE

New solar-plus-storage projects set low-price benchmark for renewable energy in Hawai'i

Seven contracts submitted to regulators for review

HONOLULU, Jan. 3, 2019 – Hawaiian Electric Companies have submitted contracts for seven grid-scale, solar-plus-storage projects on three islands to the Public Utilities Commission for review. The projects are part of the largest and lowest cost portfolio of new renewable energy resources to be assembled in Hawai'i.

The projects – three on O'ahu, two on Maui and two on Hawai'i Island – will add approximately 262 megawatts (MW) of solar energy with 1,048 megawatt-hours (MWh) of storage. The energy storage can provide four hours of electricity that can further reduce fossil fuel use during peak demand in the evening or at other times when the sun isn't shining.

HECO to install 1 GWh of new BESS
Entire BESS market in US today is 1.4 GWh

Project name	Island	Developer	Size	Storage	Cost per KWh
Waikoloa Solar	Hawai'i	AES	30 MW	120 MWh	$0.08
Hale Kuawehi	Hawai'i	Innergex	30 MW	120 MWh	$0.09
Kuihelani Solar	Maui	AES	60 MW	240 MWh	$0.08
Paeahu Solar	Maui	Innergex	15 MW	60 MWh	$0.12
Hoohana	O'ahu	174 Power Global	52 MW	208 MWh	$0.10
Mililani I Solar	O'ahu	Clearway	39 MW	156 MWh	$0.09
Waiawa Solar	O'ahu	Clearway	36 MW	144 MWh	$0.10

Source: Jan. 4, 2019, Greentech Media

Grid Scale BESS Projects (HNEI)

Demonstrate optimized BESS operating strategies for high value grid applications

Upolu Point, Hawaii Island (1MW, 250kWh)

- Frequency regulation and wind smoothing
- 3.3 GWh over 3yrs, > 6000 full cycles

Molokai Secure Renewable Microgrid (2MW)

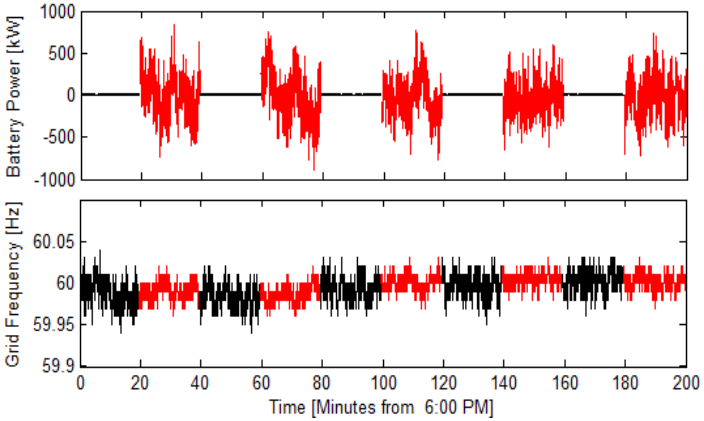
- Fast response decision and control (<50ms response)
- Operating reserves (fault management), frequency regulation,

Campbell Park industrial feeder with high penetration (1MW)

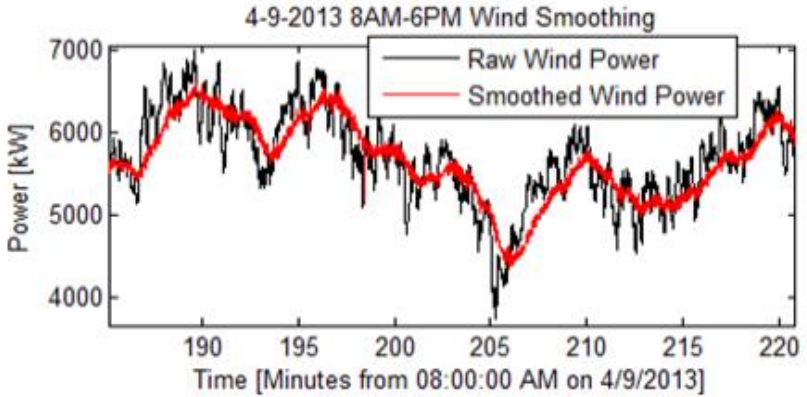
- Power smoothing, voltage and VAr support, and frequency regulation

Hawaii Island BESS Project

Frequency Regulation: 1MW BESS reduces Big Island frequency variability up to 40%

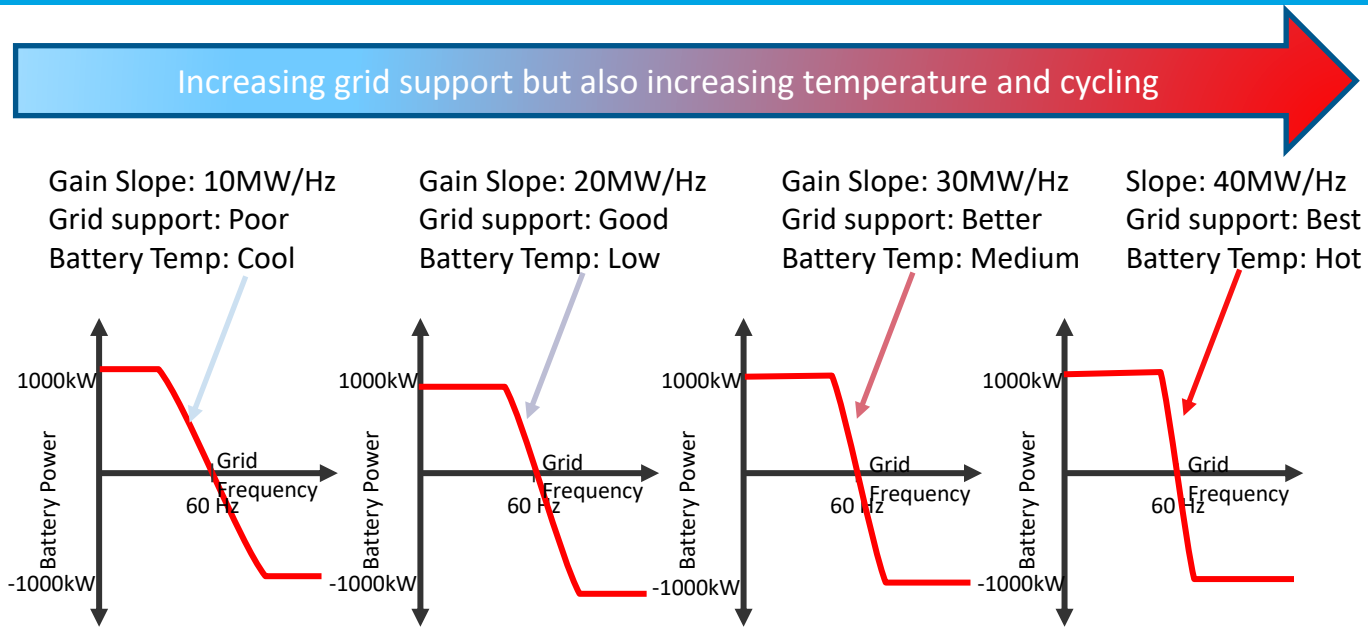


Wind smoothing: Significant reduction 1 min ramp rates



- Integrate with other technologies for longer events
- Analysis of utility operational value

Frequency Response Comparisons of Gain Settings

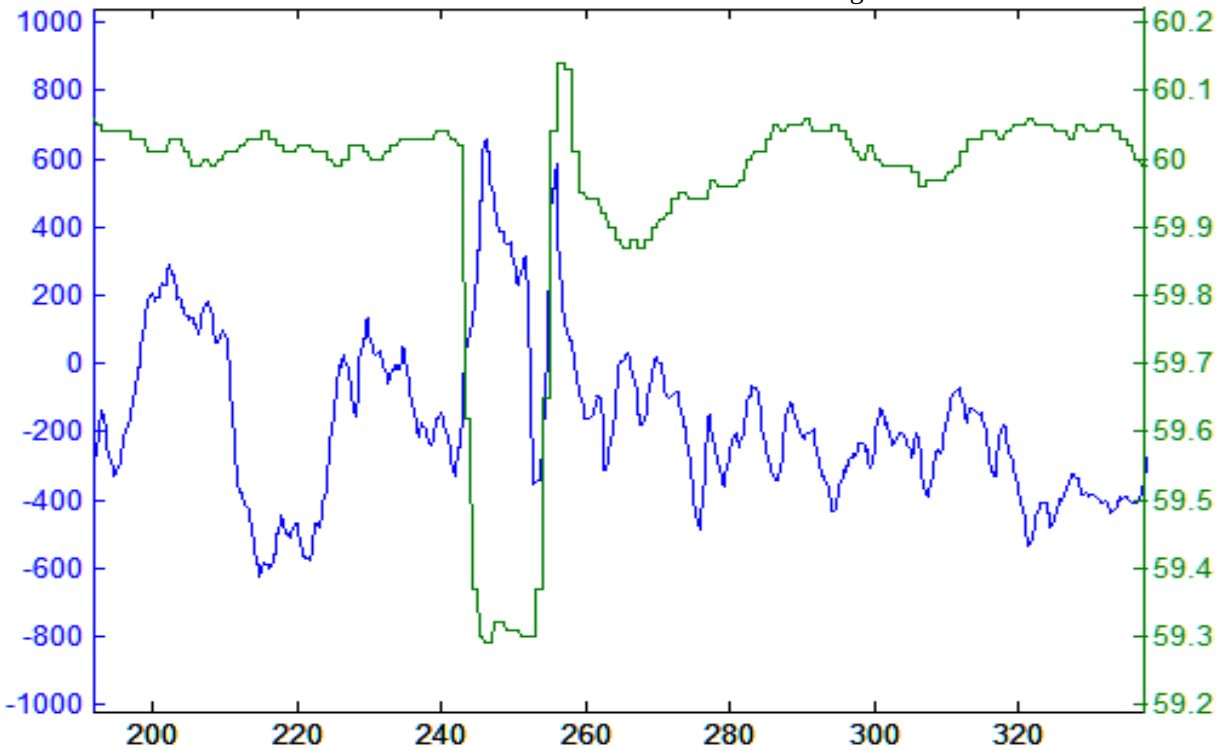


- When running at 40MW/Hz, under certain grid conditions, battery cell group temperatures approaching 55 degrees C have been observed.
- When running at 10MW/Hz, grid benefit is statistically insignificant.
- Setting is generally either 20MW/Hz and 30MW/Hz.

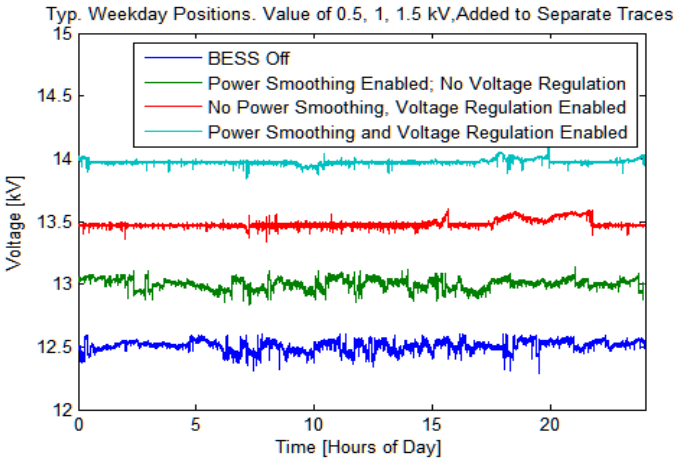
Operation Lesson Learned

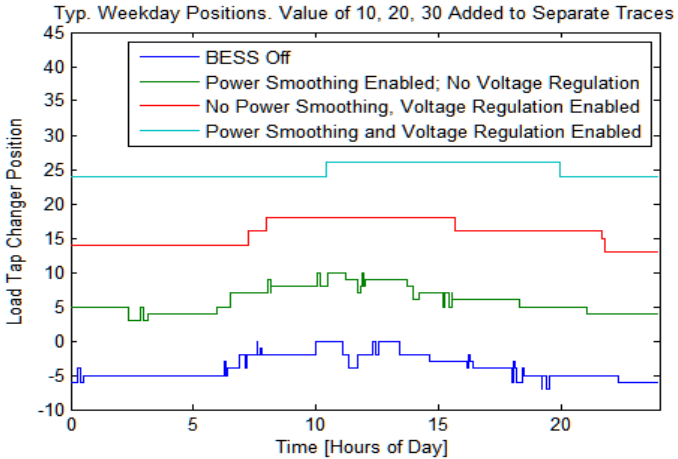
Wind Smoothing can Oppose Grid Needs

Hawi BESS on 11/9/2015: Wind-smoothing



Campbell Industrial Park BESS Project



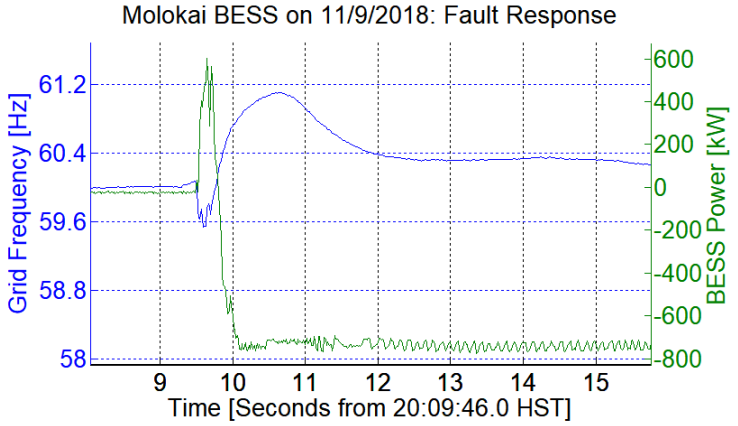


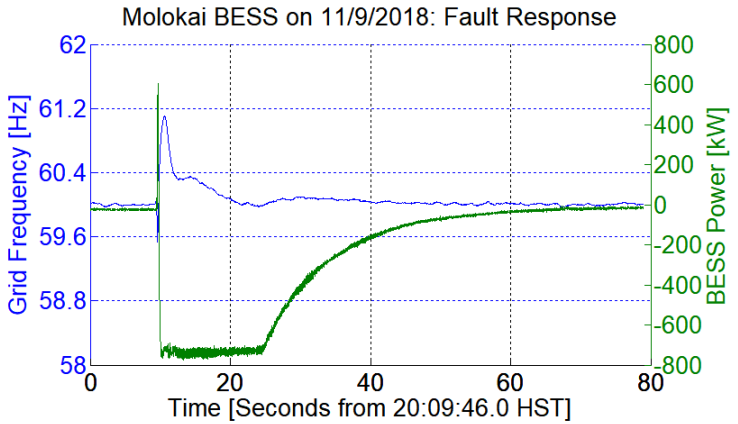
Case	Tap Changes	Voltage Variability [V]
BESS OFF	49	7.74
P Only	41	6.60
Q Only	5	4.21
P and Q	3	3.10

- Voltage regulation significantly reduces voltage variability, therefore reducing both the number of tap changer operations as well as range of movement.
- Real power smoothing is less effective in reducing voltage variability and tap changer operations.

Moloka‘i BESS Project

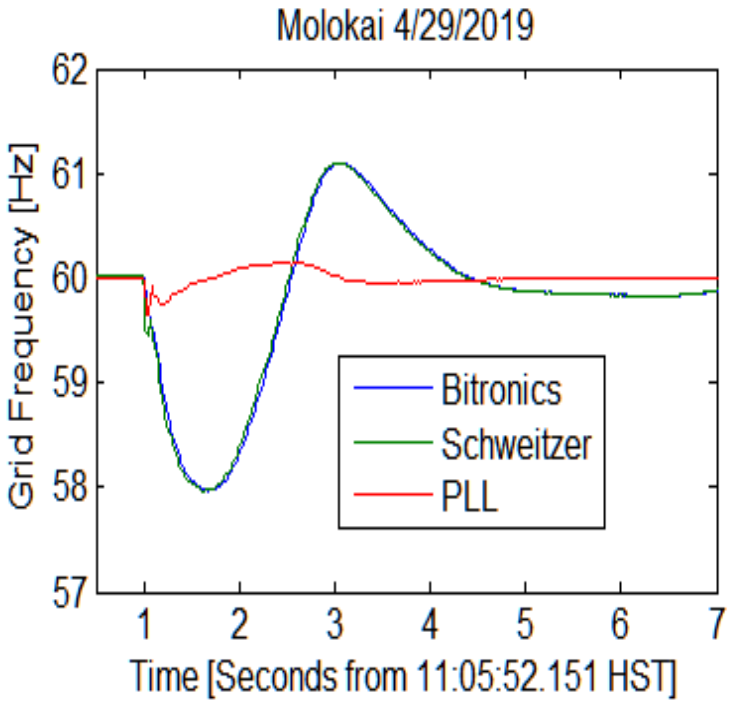
- The Molokai BESS provides fast frequency response, typically within 58 ms.
- The control algorithm can swing quickly from discharging power during a fault, to absorbing power after the fault clears.
- The algorithm then slowly hands off frequency regulation back to diesel generators slowly.



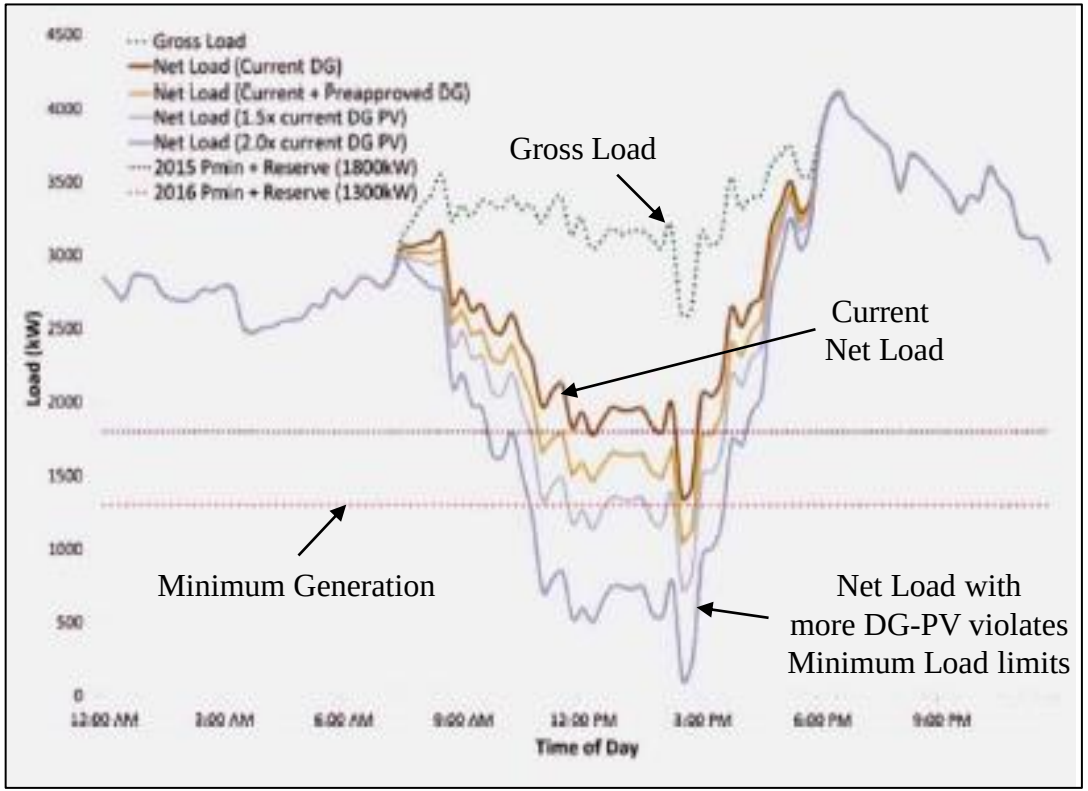


Measurement Methods Matter

- Bitronics fault data recorder and Schweitzer meter use the measurement time stamps to calculate frequency.
- The PLL algorithm in the inverter does not. Therefore the BESS did not respond appropriately during this event.
- Recent NERC guidelines highlight the importance of using appropriate measurement methods for protection actions

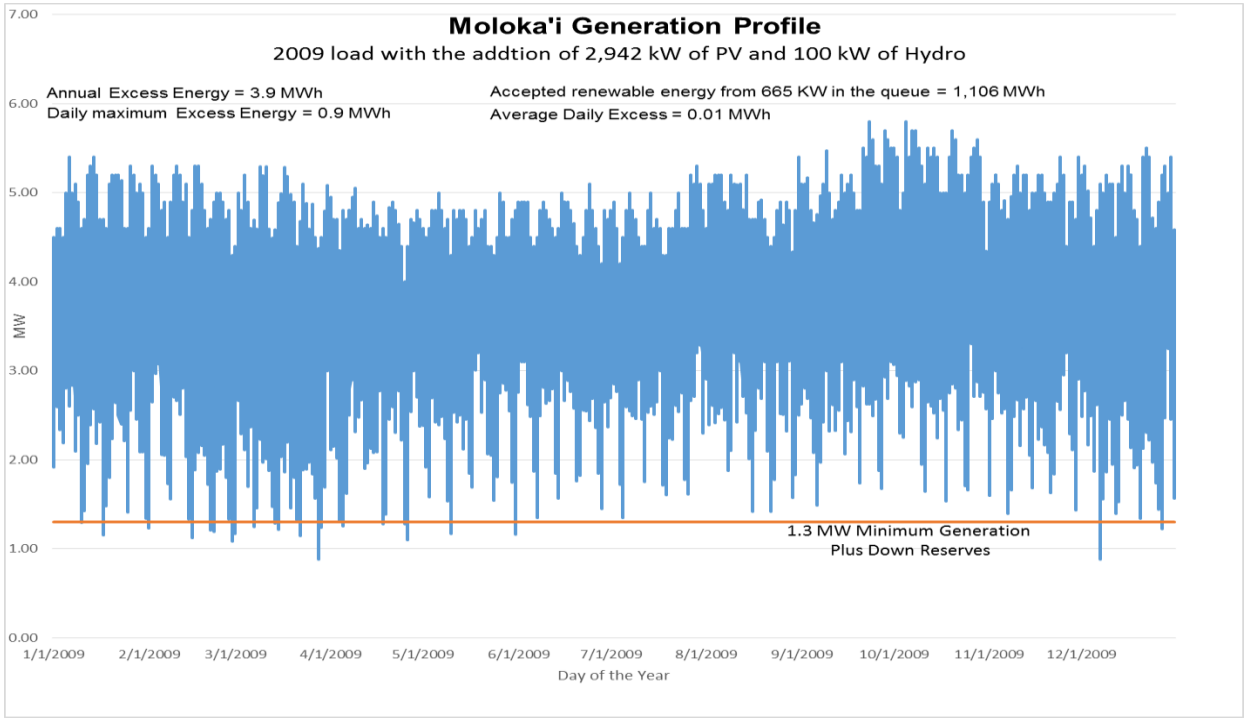


System level limit on Molokai island



Is storage the best solution?

PV curtailment can be a tool to add more …



Absorbing only 3.9 MWh excess energy enables the addition of 1,106 MWh of distributed PV on the island grid

Small to moderate amount of excess RE curtailment is a sound integration strategy

Alternatives to Storage

Dynamic Load Bank (Energy Safety Valve)

A 750kW Load bank was placed into service in November of 2018

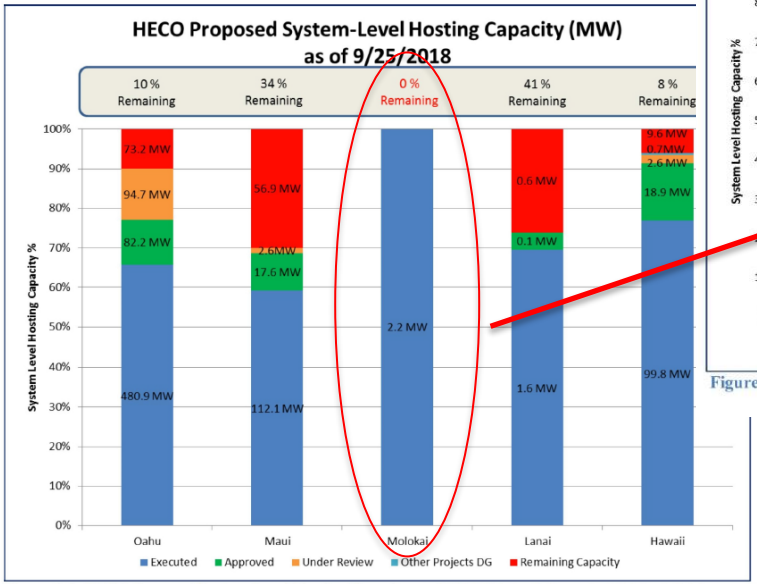


Figure 1-1. HECO Proposed System-Level Hosting Capacity as of 9/25/2018 (excludes controllable/curtailable capacity).

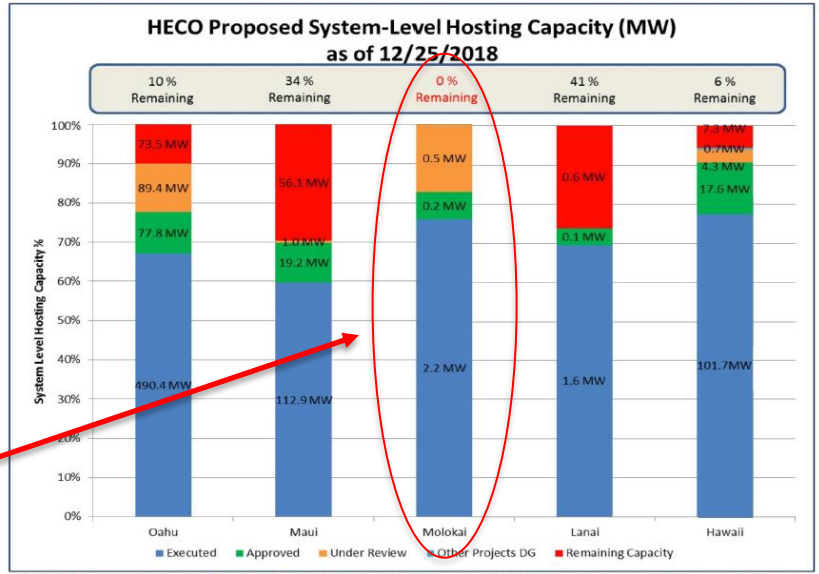


Figure 1-1. HECO Proposed System-Level Hosting Capacity as of 12/25/2018 (excludes controllable/curtailable capacity).

The 700kW held in the connection queue was then allowed to connect to the system.

Mahalo!

(Thank you)

For more information, contact:

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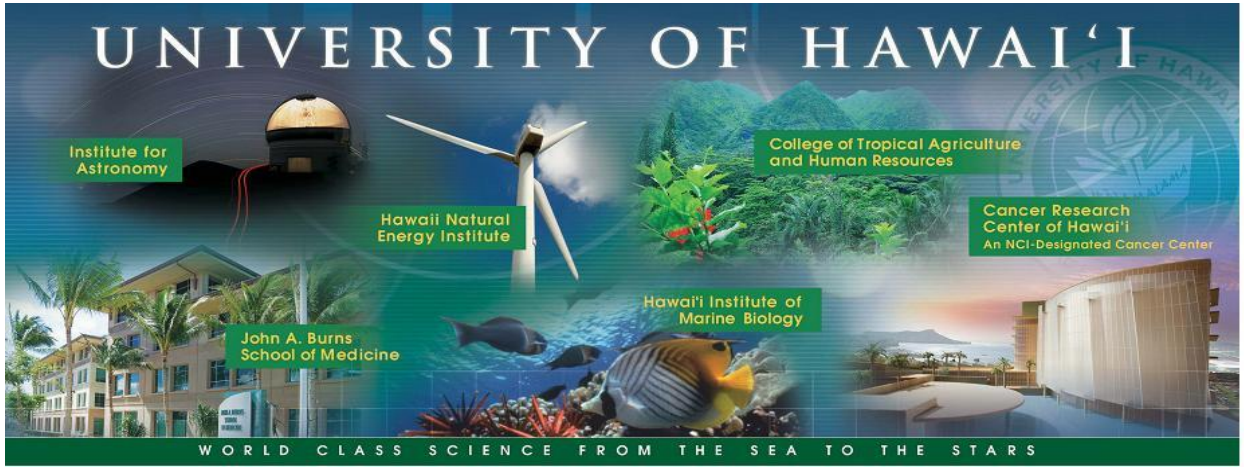
Marc M. Matsuura

Sr. Smart Grid Program Manager

Marc joined the Hawaii Natural Energy Institute (HNEI), School of Ocean & Earth Science & Technology, University of Hawaii at Manoa, in 2013 as the Senior Smart Grid Program Manager and is a founding member of Grid***START*** (Grid System Technologies Advanced Research Team).

Prior to joining HNEI, he was with the Hawaiian Electric Company for 21 years. His career at Hawaiian Electric included positions in the areas of Transmission & Distribution (T&D) Engineering, T&D Standards and Technical Services, System Operations, Transmission Planning, Smart Grid Planning, and System Integration. Marc is a licensed professional electrical engineer in Hawaii. He holds a B.S. in Electrical Engineering and an M.B.A. from the University of Hawaii.



- Established in 1907
- Statewide system with 3 universities & 7 community colleges
- Over 50,000 students
- Manoa is the largest and main research campus
  - 14,000 undergraduate students
  - 6,000 graduate students
- ***School of Ocean and Earth Science and Technology*** is the largest research unit on the Manoa campus

~$100 million extramural funding per year

Hawaii Natural Energy Institute (HNEI)

University of Hawai'i at Mānoa

Organized Research Unit in School of Ocean and Earth Science and Technology
Founded in 1974, established in Hawai'i statute in 2007 (HRS 304A-1891)

- Conduct RDT&E to accelerate and facilitate the use of resilient alternative energy technologies and reduce Hawaii's dependence on fossil fuels.
- Diverse staff includes engineers, scientists, lawyers; students and postdoctoral fellows; visiting scholars

Areas of Interest

- **Policy and Innovation**
- **Grid Integration (Grid*START*)**
- **Alternative Fuels**
- **Electrochemical Power Systems**
- **Renewable Power Generation**
- **Building Efficiency**
- **Transportation**

Core Functions

- **State Energy Policy Support**
- **Research & Development**
- **Testing and Evaluation**
- **Analysis**
- **Workforce Development**

GridSTART
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Grid System Technologies Advanced Research Team

Established to develop and test advanced grid architectures, new technologies and methods for effective integration of renewable energy resources, power system optimization and resilience, and enabling policies

- Serves to integrate into the operating power grid other HNEI technology areas: energy efficiency, renewable power generation, biomass and biofuels, fuel cells and hydrogen
- Strong and growing partnerships with Hawaii, national and international organizations including Asia-Pacific nations

Expertise & Focus:

- *Energy Policy*
- *Renewable Energy Grid Integration*
- *Smart Grid Planning & Technologies*
- *Power Systems Planning*
- *Power Systems Operation*
- *Power Systems Engineering and Standards*
- *Communications Design and Testing*
- *Project Management and Execution*

Lead for many public-private demonstration projects

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Grid System Technologies Advanced Research Team

Core Team Members:

- Richard Rocheleau — Director, HNEI
- Leon Roose * — Specialist & Chief Technologist
- Mark Glick * — Specialist, Energy Policy
- John Cole * — Senior Policy Strategist
- James Maskrey * — Energy Efficiency Program Manager
- Marc Matsuura * — Senior Smart Grid Program Manager
- Kanoa Jou * — Power Systems Engineer
- Staci Sadoyama * — Power Systems Engineer
- Thai Tran — Junior Power System Engineer
- Silas Oliviera de Toledo — Junior Power System Engineer
- Brian Chee — Communications & IT System Analyst
- Dax Mathews — Renewable Energy Resources Forecasting
- Kevin Davies — Assistant Researcher
- Saeed Sepasi — Assistant Researcher
- Jonathan Kobayashi — Research Associate
- Sharon Chan — GIS Specialist
- Yan Chen — Post-Doctoral Fellow
- Quynh Tran — Post-Doctoral Fellow
- Arif Rahman — Post-Doctoral Fellow

Team members combine for 75+ years of utility and regulatory experience

* Prior electric utility company senior management and staff
* Prior Commissioner of the Hawaii State Public Utilities Commission
* Prior Administrator of the Hawaii State Energy Office

Sampling of Sponsors & Partners: