Cost Effective Energy Storage Systems
Resources for Grid Optimization, Fast Regulation and Renewable Integration
GRID-INTERACTIVE
ELECTRIC THERMAL STORAGE

Cost-Effective
Scalable Energy Storage
Delivering Space & Water Heat

ADVANCED DEMAND RESPONSE
Renewable Integration
Fast Regulation
Smart Thermal Energy “Batteries”
Electrical Energy Demand

Figure 75. U.S. electricity demand growth, 1950-2040 (percent, 3-year moving average)

- History
- 2011
- Projections

3-year moving average
Trendline

Figure 7-2 Average hourly real-time generation of wind units in PJM: 2012

Monthly

Hourly
Solar Variation

Seasonal

Daily
Impact of DG to Net Load

Growing need for flexibility starting 2015

Net load

Significant change starting in 2015

Increased ramp

Potential over-generation

California ISO
**Win with low cost GETS**

**Lose – Lose**
- Increasing amounts of curtailed renewable energy
- Low or Negative electric energy sales growth

**Win – Win – Win**
- Grid Balance by consumers using electricity to meet the real-time needs of the Grid
- Utilities make money by delivering fast regulation services and previously curtailed renewable energy
- Participating consumers share in utility profit directly and all consumers gain from overall lower electric rates
Grid-interactive Electric Thermal Storage (GETS)

Dynamically couples consumer usage to real-time grid needs, while ensuring the real-time consumers need for space and water heating continuously met.
Provides “Double Green” benefits:

- Economic
- Environmental

And
Grid-Interactive Space & Water Heaters Are…

“THERMAL BATTERIES”

With smart control, you effect the grid exactly like other electric storage technologies
Low-Cost Electric Storage

GETS is Very Low-Cost

ES-Select™ created by KEMA for Sandia National Lab 5-2012
ES-Select EE and Payback

![Graph showing energy efficiency and discharge duration for different technologies.](image-url)
The needs of the Smart Grid today include the balancing of...

- Variable Generation
- Variable Demand
- Variable Price

ETS Space and water heaters are grid interactive solutions
Balancing Supply & Demand

**Imbalance Conditions**

**Over-generation**
- Total Generation > Total Demand
- Frequency > 60 Hertz
- Generators momentarily speed up

**Under-generation**
- Total Generation < Total Demand
- Frequency < 60 Hertz
- Generators momentarily slow down
Load Following

BPA Balancing Reserves Deployment

GETS System was set to provide only Down Regulation

Note charging when there is more wind then predicted
GETS Demonstrations

Water Heater

PJM Demonstration

- 105 Gallon Water Heater
- Control Inputs
  - Hourly Energy Price
  - 4-second Frequency Regulation Signal

PJM Headquarters Visitor Entrance

Steffes Corp © 2010
Water Heater – Optimization of LMP and Frequency Regulation

Charging during low LMP periods

And

Following frequency regulation signal

Pilot water heater in use by PJM Technology Center
Grid-interactive ETS (GETS)

Ancillary Services - Regulation

A fossil power plant following a fast regulation command signal -- it cannot keep up!!

GETS Provides High Speed, Up and Down, Regulation

Charging is varied UP and DOWN from a “bid in” base line.

Water Heater REGA Signal Following

PJM Frequency Regulation Signal

Water heater consumption
Putting it all together…

Hourly Net Energy Cost

Cumulative Annual Energy Cost

- $79

$168
Wholesale Annual Operating Cost

for Electric Water Heater

<table>
<thead>
<tr>
<th>Type/Method</th>
<th>Energy Cost</th>
<th>Demand/Trans. Other Costs</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled</td>
<td>$256</td>
<td>$50 - $200</td>
<td>$306 - $456</td>
</tr>
<tr>
<td>Grid-Interactive LMP Optimized</td>
<td>$108</td>
<td>0</td>
<td>$108</td>
</tr>
<tr>
<td>Grid-Interactive with Regulation</td>
<td>-$80</td>
<td>0</td>
<td>-$80</td>
</tr>
</tbody>
</table>

- **Uncontrolled Water Heater**: No controls installed on water heater
- **Grid-Interactive Water Heater**: Consumes energy when LMP is low, but not doing regulation
- **Grid-Interactive with Regulation**: Consumes energy when LMP is low and provides regulation (Under FERC Order 755, possibly -$230?)
Electric Thermal Storage

Storage of Renewable or Off-Peak Electricity in the form of Heat

- Electricity is stored as heat in a well insulated brick core.
- On-board Microprocessor based control system regulates charging and discharging.
- Internal blower system delivers the heat to the conditioned space as needed to maintain comfort 24/7.
- Storage occurs based on availability of renewable or off-peak energy or as signaled by the utility for ancillary services.

It’s FULLY AUTOMATIC

All heating is accomplished by using off-peak or renewable energy
Dynamically Couples Consumer Electric Usage to the Real-time Needs of the Grid
+ Actively ensuring Consumers always have heat

Two-way, Real-time, Steffes Smart Controller

• Set Precise Charge Rate (0-100% wattage)
• Set the Target Charge Level (temperature)
• Report Individual Unit Current SOC (State of Charge)
• Report Metering and Verification
Water Heater Monitoring

Note: There is greater average daily usage during winter months
Note: There is greater average daily usage during winter months
January 2012 WH Data

Average for Hour of Day

Average for Day of Week

actual data from 100+ GETS water heaters
Grouping

Feeder, substation, billing node or other

Steffes Dynamic Dispatch

GETS Group #1

GETS Group #2

GETS Group #3
Seamlessly assign preferential load levels to end points with lower reserve capacities.
• Power Measurement
• Revenue Grade Accuracy
• Real-time performance feedback
• Performance archiving and retrieval
Microgrid
Wind integration demonstration
One wind turbine went off-line

GETS

Load Regulation (Dump Load)

Diesel Power (Running at Minimum)

Wind Speed

Total Wind Power

Microgrid Dynamic Balancing
Total Wind Power

GETS

Diesel Power (Running at Minimum)

Load Regulation (Dump Load)

Wind Speed

Microgrid
Balancing Second by Second
Microgrid
Wind Ramping

- Total Wind Power
- GETS
- Load Regulation (Dump Load)
- Diesel Power (Running at Minimum)
- Wind Speed
Wide Area and Home Area Communication Options

(WAN) Utility Grid-Interactive Signal to Home
- Homeowner Broadband
- Utility Owned Broadband
- 3G or 4G Cellular
- Other Wide Area Two-Way Communication

(HAN) In-Home Communication Network
- Ethernet Cable
- Home Plug Ethernet over Powerline
- Other In-Home Two-Way Communication

Low-Cost Smart Electric Energy Storage
Steffes Corporation

“Commitment to Innovation”

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