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Ancillary Services from Distributed Storage

An EcoMotion White Paper

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Introduction

When a battery bank is installed at a host site there are multiple ways that it can be used. Some "advanced energy storage" systems are designed for peak clipping, others for peak energy savings. Other systems are installed to participate in utility demand-response programs. Still other storage systems are being deployed to support Independent System Operator (ISO) operations, at the macro, grid level.

The uses of battery banks – and other forms of distributed energy storage – and the corresponding sources of revenues for these deployment options can be categorized in three areas:

- Host Site Benefits: The first set of benefits accrues to the host site, largely in the form of demand charge and peak energy reductions. A consumer invests in batteries to control onsite demand and to limit ratcheting demand charges. Energy arbitrage involves buying cheap power at night, storing it, and then discharging during expensive peak periods.

- Utility Resource Benefits: The second set of benefits relates to utilities, batteries in the form of dis-patchable capacity to fulfill "resource adequacy" requirements. Storage systems can provide means for utilities to obviate the need for additional generating capacity, and can support regional power systems when plants are taken offline. A utility "may give exceptional incentives" to have dispatchable capacity at the ready.

- ISO / Grid Benefits: It is the third sphere of benefits that is the subject of this white paper. Specifically, these benefits are of value to the grid… to ISOs, the independent system operators. The ISOs realize the values to them of advanced energy storage. It is a good fit for grid stability. Storage can be "in the fingers of the distribution system" to manage frequency control and voltage support. And distributed energy storage providers can be paid handsomely for these ancillary services.

ISOs and the Grid of the Future

Independent system operators are responsible for controlling the grid. By definition, an ISO is an independent, federally regulated entity established to coordinate regional transmission in a non-discriminatory manner and to ensure the safety and reliability of the electric system. In California the CAISO controls ~1,000 power plants. Someone recently called the ISO "the referee" in bulk power transactions. It is certainly the scheduler.

The ISO's job is to constantly match consumer demand with power plant capacity. Every second of every day of the year, the ISO must balance supply and demand, maintaining specific system frequencies and voltage levels despite millions of things going on and off, consumers drawing variable amounts of power during the day, not to mention inter-grid exchanges.

The ISO has to meet shifting consumer demand, and cover both baseline and intermittent generators, and everything in between. This is managed using a system that involves the "Area Control Error" (ACE) – which monitors the grids to ensure proper frequency and voltage… and "Automatic Generation Control" (AGC) that automatically responds to signals from the ISO in real time and activates and deactivates power plants. Ancillary services support this balance, maintaining target system frequency and voltages.

Imagine the difficulty in balancing loads and supplies throughout the day. To assure reliability, the ISO has required utilities to maintain reserves, additional capacity at the ready. A required reserve margin of 15% was maintained by New York Power Authority when I worked there. By having resources standing by, grid operators can assure system reliability and keep the lights on. Consider this. A combined cycle, gas-fired power plant may take 15 minutes to bring on line. A lithium-ion battery pack can be discharged in a matter of 20 milliseconds. Storage is thus a valuable tool for grid operators and dispatch algorithms.

Because of their great capabilities, battery-based storage systems bring real value to the grid and to consumers that host them. EcoMotion postulates that there may be 1 – 2 million distributed energy storage systems – complementing the 1,000 power plants and the growing roster of distributed energy systems -- in California in the next 5 – 10 years all working in concert to keep the lights on at the least economic and environmental cost. SolarCity is pledging to incorporate storage with every solar system installed in California; others will likely follow suit. The State has 13 million homes. The sale of ancillary services presents win-win value and is poised for dramatic market acceleration at the distributed level.

Stacking Uses of Batteries

Rocky Mountain Institute published an instructive paper on storage in early 2016 titled "The Economics of Battery Energy Storage." It presents 13 forms types of storage that can be obtained from the same technology, such as battery banks.

A literature search reveals that ISO solutions/uses, on a $/kW basis, can be the most valuable of all storage services. Of the 13 services presented by RMI, again, ISO services may be most valuable. In one case studied, Frequency Regulation had a "service value" of over $200/kW per year. This compared to Resource Adequacy measured with a $50 – 150/kW per year value.

The key is prioritizing: Which use is most handsomely incented? Which use of stored energy provides the greatest service value, the greatest return on investment? How can the least amount of lithium or other battery chemistry create the most gold? This depends on location, site needs, and regional incentives. Prioritization leads to "stacking" benefits and determining batteries' discharge schedules.

Let's consider a spectrum of battery use. A current EcoMotion customer in Monterey County envisions using battery-based storage for emergency back-up. While an important function no doubt, emergency back-up is typically required less than 2% of the time. If batteries are deployed exclusively for backup, they sit idle for 98% of the time. At the other end of the spectrum is frequency regulation; an ISO function required 100% of the time.

There's lots of middle ground. Storage can be used for peak shaving – perhaps 3 – 5% of the time… and for peak energy reductions on a daily basis during summer peak period (~5 – 10% of the time). Batteries can also be used to meet the requirements of utility-incented, demand response programs. California's demand response participants commit up to 100 hours per year, about 1% of the time.

Perhaps most exciting are means to meld these benefits, to "stack" them, as many as possible, so that the storage asset on site is providing its investors (and hopefully hosts) with the maximum return.

Ancillary Services

Ancillary services are energy products used to help maintain grid stability and reliability. Traditionally they have been provided by conventional thermal power plants, pumped hydro plants, and other generating resources. They support the transmission of energy from generation resources to loads. For instance, as a power system ramps up from 3,566 MW to 4,035 MW, it incurs ups and downs in which generation and consumption are not ideally balanced. Thus about 55 MW of regulation services (1 – 2% of the load) are required to balance the load and maintain a stable grid frequency. Ancillary services are valued and purchased in the market, with competitive trading.

Ancillary services are provided to grid operators in a variety of ways, from centralized installations to distributed installations, down to 500 kW in California. And they can be developed by storage firms that stack ancillary services into their dispatch models. In California, resources providing regulation are certified by the ISO and must respond to automatic control signals to increase or decrease their operating levels depending on the need.

Batteries on customer sites may be used for ancillary services, perhaps mostly during non-peak periods and seasons. Dispatch algorithms are being developed such that the highest and best uses for the batteries – and the highest penalties for not being able to deliver when promised – are prioritized for use. For instance, a customer may have to first fulfill incentive program requirements, but may still have the opportunity to sell ancillary services. In cases, it may be worthwhile to incur a penalty for failure to meet a requirement if another program's incentive is large enough.

Types of Ancillary Services

There are four types of ancillary services products: Regulation Up, Regulation Down, Spinning Reserve, and Non-Spinning Reserve. In California, ancillary services include two additional services: Voltage Support and Black Start.

Most grids around the world maintain a frequency of 50 – 60 hertz (Hz). In the United States, the frequency has to be "very narrowly" maintained at 60 Hz. The frequency changes as power plants are brought on and off line, and as consumer demand varies.

Frequency regulation is the injection and withdrawal of power on a second-by-second basis to maintain grid frequency. Frequency regulation involves both "Regulation Up" and "Regulation Down." Frequency Regulation Up and Down fulfills similar objectives but are considered separate services, each with their own reliability criteria.

Regulation is a National Electricity Reliability Council (NERC) requirement for all U.S. and Canadian balancing areas. The balancing authority sends a regulation signal to generators fitted with automatic generation control (AGC) control, who vary their output up or down in response to this signal. For independent system operators (ISO) in the U.S., regulation is a market service sold on an hourly day-ahead basis. In non-organized markets regulation is provided by bilateral contracts.

- <u>Regulation Up</u>: Regulation Up results in a call for increased electricity output in response to a direct digital control signal, for example, the CAISO's Automatic Generation Control system. The signals are transmitted to maintain target system frequency.

- Regulation Down: Regulation Down results in a call for less electricity output, and storage, to “suck up” excess power on the grid to balance the system frequency. (Generators providing Regulation Down services have to maintain generation to drop load… while batteries can simply absorb surplus capacity.)

- Spinning Reserve: The portion of unloaded synchronized generating capacity that is immediately responsive so system frequency and that is capable of being loaded in ten minutes, and that is capable of running for at least two hours.

- Non-Spinning Reserve: The portion of generating capacity that is capable of being synchronized and ramping to a specified load in ten minutes.

- Voltage Support: Services provided by generating units or other equipment such as shunt capacitors static VAR compensators, or synchronous condensers maintain established grid voltage criteria.

- Black Start: Black start enables the restart of a power grid after a blackout. This is a bit like AAA coming to your house to jump start your car with a battery pack about the size of a lunch pail.

Renewables and the Grid

Renewables greatly expand the need and value of frequency regulation. In 2009, the CAISO regulation requirement was 419 MW. In order to meet the 33% RPS, the CAISO predicts that there will be a frequency regulation requirement of 1,114 MW. In New York, the NYISO determined that for every additional 1,000 MW of wind, the regulation requirement increases by 9%. To accept greater levels of renewables on the grid, there will be more need for regulation control, and energy storage is the most cost-effective way of achieving this in terms of economic and environmental benefits.

Ideal Ramping Resources

Faster response resources can result in fewer megawatts of required regulation. They are more flexible and can ramp more quickly, precisely. And they can reach their dispatch targets faster, and inversely recharging and being available for re-dispatch. They can repeat high cyclic storage without degradation. Thus they can be more accurate in meeting ISO requirements, and thus more effective regulation. In turn, storage can ramp and result in ratepayer benefits, like lower overall power costs, while reducing greenhouse gases.

The Pacific Northwest National Laboratories has analyzed frequency regulation, and what it calls “ideal resources.” These resources – batteries and flywheels – provide instantaneous response and unlimited energy. They are ideally suited to meet grid stability and reliability challenges and they are 2.7 times more efficient in providing frequency control. Thus 100 MW of an ideal resource will replace 270 MW of ancillary services provided by conventional generation. Inversely, by using ideal resources, frequency regulation resources requirements can be reduced by 40%.

Let's dig in on this. For "traditional ramping" one can assume a 5.1% per minute ramp rate for gas turbines. Thus it takes 20 minutes to reach full output. If the only resources available are gas turbines, to achieve 25 MW of generation in ten minutes, the grid operator needs to call on twice the capacity (50 MW), to have 25 MW available in ten minutes. This excess of capacity is not needed if energy storage is deployed. In fact, 25 MW of storage can be provided the full 25 MW of additional power within 20 milliseconds.

And slower-ramping resources – like gas turbines -- can be counterproductive, since they cannot switch directions quickly. And by the time they are delivering one way, for instance regulation up, regulation down may be needed. As a result of advocacy of the value of batteries as ideal frequency regulation devices, the Federal Energy Regulatory Commission passed Order 755 which requires ISOs to "pay for performance," meaning that energy storage systems receive much higher revenues per MW for regulation than traditional resources. A pricing example from the Atlantic Seaboard shows that regulation providers are paid in three parts: for capability, performance, and a bonus mileage payment… making these nimble assets all the more valuable.

The Market for ISO Frequency Regulation

The market for and size and tenure of utility-scale, energy storage installations that provide grid regulation services is surprisingly mature. Both flywheel and battery systems have been deployed that are impressive and now have track records providing frequency control. A case study from Korea is striking. While prices vary, an average "regulation clearing price" is $30 – 35/MWh… comparable to a MWh of power.

Battery and Flywheels and Regulation

A number of larger-scale battery storage systems have been deployed and operating for the as long as eight years. The Los Andes Energy Storage project in Chile uses lithium nanophosphate batteries, has 12 MW / 4 MWh in capability, and has been operational since 2009. Another system using the same chemistry – 20 MW / 8 MWh – has been operational in Johnson City, New York and integrated with the NYSISO since 2010. Lithium titanate chemistry is used in another battery bank operational since 2008.

PJM is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia. PJM – originally formed to serve Pennsylvania, New Jersey, and Maryland -- has been out front in the promotion of market-based ancillary services. In 2011, a 32 MW / 8 MWh "containerized" grid storage system was installed in West Virginia for frequency regulation services. Then in 2013, a 20 MW

/ 5 MWh system was moved from New York to Ohio to support the PJM grid. Both sites have 98% availability factors.

Flywheels also provide rapid response energy storage, and major projects have been developed, from the 3 MW system in Tyngsboro, Massachusetts to the 20 MW flywheel plant in Stephentown, Massachusetts. There's a 20 MW flywheel system in Hazle Township Pennsylvania, and another 20 MW project in Chicago Heights, Illinois. These flywheel projects, all developed by Beacon Power, are respectively providing 2%, 10%, 2%, and 2% of the regulation market in their ISO area. In most instances, the systems are sized to deliver maximum capacity for 15 – 20 minutes.

Frequency Control in Korea

The trend to install storage for grid support is global. Koreans are now showcasing the value of lithium batteries to provide frequency control for power grids. With 95 megawatts of its energy storage capacity now deployed by utilities in Korea, Canada, Germany, Australia, and the United States, the Korean company Kokam brings significant experience to this market.

Kokam recently announced that it has successfully deployed two Lithium Nickel Manganese Cobalt (NMC) Oxide battery storage systems for frequency regulation in South Korea. The system is made up of a 24 megawatt / 9 megawatt hour system, and a 16 MW / 6 MWh system. The Kokam batteries provide far less than one hour of storage… more like 15 – 20 minutes of discharge ability. The 24 MW system is the largest capacity Lithium NMC energy storage system used for frequency regulation in the world.

Operational since January 2016, the two new systems, along with a Kokam 16 MW / 5 MWh Lithium Titanate Oxide (LTO) system deployed in August 2015, provide the Korea Electric Power Corporation (KEPCO) with 56 MW of energy storage capacity for frequency regulation. They are part of the world's largest energy storage frequency regulation project; KEPCO is scheduled to deploy 500 MW of battery-based energy storage by 2017.

In addition to improving grid reliability, the Kokam storage systems will enable KEPCO to improve its operation efficiency by reducing its need for spinning power generation reserves. This will allow KEPCO to shift energy generation to lower cost, more efficient power plants and decrease "wear and tear" on all its power plants. The three Kokam storage systems are expected to save $39 million each year in fuel costs, plus commensurate greenhouse gas emissions reductions. These fuel savings are five times larger than the storage systems' purchase price over their lifetimes.

The new storage systems use Kokam's Ultra High Power NMC battery technology. Designed for high power energy storage applications, their higher density enables 2.4 MWh of energy storage to be in installed in a 40-foot container, compared to 1 – 1.5 MWh for standard NMC batteries. They also feature high power cycle life, better charge and discharge rates, and improved heat dissipation.

The California Market Today

In California, storage is just getting its legs, and attractive incentive programs are spurring activity too. Even the San Francisco 49ers' new Levi Stadium has storage. And within the world of storage is a new and potentially lucrative market for ancillary services.

Recent CAISO tariff changes have improved wholesale market access for energy storage. The CAISO reduced the minimum ancillary resource capacity from 1 MW to 500 kW. It also reduced the continuous energy requirement from 2 hours to 30 minutes for spinning and non-spinning reserves and regulation up and regulation down, allowing greater entry into these markets.

Just as the industry is abuzz about storage and the lithium ion revolution, the inner-circle industry is abuzz about ancillary services and ways distributed resources can support the grid. It's been happening at scale now for 5 – 6 years, and now is being promoted and maturing. Ancillary services markets are developing fast thanks to advanced energy storage, ideal ramping resources now becoming more and more common distributed behind the meter.