NREL’s Integrating PV in Distributed Grids Workshop: Solutions and Technologies

A View from Hawaii

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Hawaiian Electric Company
Our Vision

Cost-effective clean energy
- Achieve more than 65% Renewable Portfolio Standard (RPS) by 2030
- Meet Hawaii’s goal of 100% RPS by 2045
- 20% bill reduction

Growing and equitable rooftop solar
- Accommodate growing rooftop solar
- Equitable for all customers

Modern grid
- Smart infrastructure
- Two-way flow of electricity and information
- Energy storage

Innovative energy solutions and services
- Community-based renewables, electrification of transportation, TOU, DR, microgrids, etc.
Hawaiian Electric: 3 Electric Utilities, 5 Separate Grids

Maui Electric
Serves islands of Maui, Molokai, and Lanai
Customers: 68,000
Generating capability: 284 MW
Peak Load (Maui): 190 MW

Hawaiian Electric
Serves island of Oahu
Customers: 297,000
Generating capability: 1,756 MW
Peak Load: 1,150 MW

Hawaiʻi Electric Light
Serves island of Hawaii
Customers: 81,000
Generating capability: 293 MW
Peak Load: 190 MW

Kauaʻi Island Utility Cooperative
7.3%*

Hawaiian Electric
13.0%*

Maui Electric
12.0%*

Hawaiʻi Electric Light
10.0%*

Percentage of Customers with PV
* As of 06/30/15
** As of 12/31/13
National data courtesy of Solar Electric Power Association
Hawaiian Electric Has a Diverse Mix of Renewable Energy Resources, Including Distributed Solar

Hawaiian Electric Companies RPS of 21.3% for 2014

- Customer-Sited, Grid-Connected solar, 27%
- Biomass (including municipal solid waste), 23%
- Wind, 30%
- Geothermal, 13%
- Hydro, 3%
- Biofuels, 2%
- Utility-scale Photovoltaic and Solar Thermal, 2%
We Have Experienced an Exponential Growth in Photovoltaics on Our System
PV Systems and Inverters are Becoming a Growing Part of Our Distribution System

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<tr>
<td><strong>Total</strong></td>
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*Approximate numbers*
Variable Generation is Reducing Conventional
At The System Level, Reliability Levels are Lower Than in the Past

Today a large generator trip or system fault during peak PV periods results in:
• Loss of system inertia due to reduction in rotating generation
• Loss of “legacy” PV which acts like a secondary generation loss
• Reduced effectiveness of UFLS due to rooftop PV
• Potential of massive load shedding (3-4 of 5 blocks of UFLS)
• Faster rate of change of frequency
Battery Energy Storage System for Fast Frequency Response
BESS Helps with Transmission Line Fault Event (Overfrequency)

 Fault Occurs @ 1 Second

Frequency Nadir of ~57.6 Hz

Stage 1 @ 58.9 Hz
Stage 2 @ 58.7 Hz
Stage 3 @ 58.4 Hz
Stage 4 @ 58.1 Hz
Stage 5 @ 57.8 Hz

300 MW PV Trips on O/F @ 60.5 Hz

with battery
Evolution of PV Integration for Hawaiian Electric

15% of Circuit Peak Load (Pre-2013)

50%, 75%, 100%, 120% of DML Representative Studies (2013)

250% of DML Transient Overvoltage (2014)

Hosting Capacity Advanced Inverters (2015)

- Control
- Visibility
- Grid Management
Hawai`i is Leading the Nation in Implementing Solutions for the Integration of Distributed Solar

Distribution Level
- Steady State
  - Thermal Capacity Over Load
  - Over Voltage issues
    - Primary
    - Secondary
    - Imbalance across phases
- Protection
- Dynamic
  - Voltage Flicker
  - Voltage Regulation Impacts
  - Islanding
  - Load Rejection Over Voltage
  - Ground Fault Over Voltage

System Level
- Steady state
- Transient stability
Testing at NREL Provided an Opportunity to Perform Lab Tests in a Real World Environment
At the Distribution Level, Circuit “Hosting Capacity” Method Used to Proactively Plan for and Integrate DER

Hosting Capacity: The amount of DER (PV) that can be accommodated on a circuit without adversely impacting operations, power quality, or reliability.

Heat Map Illustrative of Overvoltages Caused by High Amounts of Reverse Flow
We Are Working Through Rooftop PV Challenges

**Cannot be Measured**
- Rooftop PV output can only be estimated

**Uncontrollable**
- Cannot be turned on or curtailed

**“Legacy” PV**
- ~60 MW of PV generation trips offline at 59.3 Hz
- ~175 MW of PV generation trips offline at 60.5 Hz

**Underfrequency Load Shed Schemes**
- Decreases effectiveness of UFLS
Hawaiian Electric Company’s Technical Plan

- **System Level Limit**
  System level screens for each unique island grid balancing system level reliability, safety, and cost-effective service to all customers

- **Hosting Capacity**
  Circuit level hosting capacities unique to each circuit to enable efficient interconnection process

- **Advanced Inverters**
  Early implementation and establishment of advanced inverter standards (fixed power factor, volt-watt, frequency-watt, communications, etc.) to cost-effectively and safely integrate distributed energy resources
Ride-through Standards Were Established to Assist During System Disturbances

Low/High Frequency Ride-Through

- **MUST TRIP REGION**
- **MUST STAY CONNECTED**

Inverter will ride-through system contingencies (i.e. loss of large load or generating unit)

Low/High Voltage Ride-Through

- **MUST TRIP REGION**
- **MUST STAY CONNECTED**

Inverter will ride-through system or circuit disturbances (i.e. short circuit faults)
Adoption of Advanced Inverter Voltage Functions to Mitigate Voltage Issues

**Volt-Watt**

Mitigates secondary high voltage by reducing real power as a function of voltage.

**Fixed Power Factor**

Provides voltage support; mitigate high voltages. May increase system losses.

**Dynamic Volt-Var**

Circuit voltage optimization
Advanced Inverters for System Support

**Frequency-Watt**

Gradually raises the inverter power output to coordinate with the ramping capabilities of the bulk generating system. Mitigates frequency swings during system restoration.

May assist in over-frequency due to loss of load/excess energy.

**Remote Connect/Disconnect**

Utility sends command to inverter to disconnect or reconnect system. To be used during system emergencies or system restoration.

**Communications**

- **Remote Configurability**
- **Measurement/Visibility**

Source: EPRI Report 3002001246
Fixed Power Factor Can Mitigate Localized High Voltage and Reduce Voltage Fluctuations
The Next Challenge: Real World Overvoltage Events
Demonstrate that DER Systems Can Cause Overvoltage

Solar Peak – Voltage rise

Circuit voltage may rise above 105% of nominal during the solar peak

Evening peak – Voltage ok
Advanced Inverters Used to Manage Overvoltage Events

Blue = KW flow through service transformer
Red = Voltage measured at the service transformer
Lessons Learned

• Rooftop solar is a customer choice
• Consider DER as a grid asset – how do you extract the greatest value?
• It is an exercise in volume
• Get ahead of the curve
Mahalo!