Grid-Interactive Electric Thermal Storage (GETS) Space and Water Heating

Paul Steffes, P.E.

Steffes Corporation
3050 Hwy 22 N
Dickinson, ND 58601

psteffes@steffes.com

Abstract

Utilities have long been faced with the challenge of balancing electric generation with consumer demand. Increasing amounts of variable renewable generation to the grid has made cost effective balancing activities very important. Grid-Interactive Electric Thermal Storage (GETS) allows for a higher percentage of renewable energy to be integrated to the grid by dynamically coupling consumer real time electric usage to available renewable generation. The ability to dispatch GETS by the hour, minute, or second in the precise amount needed to follow the immediate needs of the grid makes it ideal for enhancing grid reliability, stability and optimization. As an on-site by-product, it can provide space and water heating for residential and commercial buildings. Pilots across North America are showing outstanding "Double Green" benefits, economic and environmental. Very low or negative annual wholesale net operating costs (energy cost minus regulation value) are realized by continuously monitoring and quickly changing the charge rate of these distributed electric storage units. By varying load rather than using fuel-consuming generation to perform fast regulation, significant carbon reduction can be realized.

1. INTRODUCTION

Grid-interactive Electric Thermal Storage (GETS) is a low cost and very effective means of providing balancing services. Combining grid-interactive communication and controls with conventional water heaters and ETS space heaters makes up the GETS system. When considering all stakeholders, the universal mission of GETS systems is to be a precise, dependable, predictable and verifiable “Up” and “Down” dispatchable load. GETS systems can be used to reduce load or store extra amounts of energy as needed to help manage the power system while balancing the needs of the consumer, utility, and electric grid. This distributive electric storage technology serves as a scalable low-cost, long-life “Thermal Battery” storing terawatt hours of electric energy and is a powerful and valuable economic and environmental resource.

2. WHAT IS GETS AND HOW DOES IT WORK?

Grid-interactive Electric Thermal Storage, or GETS is the integration of intelligent and real time control signals with enhanced electric thermal storage (ETS) space and water heaters. GETS space and water heaters are “Thermal Batteries” that store electricity as heat in either very dense ceramic bricks located inside the heater or in water. Energy is stored during preferential times of the day or night or as dictated by the needs of the grid. Delivery of energy from the ETS systems occurs as needed to maintain consumer comfort. GETS space and water heaters interface with signals from the power company, ISO or other source and quickly respond by shedding load or by taking on additional energy as dictated by the control signal. Since space and water heating are the largest energy loads in consumer homes and many businesses, this combination of ETS space and water heating along with smart control (grid-interactive) provides utilities a great tool for managing and regulating sources of power supply, transmission and distribution while optimizing both economic and environmental benefits for the utility and consumer.

GETS products are distributive energy storage devices that when aggregated, are very powerful, effective and affordable tools for grid management. There are various configurations of GETS products available for residential and commercial applications. All of these units have the ability to respond to smart control signals as well as a time clock, legacy load management relays, or other utility signals and provide precise, dependable, predictable and verifiable “Up” and “Down” dispatchable load while delivering great comfort to the consumer.

2.1. Equipment Description

2.1.1. ETS Room Unit(s)

ETS room space heaters are available in multiple model sizes ranging from 2.4kW to 10.8kW inputs and storage capacities from 13.5kWh to 40.5kWh.

2.1.2. ETS Central Systems – Residential Forced Air Furnace and Hydronic Heating Units (Comfort Plus)

ETS whole house systems are available in model sizes ranging from 19kW to 45.6kW inputs and storage capacities from 120kWh to 240kWh. They interface nicely with air source heat pumps (ASHP's) to provide comfort modulation, supplemental backup heat and improved operating efficiency.

2.1.3. ETS Commercial Systems – Forced Air and Hydronic (ThermElect)

ETS commercial units range in size from 53kW to 160kW inputs and storage capacities from 320kWh to 960kWh.

2.1.4. Interactive Water Heater Control

Steffes Interactive Water Heater Controls (IWHC) are installed on domestic electric water heaters. The IWHC has the ability to accept a signal from a utility control switch or other smart signaling devices. This control enables the water heater to become a powerful year-round storage device by providing variable, up or down regulation in response to the needs of the grid. The IWHC regulates heat storage, dependent upon power availability, while insuring comfort for the consumer at all times. It can be installed on most standard electric water heaters and is most beneficial when installed on larger size models, such as the 85 or 105 gallon, to provide additional energy storage.

3. BALANCING GRID VARIABLES WITH "SMART" GRID-INTERACTIVE ETS (GETS)

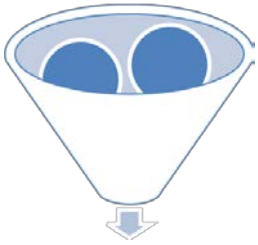


Figure 1. Manage with Grid-interactive Electric Thermal Storage

3.1. Maintaining Balance, Stabilization and Reliability with GETS

Grid operators are continuously monitoring generation resources and consumer demand in order to maintain balance and stability on the electric grid. Generation resources are increased or decreased in response to increases and decreases of consumer demand. Often times, these traditional ways of providing balancing services are slower and less efficient than Grid-interactive Electric Thermal Storage (GETS). With increasing amounts of new variable renewable power generation, there is a growing need and value for fast acting regulation resources.

GETS space and water heaters have smart controls that quickly and precisely change their charge rate and charge level, factoring in real-time generation and other critical needs of the grid. This also allows these space and water heaters to be fast acting, non-fuel-consuming regulators and frequency controllers. It provides increased grid reliability, reduces power plant cycling and fuel consumed for regulation and brings significant monetary and environmental value to electric grid operators, electric utilities and consumers.

GETS products allow the charging patterns of GETS-enabled space and water heating loads to be dispatched so as to follow a precise desired utility load shape. This load shape can be set the day prior and then altered hourly and again every few minutes or seconds if advantageous to meet the real-time needs of the grid.

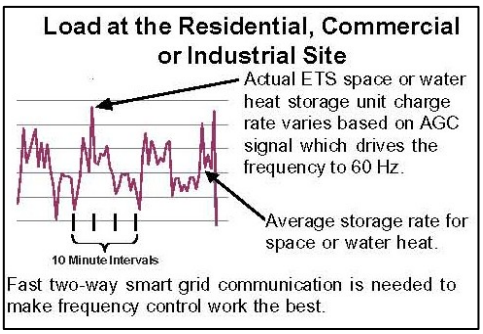
Key benefits include:

- Dynamically couple consumer electricity usage to real-time needs of the electric grid
- Cost effectively deliver assets that assist in grid reliability, stabilization, and optimization
- Track a desired utility load shape in real time
- Precisely, dependably, predictably and verifiably provide fast "Up" and "Down" dispatchable load

3.2. Frequency Control

Area Control Error (ACE) is a number which indicates the difference between supply and demand of electricity. The fluctuation in supply and demand makes power frequency go high or low.

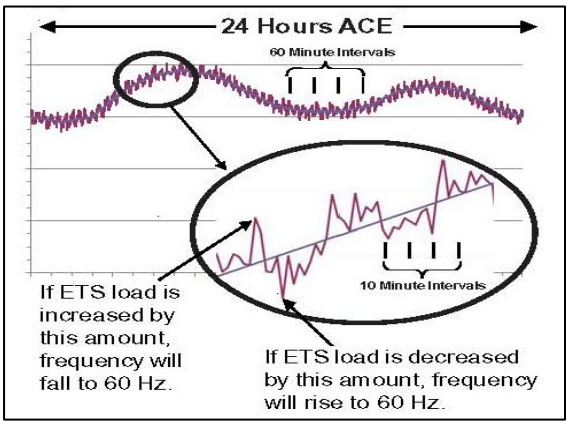
Grid-interactive Electric Thermal Storage (GETS) space and water heaters can be used as a fast regulation tool to respond to an Automatic Generation Control (AGC) signal, thus reducing generator fuel consumption and associated emissions. In addition, grid reliability is improved. This yields monetary ancillary payments or reduced cost of regulation for utilities.



3.3. Example

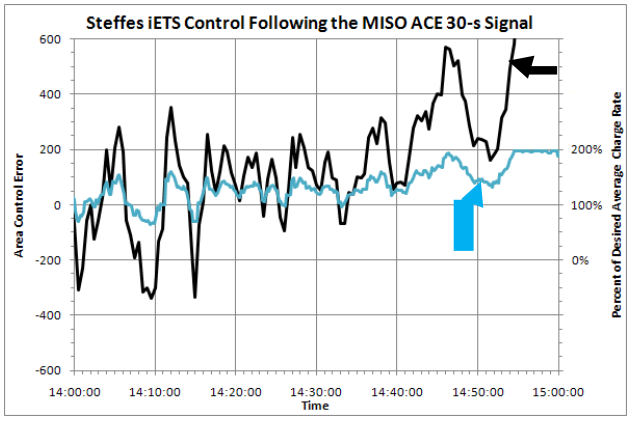
If you set the average charge rate of a group of water heaters to 1Mw for the hour ending at 4AM, the actual charge rate of this block of GETS space or water heaters can change quickly as dictated by the automatic generation control (AGC) signal to be anywhere between 0Mw and 2Mw. This provides precise, predictable and verifiable "up" and "down" regulation for ancillary value and carbon reduction.

PJM ISO has a need for about 700Mw of up and down regulation. As more variable renewable generation is added, more regulation will be needed. All ISO's have a market structure to compensate for regulation. Utilities that do load balancing on their own have associated costs that can also be reduced.



3.4. Example of MISO Smart Signal Following

The Midwest ISO (MISO) has an Area Control Error (ACE) signal that indicates the instantaneous difference between net actual and scheduled interchange. When the ACE signal is positive, it indicates that generation exceeds demand and when the ACE signal is negative, it indicates that demand exceeds generation. Grid-interactive space and water heater controls can respond to the AGC signal to add load when the ACE goes high and shed load when it goes low. The following graph shows how GETS responds to ACE.



3.5. Improving System Efficiency and Environmental Value

There is great environmental value for doing power regulation with a non-fuel consuming resource. KEMA Incorporated conducted an evaluation and comparison for doing regulation with a fast response system versus using conventional fossil fuel generation system (KEMA Project: BPCC.0003.001)[1]. The Oakridge National Laboratory also conducted a study of this (ORNL, ORNL/TM-2004/291) [2]. Refer to the table that follows which shows the emissions savings for doing regulation with a flywheel on the PJM network. You will notice a carbon savings of 67%. Like flywheels, GETS space and water heaters can provide non-fuel consuming regulation for utilities and reduce power plant cycling thereby increasing system efficiency. This adds a new dimension of conservation, reliability and efficiency to the electric grid. It is commonly agreed that fast acting regulation devices are several times more effective at performing frequency control and therefore should be encouraged through the implementation of "pay for performance" pricing. GETS products can provide fast regulation services which allows for the movement of a greater amount of power in a shorter period of time than other slower responding, less efficient balancing resources.

Key benefit includes:

- Improved system efficiency by reducing fuel used to increase or decrease frequency as needed for grid stability

Emissions Comparison for PJM

Flywheel Emission Savings in Tons, Over 20-year Life: PJM	Coal		Natural Gas		Pumped Hydro
	Baseload	Peaker	Baseload	Peaker	
CO2					
Flywheel	107,902	107,902	107,902	107,902	107,902
Alternate Gen.	331,879	626,477	172,680	187,822	175,189
Savings (Flywheel)	223,978	518,576	64,779	79,920	67,287
Percent Savings	67%	83%	38%	43%	38%

3.6. Integration of Variable Renewable Generation Resources

Renewable energy is recognized as the "green" or environmentally-friendly energy solution. Many states have adopted aggressive renewable portfolio standards (RPS) in an attempt to shift power generation away from fossil fuel generation sources. Most of this new generation will come from wind or solar. When load or other generation resources cannot change as fast as the wind or solar, significant amounts of this carbon-free resource are wasted. A growing amount of this variable resource is curtailed or unusable because it cannot be consumed when it is generated. This variability must be carefully integrated with other generation sources to maintain grid stability.

The inability to integrate renewable energy into the grid can happen at any hour of the day. GETS space and water heater loads can adjust their charge rate and change as fast as wind

and other renewable generation, allowing more renewable energy to be fully-integrated into the grid. The ability to quickly turn a GETS space and water heater charge rate up or down can provide significant value to fully-utilize renewable energy. GETS control provides better integration of renewable energy into the grid, brings a new dimension of system conservation and efficiency and keeps electric rates low.

This ability to track and use real-time renewable generation and monitor and react to other critical needs of the grid can significantly decrease the space and water heating carbon footprint **and** lower the cost of operation for consumers.

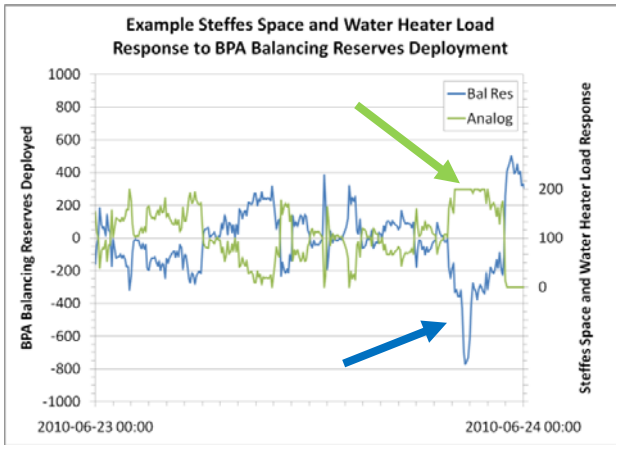
Key benefits include:

- Scalable integration of a higher percentage of renewable energy on the grid
- Store terawatt hours of electric energy to create a low cost storage resource

3.7. Example - Balancing Reserves Deployment Signal Following Renewables

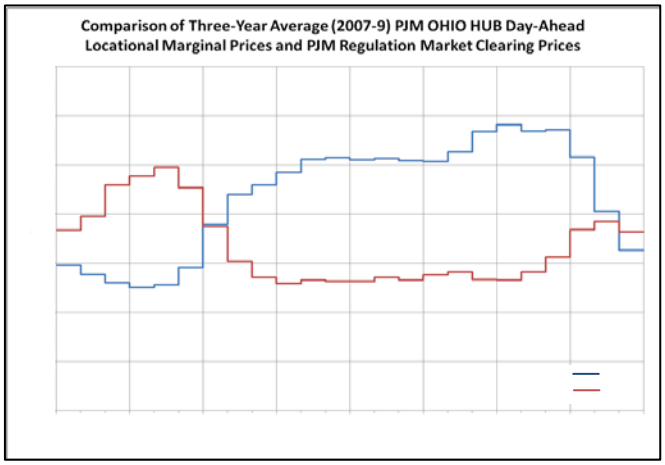
The Bonneville Power Authority (BPA) has a Balancing Reserves Deployment signal that is used to balance renewable energy resources and demand variations with generation resources. This is the difference between predicted wind and actual wind generation in the area. When the Balancing Reserves Deployment signal is positive, it indicates that generation was increased to balance the grid and when the signal is negative, it indicates that generation was decreased to balance the grid. GETS space and water heaters can use this signal to shed load when the signal goes high and add load when it goes low. BPA has identified a great need in integrating large amounts of renewable energy is adequate, precisely controlled, down regulation.

The following graph shows the GETS load responding to the BPA Balancing Reserve Deployment signal.



3.8. Economic Value – Regulation Services, LMP and Other Optimization

In addition to providing grid reliability and environmental benefits, there are significant economic benefits of doing fast regulation with GETS space and water heaters. During hours when the demand for electricity is low, the associated market price (or LMP price) is also low. It is during this off-peak time that the need and value for doing regulation is the greatest. Refer to the graph which follows. This shows a 3-year average of LMP prices and the regulation market clearing price (RMCP) for PJM, an ISO located in the Northeast. This confirms that when LMP is lower, the RMCP is higher. During hours when RMCP is equal to LMP, smart controlled grid-interactive electric storage space and water heaters can provide regulation services that are equal in value to the energy needed to charge them or have a net wholesale operating cost of zero. When RMCP is greater than LMP, the net cost of operation is negative. As you will see, in the middle of the night, the 3 year average RMCP is greater than LMP, so the net annual wholesale cost of operation of a smart grid electric storage space and water heaters is negative. This is in addition to the carbon savings associated with doing regulation with a non-carbon emitting resource (refer to information in the prior section). In the PJM region, the annual wholesale energy cost for having a GETS water heater under control for Regulation and LMP Optimization is -$80 per year (negative). See table which follows:

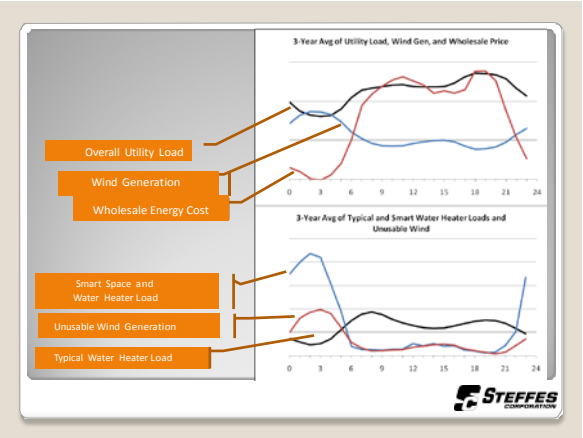


Electric Water Heater Control Comparison

Type/Method	Energy Cost	Demand/Trans. Other Costs	Total Cost
Uncontrolled	$256	$50 - $200	**$306 - $456**
Grid-Interactive LMP Optimized	$108	0	**$108**
Grid-Interactive w/LMP Op. and Regulation	-$80	0	**$-80**

4. PUTTING IT ALL TOGETHER

- The annual average overall utility load is low in the middle of the night.
- The average annual wind generation is almost the exact opposite of overall load and the time with the highest percentage of wind is in the middle of the night.
- The wholesale energy price is lowest in the middle of the night.
- Most unusable wind is in the middle of the night.
- Unfortunately, the typical consumer load is also lowest in the middle of the night.



GETS heaters are a fast "Up" and "Down" regulation tool that provide grid stability and integrate renewable energy. At the same time, they bring economic value to the consumer, utility, ISO and other stakeholders. GETS load can continually change in real-time based on the current output of renewable energy source, LMP, and other needs of the grid.

It is clear that fast-acting electric energy storage can cost effectively manage the variability while maintaining grid stability and reliability. Furthermore, Grid-interactive Electric Thermal Storage space and water heaters can fill a significant portion of our nation's electric energy storage need at a fraction of the cost of other technologies. GETS can also be a valuable, carbon reduction component of the Smart Grid and other clean energy initiatives in the future. In order to achieve a low-carbon economy, we must encourage the use and development of innovative products and technologies that have the potential of getting us there.

5. CONCLUSION

In a perfect world, there would be no fluctuation of energy consumption, generation and prices. Everything would be well-defined and very predictable. In the real world, there is much variability and uncertainty.

Maintaining grid balance and stability with the variability of consumer demand, unpredictable grid events and variable generation from renewables is increasingly challenging. GETS systems provide precise, dependable, predictable and verifiable "up" and "down" dispatchable load to help with grid management. Setting the target 24-hour load shape the day prior and then re-confirming and setting the hourly average load 2 hours before the operating hour within the operating day helps to lower peak demand for electricity, better utilizes existing utility infrastructure and allows utilities to buy the lowest market-priced electricity. In addition, with a smart communication signal going to the GETS products every few minutes or seconds, the hourly average load can be adjusted up or down in real-time for low-carbon, fast regulation and integration of higher percentages of variable renewable energy. The GETS metering system verifies the operational accuracy of the communication and response exchanges. When aggregated, a GETS product can deliver predictable and verifiable regulation services that can be equal to, or in some cases greater than, the annual wholesale cost of the electricity it consumes. Grid-interactive Electric Thermal Storage space and water heaters are great tools for utilities and consumers to use for managing our energy future.

References

[1] KEMA Project: "BPCC.0003.001 – Emissions Comparison for a 20 MW Flywheel-based Frequency Regulation Power Plant." Available at http://storagealliance.org/resources/KEMA_Flywheel_Report_CO2_Reductions.pdf

[2] ORNL, ORNL/TM-2004/291, "Frequency Regulation Basics and Trends," Brendan J Kirby December 2004; accessed on August 3, 2011 at http://www.ornl.gov/~webworks/cppr/y2001/rpt/122302.pdf

[3] Other references and documents available on Steffes' website: http://www.steffes.com/off-peak-heating/smart-grid.html

About The Author

Paul Steffes P.E. is the CEO of Steffes Corporation based in Dickinson, ND. Steffes Corporation is a North American manufacturer of Electric Thermal Storage (GETS) residential and commercial heating solutions. He has worked closely with power companies from across North America for the past 25 years which has led to the development, refinement and application of load and demand management products that are now being used successfully by power companies to enhance their demand response programs. Paul's current work is focused on

applying GETS systems as a “Thermal Battery,”, to provide “up” and “down” fast regulation services and assisting in integrating large amounts of renewable energy. Paul is a Professional Engineer and is nationally recognized by many Investor Owned, Municipal, and Rural Electric Cooperative power companies as an expert in ETS technology. Paul is a charter member of the Smart Grid Inter-Operability Panel.