Making the Case for Grid-Interactive Electric Water Heating in 2014

Frequency Regulation: “The Holy Grail”
What We Do

We supply electric utilities with “smart grid” technologies for 24/7 real-time, grid-scale management of electrical devices. Our focus is on:

- Generation and Demand Response
- Energy Storage
- Ancillary Services including Frequency Regulation
- Integrating Increasing Renewable Generation

We have patents on a transformational grid scale energy storage technology that is proven and starting to be deployed by our partners and customers.
“Electric water heater storage is the most cost-effective form of energy storage available and has enormous potential to help PJM integrate the projected 33,000 MW of wind and 9,200 MW of solar energy....

A recent study showed that **PJM will need 1,500 MW of added regulation resources for load frequency control as wind is added to our system.**”

Terry Boston, President and CEO

April 7, 2014 Letter to U.S Department of Energy  EERE-2012-BT-STD-0022
Let’s Understand Frequency Regulation

Generators Providing Frequency Regulation

Generator Steady State Output

Relative Operating Range Power +/-

Supply Side

Generator: “ZERO” Reference

Demand Side

Time of Day

11:02 PM  3:50 AM  8:38 AM  1:26 PM  6:14 PM  11:02 PM
AGC Signal delivered every 2-4 seconds. Real time signal following required.
Different “ZERO” Same Net Effect

Frequency Regulation Service Technologies

- Generator Steady State
- Generator Modulated By AGC
- Battery Steady State
- Battery Modulated By AGC

Supply Side
- Generator: Inject More Or Less
- Battery: Inject Through Inverter

Demand Side
- Battery: Absorb Though Charger

Time of Day

11:02 PM  3:50 AM  8:38 AM  1:26 PM  6:14 PM  11:02 PM
Grid Use of Water Heaters

A. Peak Load Shedding

A. Off-Peak Water Heating

B. Peak Shaving and Valley Fill + A,B

C. Frequency Regulation + A,B,C
Water Heaters for Frequency Regulation

What Is Required:

- Safety and Reliability (cold shower = loss of resource)
- Real-Time Bi-directional Control (every second!)
- Constant Measurement and Verification (to get paid)

What Is Preferred:

- Complete control of the KWHs 24/7 (to maximize revenue)
Energy Use Pattern of a Standard Water Heater

So How Do We Use A Water Heater For Frequency Regulation?

Measured Energy Use of Actual Home Over 24 Hours 15.8 KWH
15.8 KWH Over a 24 Hour Period = .66 KW Continuous
4.5 KW Heating Element Operating at 14.7% Duty Cycle
Duty Cycle is Modulated in Real-Time By AGC

Sequentric Water Heater Grid Battery
Providing Frequency Regulation Services

15.8 KWH Over a 24 Hour Period = 0 - 1.32 KW (Averaging .66KW)
4.5 KW Heating Element Operating at 0 - 28.4% Duty Cycle
Providing 24/7 Frequency Regulation .66KW (+/- .66KW)
Frequency Regulation Service Technologies

Different “Zero” Reference / Same Regulation Result

Generator: Inject More Or Less
Battery: Absorb/Inject
Water Heater: Absorb More or Less

Supply Side
Demand Side

Time of Day

EXACTLY The Same Net Regulation Effect On The Power Grid
Utility “Pre-Heating” is the Key To 24/7 Frequency Regulation with SAFETY, RELIABILITY AND NO COLD SHOWERS

Primary Water Heater
- Internal Thermostat
- Temperature is Self Maintaining

125° F
100% of KWH
0% of KWH

125°-130° F

Utility Controlled Pre-Heater
- 100% Remotely Controlled

60° F
125° F
0% of KWH

60° F

0% of KWH
100% of KWH

Without Utility Control
With Utility Control

SEQUENTRIC Smart Grid Technologies
SEQUENTRIC’s Variable-Capacity Grid Interactive Water Heater

Utility Controlled Pre-Heating

Complete control the timing of 100% of the energy used: no cold showers

Internal thermostats limit temperature and provide “fail-safe”

Without communication, defaults to a standard water heater

- Safe
- Reliable
- Extraordinarily Capable

Independently tested and being deployed in projects in North America

US Patents 8,121,742 8,571,692 many others pending in the US Canada & PTC Countries
A Network of Water Heater “Grid Batteries”

- Frequency Regulation
- Virtual Storage
- Neutralizing Variability
- Ancillary Services
- Energy Cost Arbitrage

Real-Time Grid, Forecast and Market Data plus AGC Signal

IP Networks

Real-Time Feedback and Control

Analytic and Dispatching Servers at System Operations Center

Electric Grid

Variable Capacity Grid Battery Water Heaters
# Water Heater Control In Utility Programs

With an 8% Annual Replacement Rate, It’s All About the Replacement Cycle

## Implementation Costs

<table>
<thead>
<tr>
<th></th>
<th>Conventional Demand Response Water Heater Load Controller</th>
<th>Next Generation Demand Response Variable Capacity Water Heater (Targeting the Replacements)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Device</strong></td>
<td>Paid By Utility</td>
<td>Paid by Customer</td>
</tr>
<tr>
<td><strong>Communication Hardware</strong></td>
<td>Paid By Utility</td>
<td>Paid By Utility</td>
</tr>
<tr>
<td>&quot;Truck-Roll&quot;</td>
<td>Paid By Utility</td>
<td>Paid by Customer</td>
</tr>
<tr>
<td><strong>Electrical Permit</strong></td>
<td>Paid By Utility</td>
<td>Not needed or paid By Customer</td>
</tr>
<tr>
<td><strong>Average Life Before Service</strong></td>
<td>6 Years</td>
<td>Life of the Water Heater Customer Calls</td>
</tr>
<tr>
<td><strong>Recruitment and Scheduling</strong></td>
<td>Utility Responsibility</td>
<td></td>
</tr>
</tbody>
</table>

## Performance

<table>
<thead>
<tr>
<th></th>
<th>Conventional Demand Response</th>
<th>Next Generation Demand Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Load Shedding</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Use For Off-Peak Water Heating</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Use For Frequency Regulation</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Use For Phase Imbalance Correc</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Reducing Transformer Variability and Overload</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Use For Energy Cost Arbitrage</td>
<td>Limited</td>
<td>Yes (if and when contacts allow)</td>
</tr>
<tr>
<td>100% Energy Use Timing Control</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Cold Showers Possible?</td>
<td>Under Certain Conditions</td>
<td>No</td>
</tr>
</tbody>
</table>
Water Heaters Used for Frequency Regulation:

- Safe and reliable technology being deployed today
- Can track the year round need for 24/7 regulation
- 1-2 orders of magnitude cheaper than batteries
- More efficient and faster than generators and batteries
- Essentially $0 operating cost to manage
- Capable of generating > $120 / year / water heater
- Deploy through installation in the replacement cycle
- AIM HIGH After Frequency Regulation, everything else is easy
THANK YOU

www.sequentric.com