Integration of Renewable & Distributed Energy Resources

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7th International Conference on Integration of Renewable and Distributed Energy Resources

Niagara Falls, Ontario
October 24-28, 2016
Hawaii’s isolation poses serious risks ....

Nearly 90% of Hawaii’s energy is met using \textit{fossil fuels}

100% of the crude oil for the State is \textit{imported}

Risks to our
• Economy
• Security
• Environment
High Electricity Price and Volatility Linked to Overdependence and Cost of Oil

High Cost of Service

Hawaii ranks #1 in US electric energy costs:

45.85 cents/kWh    Lanai
47.06 cents/kWh    Molokai
41.89 cents/kWh    Hawaii
37.83 cents/kWh    Maui
35.48 cents/kWh    Oahu
(Avg. Residential rates in 2014)

11 - 12 cents/kWh    U.S. avg.

Source: Hawaiian Electric Company and Hawaii DBEDT

Renewable Energy Aimed to “Break the Link” and Lower Cost
Hawaii Retail Electric Rates
2015 – 2016  ¢/kWh

<table>
<thead>
<tr>
<th>Sector</th>
<th>March 2015</th>
<th>March 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>$0.3087</td>
<td>$0.2735</td>
</tr>
<tr>
<td>Commercial</td>
<td>$0.2797</td>
<td>$0.2399</td>
</tr>
<tr>
<td>Industrial</td>
<td>$0.2379</td>
<td>$0.1986</td>
</tr>
<tr>
<td>All Sectors</td>
<td>$0.2712</td>
<td>$0.2324</td>
</tr>
</tbody>
</table>
Hawaii’s Progressive Leadership in Clean Energy Policy

Hawaii Clean Energy Initiative (HCEI)

The State of Hawaii, US DOE, and local utility launched HCEI in January 2008 to transform Hawaii to a 70% clean energy economy by 2030:

- Increasing Hawaii’s economic and energy security
- Fostering and demonstrating Hawaii’s innovation
- Developing Hawaii’s workforce of the future
- Becoming a clean energy model for the U.S. and the world

2008

Ambitious energy agreement charts right course

Hawaii Powered
Hawaii Clean Energy Initiative

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2009

Strong Hawaii Policies

Highest RPS Target in the United States

40% by 2030
(2015 - 15%; 2020 - 25%)

Other key policies:
- Tax incentives
- Retail Rate Net metering
- Feed in tariffs

2011

Policy Evolution Reflecting Market Realities …

Amended the definition of "renewable electrical energy" to include starting in 2015, customer-sited, grid-connected renewable energy generation

2015+

Continued Policy Evolution …

- New RPS targets: 30% by 2020; 100% by 2045
- Net metering change – wholesale rate sale
Exceeding Hawaii RPS Goals

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

State-wide 2015 RPS Goal = 15%
RPS year-end 2015 @ 23.42%
(9.5% RPS at year-end 2009)

Renewable Energy Production by Resource

At year-end 2015 RE Production by:
- Distributed PV - 31%
- Wind - 27.9%
- Biomass - 19.2%
- Geothermal - 10.5%
- Hydro - 4.8%
- Commercial Solar - 4.2%
- Biofuels - 2.4%

Hawai‘i Natural Energy Institute (HNEI)
Advancing Renewable Energy and Grid Technologies

Established to develop, test and evaluate advanced grid architectures, enabling policies, and new technologies and methods for effective integration of renewable energy resources and power system optimization.
Maui Island
Leading the way in Wind and Solar Power

- Kaheawa I (30 MW)
- Kaheawa II (21 MW)
- Auwahi (21 MW)
- 74 MW Existing Distributed PV
- ~40 MW PV Pre-approved/Review
- 114 MW Total

Wind - 72 MW
PV - 114 MW
186 MW

63,000 Customers

Daily Load Shape

69kV/23kV/12kV T&D System
Maui Advanced Solar Initiative

US DOE & ONR funded, HNEI led project to develop and demonstrate advanced PV inverter functionality in a smart grid environment

~800 customers
~200 PV systems = 2MW
MDL = 976kW

% Penetration = \frac{2MW}{976kW} = 205%
Field Performance & Data Mining
Software sends control curves to adjust inverter

1. Sends Volt-VAR or Volt-Watt curve to Smart Inverter to adjust inverter VAR or Watt injections into the grid.

2. Smart Inverter receives curve, senses system voltage.

3. Smart Inverter adjusts VAR or Watt output based on curves to respond to system voltage fluctuations.

2-way data flow
Wireless communications

PC (Honolulu) → Server → Cell Network → Translator Device → Smart Inverter
Technology Validation and Optimization

- Field survey and circuit modeling
  - Investigate / collect circuit information
  - Analyze and model circuit data and smart inverter functionality
  - Use model to develop and optimize smart inverter control algorithms and iterate with field operation and measured performance
Voltage Along the Feeder

7pm-11pm

10am-4pm
Voltage Along the Feeder (cont.)

November 1, 2015 (10am-3pm)

10am-4pm

10am-4pm
Real Power & Voltage

Magnitude of voltage effects on neighbor is dependent on sec ckt configuration

Graphs showing Real Power (kW) and Voltage over time with different inverter configurations.

Inverter 1

Transformer Location

Inverter 2

Graphs show SCADA, Distr Tsf, Inverter 1, and Inverter 2 data over time.
Reactive Power & Voltage

- Reactive Power (kVAR)
  - Capacitive
  - Inductive
- Real Power (kW)
- Voltage

Graphs showing the variation of reactive power, real power, and voltage over time for both capacitive and inductive conditions.
Lessons Learned: Inverter Standardization

- Real Power Curtailment
  - % of Inverter Rating
- Volt-Var Curve
  - Number of points
  - Y-axis = % of Available VARs, % of Max Vars, % of Max Watts
    - SMA = 50% of KVA rating
    - Hitachi = 100% of KVA rating (will reduce real power output)
    - Fronius = limited to power factor >= 0.85
      - Steepness of curve
Next Step Applications

• Smart inverters can be used to control voltage
• Voltage effects are dependent on:
  – Loading
  – Topology
• Development of control algorithms to manage voltage

ΔV = 0.10V
ΔV = 1.68V
Mahalo!
(Thank you)

For more information, contact:

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