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Tech Take:

SMART GRID NEWS SMART GRID SCORECARD


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Ice Bear Energy Storage System — 90 out of 100

In SGN's Tech Take articles, power engineer and architect Erich Gunther evaluates actual products and services against the SGN Smart Grid Scorecard. Unless disclosed explicitly at the beginning of the article, neither SGN nor Erich Gunther has received any compensation from the vendor nor do they own stock in the company.

Used with existing controls, the Ice Bear™ distributed energy storage technology provides a significant permanent peak load shift benefit to both end users and grid operators. The technology from Ice Energy LLC also has a significant upside that can be realized with some key investments.

To understand my evaluation, you need to grasp these essential elements:

- The Smart Grid News Scorecard
- Why is peak load shifting so valuable?
- What is the Ice Bear?
- How do storage technologies interact with a smart grid?
- What is the demonstrated local value?
- What is the potential global value?

The SGN Scorecard

The SGN Scorecard was developed for a very important reason: *most of today's products do not adhere to Smart Grid principles.* They do not support the requirements envisioned by Smart Grid researchers such as EPRI, the California Energy Commission's Public Interest Energy Research program, the Modern Grid Initiative, and DOE's GridWise program. Nor do they adhere to the mandates in the Energy Independence and Security Act of 2007.

In particular, several elements of the EPRI IntelliGrid Architecture are critical to implementing a Smart Grid:

- Proven, Internet-derived communication technologies
- Service based architecture at the enterprise level
- Self-healing technology
- Well-defined interfaces and points of interoperability
- Application of industry and international standards
- Built-in security and network management

The SGN Scorecard is a checklist that measures whether products meet minimum standards for a Smart Grid. We will use it as the benchmark for all *Tech Talk* reviews. You are invited to use it free of charge for your own evaluations.

The purpose of demand response and peak load shifting technologies

Consumers of electricity are well versed in the concept of energy consumption; that is, we are billed and pay for kilowatt-hours (kWh), the use of power over a period of time. High consumption customers are often billed on other factors such as demand in kilowatts (kW), power factor (p.f.), reactive energy (volt-amperes reactive ,or VAr) and apparent energy (volt-amperes, or VA). The simplest of those factors to use is demand in kW as that value is already measured by the meter to calculate kWh for billing. It is common to track the peak consumption, or peak demand, measured during an interval (such as 15 minutes, or even a day) then report the maximum peak demanded during the billing period (such as over a month). Of these two factors, the kWh is actually the lesser of interest as this is an average value.

When a utility runs out of capacity, it means that there is not enough generation and delivery infrastructure necessary to meet the instantaneous concurrent peak demand of the customers. Utilities use comprehensive software tools to estimate the expected demand based on factors such as historical average per customer load, temperature, wind speed, precipitation type and rate, to name a few. With this information, the utility can then predict the amount of generation needed to meet the expected load, where the load is made up of the demand plus the transmission and distribution losses.

The software tools include the ratings of transmission and distribution equipment (lines, transformers) and are capable of highlighting potential overloaded delivery paths. This allows the utility to prepare either predictive corrective measures or reactive corrective measures. With a deterministic load shape that can be achieved with demand response and/or peak load shift efforts, the need for reactive corrective measures is obviated except under emergency conditions. These emergency measures include bringing peaking generation online (extreme supply) and performing rotating blackouts (extreme curtailment).

The value of Demand Response (DR), or Peak Load Shift (PLS), programs is easily quantifiable by utilities if the actual demand reduction can be precisely calculated rather than estimated. Since the technical characteristics of the grid are often well known, the most uncertain parameter is the actual load at any given time. This is tied to the fact that utilities most often collect averaged data over a monthly period (kWh consumed for the month).

The problem with many DR technologies is they are based on stochastic response. For example, a utility may know that they have sent a command to turn off all the water heaters in their territory, but do not usually have information on either the number of water heaters that will respond (elements in use when asked to shut off) or the exact amount of demand that each single device represents, and hence the exact amount of demand reduction the entire population of water heaters will provide at a given moment in time.

An ideal demand response technology is therefore predictable (a known number of units and their operating state) and quantifiable (amount of demand reduction per unit) that can automatically communicate and intelligently interact with the grid operation systems. With this information, a utility can then better calculate (with an amount of uncertainty) the investment in power generation (generators) and delivery infrastructure (transformers, lines, substation equipment) needed to meet the continually growing demand.

This is precisely the value of permanent load shifting. In permanently shifting a known quantity of peak consumption, utilities not only gain the value from predictable and verifiable peak demand reduction but also benefit from predictable and quantifiable off-peak consumption. This increased off-peak consumption significantly increases the T&D asset utilization factor, firms off-peak intermittent wind generation, and optimizes the efficiency of the entire system, not just the efficiency of the on-site device.

Ice Bear Technology

The Ice Bear technology is a thermal energy storage system targeted for installation on low-rise (under three stories) buildings which represents over 95% of the buildings in the U.S. The system consists of four primary parts, an insulated ice storage tank with main heat exchanger, an ice make compressor, a refrigeration management system, and a sophisticated controller. The system is installed with the existing (typically) rooftop air conditioning system and leverages the existing blower subsystem. An example of this is shown in Figure 1. The condenser subsystem is used to create the nighttime ice stored in the unit as well as for cooling during daytime operation.

Four possible operating configurations have been identified:

- Adding an additional evaporator coil inside a packaged unit
- Adding an additional evaporator coil in the ductwork
- Adding a ductless evaporator
- Re-purposing an existing coil, and removing its associated compressor

For all four configurations, the Ice Bear system is installed using conventional techniques (no special training required) and existing equipment (tools, gauges and test equipment). The condenser subsystem is charged with R410-A refrigerant, the mandatory replacement for all direct expansion units manufactured after December 31, 2009. One characteristic of this refrigerant that is exploited by the Ice Bear system is that it is more energy efficient operating in an ambient environment of 95°F or less than the more commonly used R-22 refrigerant.

In addition to the refrigerant choice, the key technology elements of the Ice Bear system are the ice coil design, controller, and control interface. The ice coil and refrigerant loop subsystem are designed for maximum energy exchange at all temperatures,

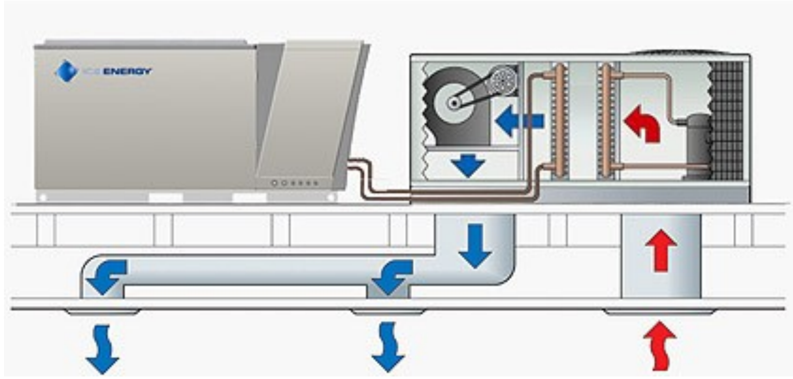

Figure 1: Illustration of Ice Energy Ice Bear unit with cooling coil integrated into existing A/C

using an oil-less liquid overfeed system. As this subsystem is physically isolated from the compressor, the proper oil ratio needed to maintain compressor operation can be independently controlled. The refrigerant loop uses an adjustable pump to regulate ice consumption during operation, and the power draw is limited to less than 300 watts for the pump.

The controller is capable of operating in intercept mode, whereby it receives the signals from the existing thermostat or building control interface. In this configuration, the end user simply sets the temperature and the Ice Bear controller optimizes the use of the stored ice in conjunction with the existing air conditioning unit. The controller is also capable of more exotic schemes, including one known in the control industry as "PID" (proportional-integral-derivative) control. The controller interface has been designed to work with a well-known time-series data application, but also is designed to deliver information using typical internet technology and the browser interface.

Figure 2 is helpful to understand one of the Ice Bear operating modes and is representative of the system shown in Figure 1. The green curve traces the operation of the existing air conditioning compressor / blower pair, the blue curve the outside ambient air temperature, the red curve the Ice Bear pump (ice using), and the purple the Ice Bear condenser (ice making).

This figure represents operation of the Ice Bear unit from 12PM to 7PM with the measured demand falling to around a constant 3.6kW (3.3 + .3) from up to a peak of 9.3kW, or even higher if allowed to run through the hottest time period, for a demand reduction of at least 5.7kW, while the temperature spiked at 93°F.

The purple curve shows the ice-making condenser operation over five hours to be a constant 3.7kW. On an average-over-time basis the net demand reduction is about 2.1kW. However, if the peak demand is taken into account, this reduction potentially saves the customer from facing a charge based on the 9.3kW peak during the afternoon, as the actual total demand is only 3.6kW over that period.

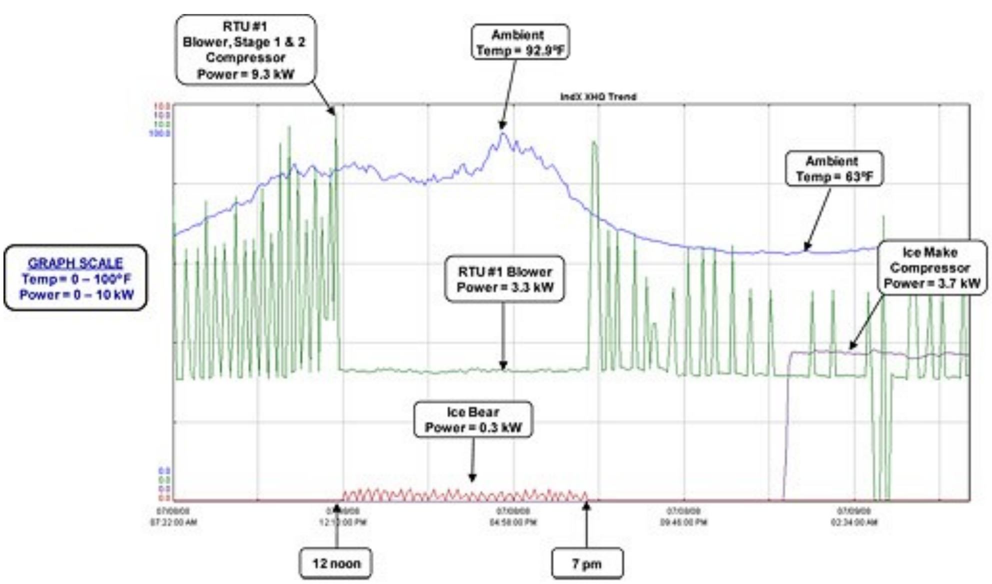

Figure 2: Actual Ice Bear performance in field installation

Field tests have shown up to 95% of the energy needed for cooling during operation in a single location can be shifted to the off-peak period, with one installation realizing a 40kW peak reduction during the afternoon from twelve to seven PM (three Ice Bear units installed). The power needed to run the Ice Bear during it cooling cycle is around 300 *watts*. With time-differentiated rates (TOU, demand charges, critical peak prices), single customer installations can receive a significant benefit from the Ice Bear installation (extremely short payback periods).

Evaluating the Ice Bear Distributed Energy Storage Technology

This evaluation has been particularly satisfying to my staff and me in that it involves some very basic engineering and thermodynamic principles that qualifies it as Smart Grid technology by leveraging very basic and elegant principles of physics rather than a complicated series of algorithms, communications, and information exchanges. As a result, I had to rethink how to interpret some of our scoring methods that had more computer-technology-based concepts in mind when we developed it.

On the core technology side, few methods of thermal storage could be simpler or more directly usable. The Ice Bear system creates ice during off-peak periods (both electricity demand and ambient temperature) then consumes it for cooling during the on-peak period, maximizing round trip thermal energy conversion. Existing equipment stress is also lowered as there is a reduced need for air conditioning compressors to operate during the high-temperature period of the day when cooling demand is greatest, extending the compressor service lifetime. Likewise, the condenser and compressor used to create the ice are operated during the low temperature period of the day, with the same resultant benefit.

Furthermore, the Ice Bear system's output does not degrade with temperature. As a result, the maximum capacity of the base system can be "right-sized," with the resulting reduction in compressor capacity (of 10-25%) producing energy savings even when ice is not being used.

The choice to build a system around conventional installation and operation techniques is quite savvy as it is tempting for many engineers to overdesign a system, with complications for the end user as the result. This then leads to low acceptance by the marketplace, no matter what might be the resultant benefit.

Another forward-looking design choice is using a refrigerant that is optimized for lower temperature operations. This allows the most efficient round-trip conversion of thermal energy while matching the expected operational times. The ability to use the system in both standalone and retrofitted applications lowers the anxiety of end users with respect to the risk of operating a nontraditional cooling system on this scale.

Finally, the industry changeover from R-22 to R410 has an especially significant negative efficiency impact to conventional equipment operating at high temperatures, over 100°F. By displacing the need for the conventional systems to run during the peak periods, this issue is abated.

The control side of the technology, and the back-end systems to support advanced applications, form the basis for much of the potential future value. Each Ice Bear unit has an Ethernet-ready controller. If Ethernet is not available, other modem-based technology may be used. The controllers are all connected to the Ice Energy home office through the "CoolData" network and send their captured raw data from up to 800 different sensor inputs to a central repository every twenty minutes or so (this is a configurable option). The operating mode of each Ice Bear unit is also captured and stored, as well as any application settings that a user may have set for any particular unit. All of this data is then processed by a suite of in-house applications, and most commonly served to end users and utilities through a Web portal.

By network-enabling each controller, Ice Energy then continually monitors the performance of each Ice Bear unit against whatever key performance indicators have been defined for a single unit, group of units, or population of units as a whole. The company is in a fashion performing continual "upgrades" of the software and firmware of the controllers, and leverages the network to serve those updates to each individual unit. The interface to the end customer, service personnel, or utility is through a browser-based Web portal than can even run on certain mobile phone devices.

Through their IT infrastructure, Ice Energy can also deliver demand-response solutions to a utility in a manner they are familiar – what is known as supervisory control and data acquisition, or SCADA. The utility could choose to send supervisory control (the "SC") orders to Ice Energy. These are then processed by an Ice Energy optimization application, which in turn sends out the commands to the units needing to take action.

Finally, the individual controllers return the captured data (the " ADA") to Ice Energy, which serves the data back to the utility either through a Web portal or other third-party integration path, allowing the utility to confirm that their control issue achieved the desired result.

An example of the control issues might be to cycle on and off all available units every 30 minutes to provide regulation services. Another example would be to maximize the load reduction on a certain feeder. The IT infrastructure adheres to standard interfacing protocols for B2B and interoperability communications; it is SOA based and offers a host of foundation services and interfaces (SOAP, XML, WCF, Web services, etc.), well suited to meet the current and future needs of CIM and Multispeak protocols, as examples. The controller infrastructure (Ice Energy calls it a Smart Grid controller) also is a host to a workflow engine, has a well-integrated security framework, and an industrial-strength data historian.

How Ice Bear Distributed Energy Storage Compares to Other DR Technologies

A few of the publicly proposed demand response technologies require active, and sometimes significant, end user behavior modification. Thermostat temperature changes, clothes dryer heating element switching, and water heater cycling are all immediately perceptible to the end user. A change of even a few degrees in temperature during a hot afternoon while the house or business is occupied is often perceived to be a poor trade-off for the minor reduction in the end-of-the-month bill. Finding a dryer full of wet clothes when they are needed for an important dinner is not a very satisfying result of being a demand response participant. An unexpected cold shower would also tend to dampen one's enthusiasm for participation in an activity yielding little direct benefit. Few commercial activities would also appreciate or support significant behavior modification as there are manufacturing facilities with strict temperature and humidity bands to protect against problem such as static electricity buildup.

The Ice Bear avoids these results by simply not modifying end user behavior. As the Ice Bear allows the cooling system to be run as desired while shifting the actual peak demand to more favorable periods, this provides the simplest method for end users to actively contribute to the peak reduction solution. The Ice Bear makes ice during off-peak periods (overnight) and expends the ice during the day for cooling. Simple temperature feedback and compressor operation is handled by the Ice Bear controller, leaving the end user to perform any necessary thermostat temperature settings.

The Ice Bear controller can also accept up to 800 sensor inputs and relay outputs to be used for additional DR functionality (such as participating in California's AutoDR program) beyond the Ice Bear system's own needs. However, even simple input, output, and thermostat temperature feedback can provide enough information for the system to provide its maximum peak load shift benefit. This simplicity and elegance is what makes this technology of especially smart.

Another advantage of this particular thermal storage system is the ability to deploy the units surgically, tactically or strategically across the power grid. For the first, the utility could target known problem locations, feeders, or zones in their system, improving localized system stability and grid conditions. For the second, the utility leverages their operational experience and their load growth forecasts to defer planned grid enhancements for feeders, substations and areas. Finally, a large-scale deployment of the units (up to 100's of MW capacity) defers investment in new peak-matching generation or lessens the need to run existing peaking generation.

With proper controls and response feedback, this type of energy storage could be used as a virtual spinning reserve, bid into the demand markets, or participate in any number of internal and external load management programs. Even if advanced controls are not used, simply running all available units within a territory flattens the daily load curve of the utility and defers both investments to support the demand and running of any peaking units to serve that demand.

How to Maximize the Upside

A few areas do require some additional investment to completely realize the upside of the Ice Bear units. The operating states and control algorithms are well known, and in fact are already available to be explored through the National Renewable Energy Laboratory (NREL) HOMER tool. As more system designers become familiar with the Ice Bear unit operation and potential, they can provide user feedback to Ice Energy and help improve or even modify the operating states and control algorithms. This might provide some improvement over the ongoing monitoring and diagnostics performed by Ice Energy.

Once utilities have deployed Ice Bear units across their system, they could manage them as a dispatchable demand reserve system in addition to daily operation. Advanced decision and control applications will then need to account for these operations.

Scorecard for Ice Energy LLC Ice Bear: 90 out of 100

Metric	Score (10 is best)	Comments
Impact	10	Few demand reduction technologies have lower impact on end-customer perception yet a higher impact on utility operations.
Openness	7	This evaluation depends on where you draw the interoperability line. All APIs at the enterprise integration level are open, published, and based on SOA standards but do not follow a standardized information model.
Standardization	9	Since communications are not needed for the Ice Bear to fulfill its function, the most important standards are those related to the mechanical and thermostatic interface aspects and compliance with HVAC industry standards, which this device does. Tested according to ARI, ASHRAE, and UL standards. Communicates using vendor-specific (though widely accepted) APIs but does so using accepted Internet (IETF and W3C) standards. Through the use of its interface to OSISoft's PI historian, the system supports the IEC CIM and other enterprise information model standards.
Security	9	This one is difficult to evaluate for the Ice Bear since communications are not necessary at the device level to achieve its objective. Since the enterprise interfaces utilizes best of breed TCP/IP based technologies for security, I have to give them a high score.
Manageability	10	Ice Energy provides turnkey, remote management capability. The huge sensor count allows Ice Energy to gather the information they need to continuously improve the product and manage it in real time. The integration with OSISoft's PI Historian allows Ice Energy to employ all of the analytical tools that the PI platform brings to the table.
Upgradeability	9	Core technology is solid, control technology easily and continually upgraded. Hardware in the field is typically not field-serviceable (no replaceable components).
Scalability	10	Units can be added to meet installation capacity requirements; local optimization should be extended to permit coordinated operations. A utility scales the overall amount of peak shifting available by arranging for more units to be installed in the area of concern.
Extensibility	9	Individual controllers extremely capable. It appears that there is a lot of capacity for future functionality.
Self-Healing	7	Low running demand requires less "cold start" capacity from grid versus conventional A/C systems. Controllers can run without networked connection.
Interactivity	10	Existing controller allows for up to 800 control points through a Web interface.
Total	90	

Conclusion

Only one obvious weakness (needs electricity to provide its benefit) keeps this thermal energy storage technology from a higher score. Investment in standardized communications and control interfaces down to the unit level (*i.e.*, moving the line or zone of interoperability down to the individual unit controller level) will open up the management of individual and grouped units to a broader spectrum of existing applications. As more units are deployed and more end users and utilities become comfortable with their operation, pairing the Ice Bear units with another type of generation to permit off-grid or power-loss operation would seem to make widespread deployment a trivial decision for an executive to approve. If many units were combined and used as a demand response system, the communications path would be a limiting factor – not unique to this technology.