Electrolysis on an Island Grid

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28 February 2014

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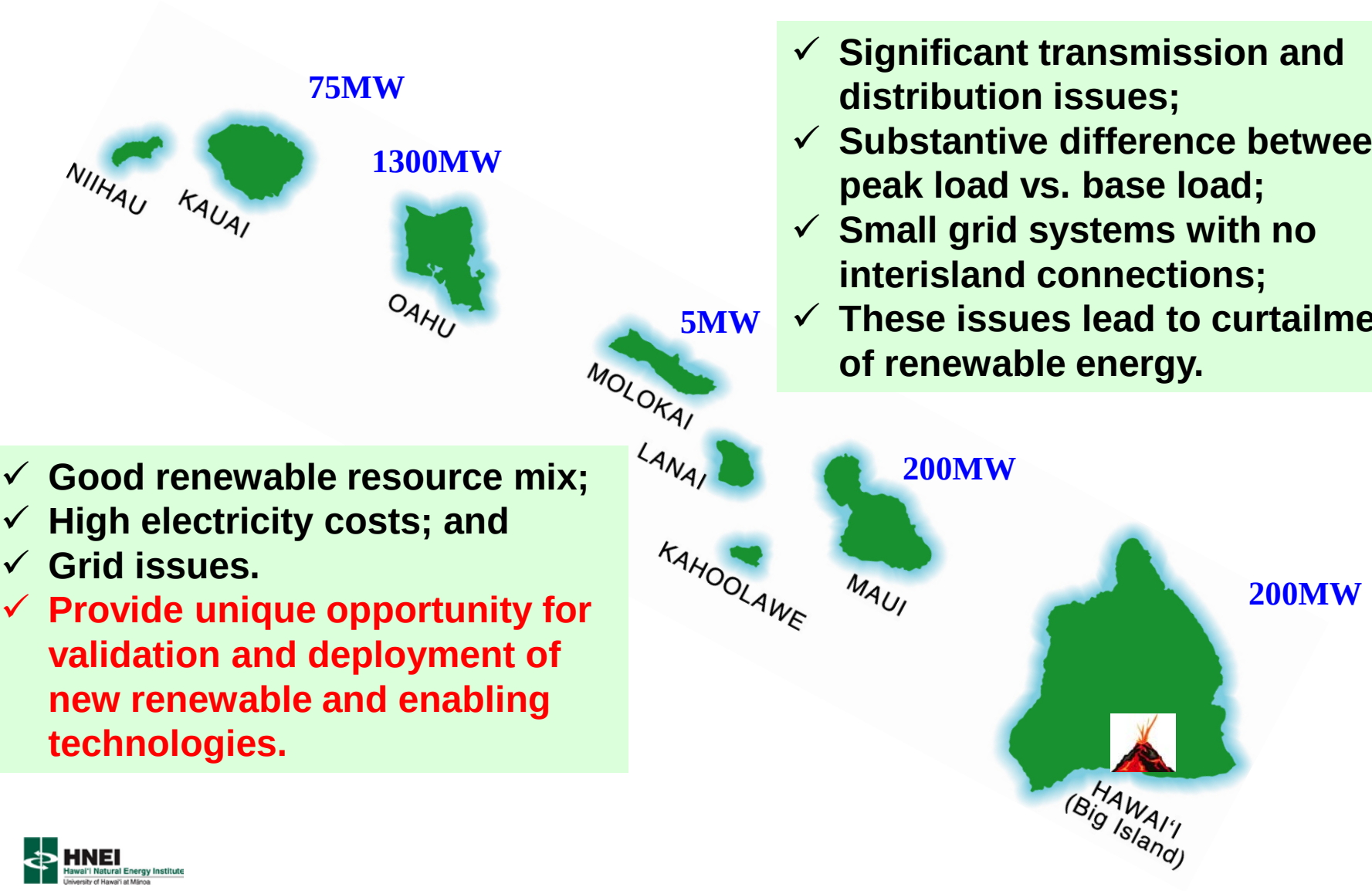
High Percentages of As-Available Renewable Resources Creates Problems for Grid Systems



- ✓ Significant transmission and distribution issues;
- ✓ Substantive difference between peak load vs. base load;
- ✓ Small grid systems with no interisland connections;
- ✓ These issues lead to curtailment of renewable energy.

- ✓ Good renewable resource mix;
- ✓ High electricity costs; and
- ✓ Grid issues.
- ✓ **Provide unique opportunity for validation and deployment of new renewable and enabling technologies.**

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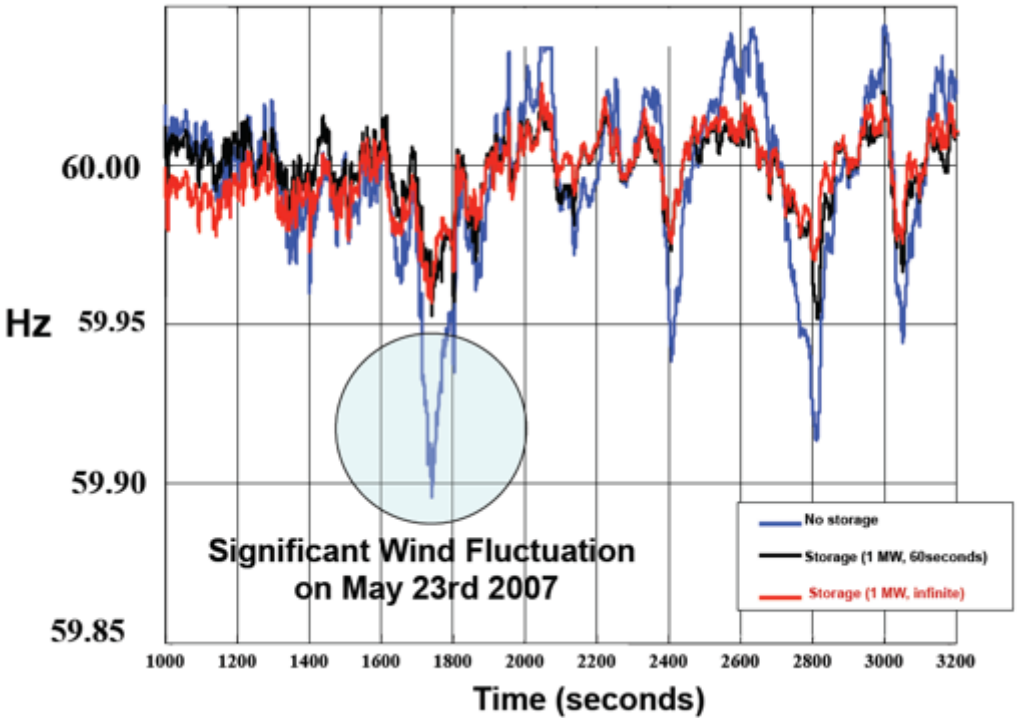
Models indicate modest energy storage can mitigate effects of intermittent renewables



Frequency Comparison

- **High penetration intermittent renewables can cause load mismatch leading to frequency variability;**
- **Dynamic load response can provide same reserve response as storage;**

Demonstrate added value of electrolyzer producing hydrogen fuel while providing ancillary services to the grid

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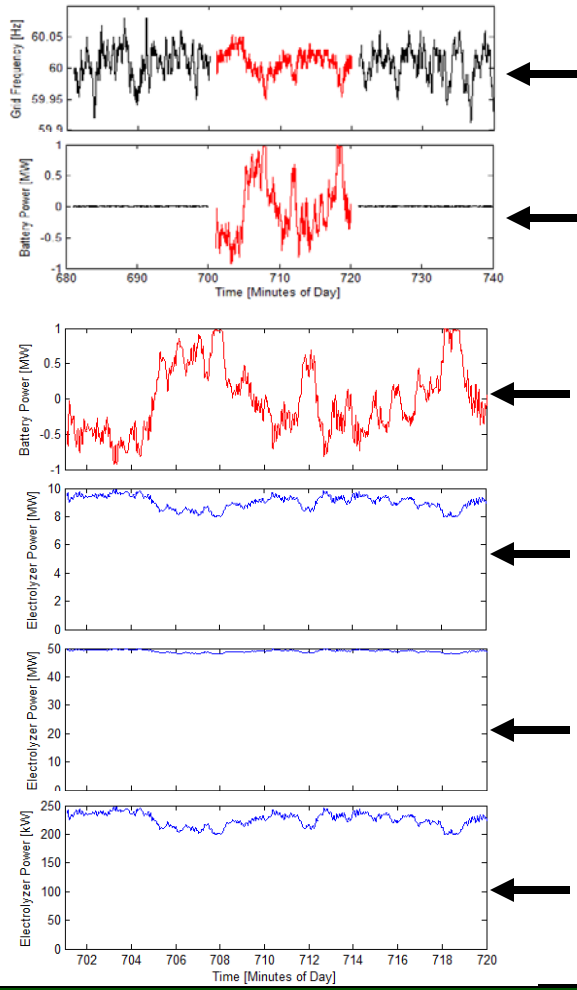
Electrolyzer vs. BESS Management of Grid Frequency



Grid Frequency (Hz): Measured with battery off (black) and on (red) at twenty(20) minute intervals

Battery Output (MW): Can alternate between charge and discharge up to 10 times per second

Battery Output (MW): Expanded scale

10MW Electrolyzer: variability in power consumption to provide same frequency support as 1 MW battery

50MW Electrolyzer: variability in power consumption to provide same frequency support as 1 MW battery

250kW Electrolyzer: power cycle proposed to test durability assuming part of a 10 MW system

Frequency variability on 150MW grid system reduced with a 1MW, 250kwh fast BESS. Same power range as 1MW BESS easily achieved with 'low' stress and good CAPEX utilization using MW-scale electrolyzers.

Technical Challenges

- ✓ **Internal**
  - ➢ **Scale up electrolyzers to 2000 kg/day+++**
  - ➢ **Scale up compressors to handle large H2 production volumes**
  - ➢ **Develop better power supplies**
    - **More dependable**
    - **More efficient**
  - ➢ **Reduce costs**
- ✓ **External**
  - ➢ **Codes & Standards development process an "anchor" on innovation.**
    - **Not keeping up with pace of innovation.**
    - **Either expedite the process or develop an alternative**

Non Technical Challenges

- ✓ **Choice of 700 bar for LDVs ~ doubles cost of infrastructure and reduces energy efficiency.**
- ✓ **Legal profession & insurers slowing the process**
  - ➢ **Liability & indemnification issues take too long**
    - **Why do we need to reinvent the wheel for every project?**
    - **3.5 years to develop agreements.**
    - **Need "straw man" set of standard terms & conditions**
    - **Risk analyses available to insurers and lawyers.**
- ✓ **Sense of Urgency**