The Emerging Market for Grid-Interactive Electric Water Heating

Presenter: Daniel Flohr, CEO
We supply electric utilities with “smart grid” technologies for real-time, grid-scale management of electrical devices. Our focus is on:

- Generation and Demand Response
- Energy Storage
- Integrating Increasing Renewable Generation
- Ancillary Services including Frequency Regulation
26 Smart Grid Projects for electric utilities since 2008

~2,100 Devices connected to licensed utility servers in 2012

Relevant projects: Reading MA Municipal Lighting District and the Canadian PowerShift Atlantic Wind Integration Project (MECL, NBP, NSP) centered around Grid Interactive Thermal Energy Storage

Coolest current project: “dispatching” of water heaters off of AGC signal following for Frequency Regulation Services

Growing Patent Portfolio in the areas of:
1. Real-time synchronization of asynchronous loads to lower demand
2. Generation-Following Load Management
3. Managing frequency regulation/phase imbalance using water heaters
4. New configurations of electric water heaters for utility control
High Level Network Architecture

Utility Operating Center

IP Network
Public or Private
Cable, DSL, CDMA, GSM, 3G, 4G
WiMAX, LTE, WiFi

Servers
Windows Server 2008
Microsoft SQL Server 2008
vmware

Forecastsing Modules
Grid Optimization Modules
Customer Portals, Billing
Load and Customer Databases

Local Network of Devices

DECISION AND DISPATCH ENGINES

- Forecasting Modules
- Grid Optimization Modules
- Customer Portals, Billing
- Load and Customer Databases

Residential and Commercial Sites

Various Providers:

- viridity energy
- SIEMENS
- Battelle
- BPL Global
- enbala
Load Leveling Allowing Best Generation to Follow Demand

Original Load (Before)

Levelized Load (After)

Load by Transformer

Choreography Results at the Transformer Level
MTBF Increased 3X

Data Courtesy of Integral Analytics

Real-Time Demand Side Dispatching
Duke Energy Programs 2008-2011

Neutralizing Variability

Peak Demand Response, Supply/Demand Balance, Neutralize Variability
Server Controlled Pre-Heating Field Tests Using Dual Water Heaters in 2008

Existing Primary Water Heater
- Internal Thermostat
- Temperature is Self Maintaining
- Runs Only To Make Up Standby Losses

New Pre-Heater
- 100% Remotely Controlled
- Internal Thermostat Limits Temperature

125° F

60° F

125° - 130° F

100% of KWH
0% of KWH
<10% of KWH
>90% of KWH
Managing Wind Generation with “Virtual Power Plants” and “Virtual Storage”

Load Control to Balance Variable Generation

Wind capacity set to double

Time to convert Oil Water Heaters (80% of Customers)

40% Wind by 2020

PowerShift Atlantic focused us on developing and commercializing Thermal Energy Storage research we began in 2008.
The Challenge
Design a New Water Heater

Background
Demand Response is about occasionally turning things off
Existing water heaters good for shedding not adding load
~50MM water heaters use 3-4% of electric generation
Installed water heaters replaced at 8% annually (10%=1.8GW)

What A New Water Heater Must Do
Give the grid operators control of 100% of the timing
Insure Safe and Guaranteed HW supply for customer
Be simple and familiar
Step One: It’s Just a Water Heater

Upper Element: First priority. Makes some hot water quickly from a cold tank. Provides limited redundancy on failure of bottom thermostat or element.

Middle Element: Slaved to top element. Only runs when top is hot. Does virtually all of the water heating and always works to keep entire tank volume hot when utility is not connected.

But there is a twist......
SEQUENTRIC’s Variable-Capacity Grid Interactive Water Heater

Utility heats incoming **COLD** water

Utilities control the timing of 100% of the energy used

Internal Thermostats limit temperature and provide “fail-safe”

Without communication, defaults to a standard water heater

Buildable in any construction material

Adds < $20 in Parts

Currently being independently tested

Licensing discussions underway

US Patents  8,121,742  8,571,692  others pending in the US and Canada
Our Network View Of Grid-Interactivity

IP Networks

Feedback and Control

Variable Capacity Water Heaters

Real-Time Grid, Forecast and Market Data

Analytic and Dispatching Servers
Operated By Utilities / ISOs / RTOs

Electric Grid

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

Virtual Storage, Neutralizing Variability, Frequency Regulation, Ancillary Services, Energy Cost Arbitrage
Requiring a New Way of Thinking
A Water Heater “Can Be” a Battery

Conventional Water Heaters: Always ON Until Shed

Think About Battery Charging

Electro-Chemical Battery:
The Battery Charger is OFF by default
Only turned on when charging is required / desired

Variable-Capacity Grid-Interactive Water Heater:
The Water Heater is OFF by default
Only turned on when charging is required / desired
Available Hot Water Capacity
Charging Throughout the Day

Minimum Volume of Hot Water Available

Volume of Water Available for Energy Storage

Full Server Control: AGC Signal-Following Frequency Regulation
Once daily KWH use is known, the run schedule is 100% de-coupled from hour-by-hour use.
Operational Graphs

Off-Peak Water Heating

Server Controlled Temperatures

Autonomous Operation w/Load

Bottom Element Providing HW
The 2015 DOE Rules > 55 Gallon Rules
Maybe We Can Simplify the Waiver

This is a 45 Gallon Water Heater

Hot Water Capacity: 45 Gallons of Hot Water When Fully Heated

Stand-By Heat Loss: ~1.4 KWH / Day (Energy Star)

Recovery Rate: 240VAC w/4.5KW Element = ~30 Gallons / Hr.

Meets DOE Standard: Yes
Would this be legal under the DOE 2010 EE Rules?

- **Hot Water Capacity:** 45 Gallons of Hot Water When Fully Heated
- **Stand-By Heat Loss:** \(~1.4\) KWH / Day (Energy Star) (*)
- **Recovery Rate:** 240VAC w/4.5KW Element = \(~30\) Gallons / Hr.
- **Meets DOE Standard:** ☹️☹️☹️☹️ (Not currently)

(*) Heat loss measures slightly less than a conventional 45 gallon water heater because there is no “bottom” heat loss. In addition, the heat gain from warmer room air into the cold water at the bottom may, to some extent, reduce the net heat loss even further.
Manufacturer ships a LEGAL water heater

Bottom Element LOCKED OUT

Customer has water heater installed

Utility comes in afterwards (like always) and unlocks the Bottom Element with a waiver to exceed 55 Gallons for ETS

Bottom Element only operated over the network by the Utility

Without the network, defaults to legal size
Sequentric’s Variable Capacity Water Heater
A Different Approach for DOE

Sequentric Model:

- (Theoretically) having the water heater delivered in a **legal** and complying configuration under 2010 EE guidelines (**no waiver required**)
- Utility **unlocks** the higher capacity for ETS (**waiver required**)
- Automatic reversion back to legal and complying configuration when communication to utility not present or customer de-enrolls

Currently Proposed Model:

- Water heater **never legal** under current 2010 EE Guidelines (**waiver required**)
- **Penalty** assessed by somehow de-rating delivery (which doesn't effect the non-complying stand-by heat loss)
- Utility **unlocks** to remove penalty
- Automatic reversion back to penalty mode when communication to utility not present or customer de-enrolls