Renewables Integration – Market and Product Review, Phase 2
Comments of Beacon Power Corporation on Initial Straw Proposal
July 29th, 2011

Beacon Power Corporation (Beacon) – a manufacturer and merchant developer of flywheel energy storage plants that provide fast and accurate Regulation Service – appreciates the opportunity to comment on the CAISO's ***"Initial Straw Proposal – Market Vision & Roadmap/Day-of Market"*** ("Proposal") and the discussion at the July 19th stakeholder meeting about the Proposal.

The Proposal is part of the CAISO's Renewables Integration - Market and Product Review, Phase 2 ("RI-MPR2") initiative and contains: (1) proposed enhancements to the CAISO Real-Time Market ("RTM"); and (2) a stated intention to develop a longer-term "vision" and "roadmap" for forward-market enhancements in the future.

Beacon's flywheels, and other types of Limited Energy Storage Resources ("LESRs") like batteries, provide Regulation by rapidly injecting and withdrawing power from the grid to follow moment-by-moment demand and frequency changes. Beacon's flywheel technology can respond with full up or down power less than four seconds after receiving a CAISO control signal. By comparison, the CAISO allows generators in its current Ancillary Services ("A/S") markets, including the Regulation market, up to 10 minutes (600 seconds) to ramp to full power.

The Proposal would:

- ***Change the CAISO Regulation market to a true "grid balancing" service***, which would only provide Regulation for a very short period (1-2 minutes); and
- ***Create a new A/S product called Real Time Imbalance Service ("RTIS")***, to better balance the system between Real Time Economic Dispatch ("RTED") intervals and drive Regulation units back to their "null point" every 1-2 minutes. The Proposal assumes that fast resources like LESRs will provide Regulation in the future, with slower resources gravitating to RTIS. The Proposal includes compensation for both Regulation and RTIS with capacity and mileage payments, and an accuracy adjustment –a "pay for performance" framework.

Beacon Power *strongly* supports these elements. The CAISO 20% Renewable Portfolio Standard ("RPS") study showed significant need for more Regulation capacity *and* ramp-rate to integrate Variable Energy Resources (VERs), and later studies show even greater need at a 33% RPS. However, the current Regulation market and compensation structure does not dispatch storage resources to take advantage of their fast-ramping capabilities or send price signals to encourage all resources to perform faster or more accurately than the allowable 10-minute ramp time.

CAISO's proposal to effectively split the current Regulation resources into a fast-moving group that would provide Regulation service to respond to the second-by-second changes on the system and a (relatively) longer-duration RTIS to manage the greater-than-a-minute system imbalances, coupled with a performance-based compensation structure, will result in a market structure that encourages fast-ramping storage technologies to enter the market and sends the right market signals to all resources to achieve the additional capability required to manage more VERs on the grid.

Guiding Principles

Beacon Power agrees with the Guiding Principles in the Proposal, especially these principles:

1) Transparent: The CAISO market should rely on price signals to incent participant behaviors and performance that support CAISO operating needs.

2) Durable and Sustainable: The CAISO market should procure an efficient and commercially viable resource mix to maintain reliability and attract new investment when/where needed, through a combination of market revenues, forward contracts, and availability and performance incentives.

3) Cost-effective and Implementable: The CAISO market design should leverage existing CAISO infrastructure, industry experiences and lessons learned, including the experience of other ISOs/RTOSs about what works and what does not.

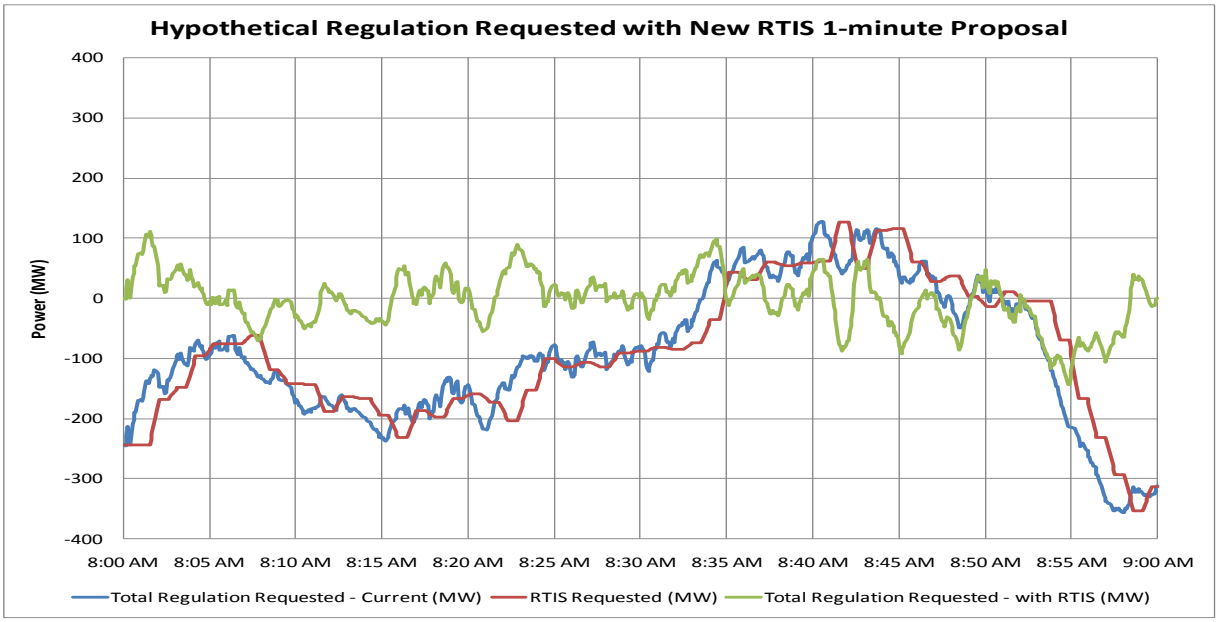
Proposed Changes to Regulation and new RTIS

Regulation and RTIS service

- ***Creation of new RTIS service:*** Beacon agrees with the Proposal assumption that the Regulation product is better suited for fast-ramping units, and RTIS is better suited to slower-ramping units, especially if the market change is accompanied by a faster-moving Regulation signal that utilizes the capabilities of LESRs and other fast-ramping resources (see below). A separate service for slower-ramping resources will benefit both types of resources and, more importantly, result in operational efficiencies for the grid.

  Figure 1 shows a hypothetical Regulation dispatch with a 1-minute RTIS dispatch interval, assuming RTIS is dispatched via an AGC signal (see below) and the Regulation dispatch signal returns the Regulation resources to their null point with each RTIS dispatch.[1]

Figure 1



[1] Figure 1 Assumptions:

- "Total Regulation Requested" comes from the CAISO REM Model posted for 12/21/2010 meeting
- At the beginning of each 1-minute interval, the "Total Regulation Requested – with RTIS" is measured
- Halfway through the same 1-minute interval, the RTIS begins to dispatch (ramp) resources to meet the Regulation dispatched 30 seconds earlier, so RTIS returns the Regulation resources to zero by the next 1-minute interval
- The "Total Regulation Request – with RTIS" for the next AGC cycle is then calculated by subtracting the "RTIS Requested" for the current interval from the "Total Regulation Requested"

Figure 1 shows that the slower RTIS signal is easier to follow and cycles less frequently than the 4-second Regulation signal, so RTIS generators could run at lower heat rates[2] and incur lower operating/maintenance costs. When a slow-ramping unit follows a fast signal and does not control accurately, that inaccurate control creates the need for even more control actions (i.e. "over-control"). If slow-ramping units function mainly to return Regulation resources to their null point, that would limit the amount of over-control of those resources, allow for the system to be more effective and use less total capacity to provide the same reliability level.

Figure 1 also shows that the proposed new Regulation market, designed to manage the second-by-second imbalances, should result in a dispatch signal to Regulation resources that changes direction very often. This would take advantage of fast-ramping resources' ability to ramp quickly and provide improved system control.

The proposed market design should also result in a Regulation dispatch that tends to be energy-neutral, because the CAISO expects to set the resources back to their "null point" every minute. It would thus be well-suited for many storage and demand response technologies, thereby likely broadening the mix of resources participating in the Regulation market.

Overall, the CAISO's proposal to create a new RTIS market and redefine Regulation should provide the following advantages:

- **Advantages to the grid:** Lower total procurement, more effective and tighter control, fewer emissions associated with ramping resources;
- **Advantages to fast-ramping capacity-limited resources:** Utilizes fast-ramp capabilities, energy-neutral signal increased utilization of resource capacity; and
- **Advantages for conventional (ramp-limited) resources:** Less-frequent cycling, operation closer to preferred operating point, lower O&M.

- ***Procurement of Regulation vs, RTIS:*** The CAISO said at the meeting that RTIS could be a subset of the Regulation requirement. However, there was confusion around that point when it became clear that the CAISO is not sure whether RTIS dispatch would be automatic (e.g., via AGC) or via Automated Dispatch System (ADS) like Imbalance Energy (I/E).

  Beacon does not see how RTIS, with its much greater dispatch interval, could provide the same level of system control or reliability as Regulation even with an AGC signal, and it definitely could not do so with an ADS dispatch. There certainly could not be a 1-to-1 substitution of one for the other.

  Instead of a subset of Regulation, Beacon suggests that RTIS is really a subset of I/E – a faster imbalance service that would perform the functions of the current I/E service, only better. Like the current 5-minute I/E service (or potential 15-minute I/E service in the future), RTIS would function both to return Regulation units to their null point and follow longer-duration load and VER changes (e.g., sustained ramping needs).

  Thus, the RI-MPR2 effort should consider:

  - The RTIS dispatch method – whether to dispatch via AGC or ADS; and
  - The procurement split between RTIS and longer-response I/E service.

[2] Heat rate is the number of British Thermal Units of Fuel that is used to produce one kWh of electricity

Changes to Regulation service

- ***Bi-directional Regulation product:*** Beacon supports conversion of Regulation into a bi-directional service. This is the form used by other ISOs, and it will accommodate the new faster-moving resources that the CAISO expects will provide Regulation in the future. The redefined product would be true "grid balancing," since the CAISO will return the units to their null point every 1-2 minutes. Therefore, procuring Regulation as a bi-directional product makes sense.

- ***Regulation dispatch signal:*** The current CAISO Regulation dispatch signal does not take advantage of LESR and other fast-response resource capabilities, because it: (1) damps the rapidly moving, instantaneous ACE to minimize generator movement and directional change; and (2) further slows overall response by "allocating" the dispatch instruction pro rata (based on MWs of Regulation capacity) to all of the generators providing the service, regardless of their response speed, instead of prioritizing the dispatch to those resources that can respond the fastest (as is done in other markets, such as ISO-NE).

  The allocation of Regulation dispatch between units should be less of an issue if Regulation is converted to a service primarily provided by faster-ramping resources. However, this conversion offers the CAISO an opportunity to optimize the Regulation signal by eliminating the damping component. This change would provide true management of second-by-second imbalances by changing direction more frequently to take advantage of fast-ramping capability, limiting the amount of energy necessary to provide this service.

- ***Regulation compensation overall:*** Beacon Power *strongly* supports the CAISO's proposed payment structure to compensate Regulation resources based on capacity, mileage, and perhaps an accuracy adjustment. This type of payment structure would compensate resources commensurate with the amount of service they perform for the system operator. Performance-based payments would also promote improved market performance, i.e.:

  - ***Encourage all resources to increase their ramping capabilities*** and the speed and accuracy of their response; and

  - ***Encourage market entry of new, faster-ramping technologies*** capable of responding nearly instantaneously with precise accuracy to a control signal.

  By improving the performance of the Regulation fleet, this structure should reduce the amount of capacity that must be procured to integrate VERs, with cost savings to consumers. Furthermore, structuring payments into two-components, capacity and mileage, will better reflect supplier costs, i.e.:

  - ***Capacity costs***, the opportunity cost of making capacity available to provide Regulation or RTIS – primarily, the lost revenue for not using the capacity for a different product and the additional fuel cost of operating the unit at a lower operating set-point; and

  - ***Mileage costs***, the additional fuel cost of operating the unit at a lower operating set-point and moving up/down in response to a Regulation signal – increased fuel costs of operating in a non-steady state condition, increased O&M due to additional 'wear and tear' on the equipment, and potentially the cost of decreased cycle life.

- ***Regulation capacity payment:*** Amount of capacity offered (MW) and price per MW of capacity ($/MW). [The CAISO should also calculate the resource's lost opportunity cost and include it in the marginal resource's total cost.]

- ***Regulation mileage payment:*** The price should be market-based. Market-based pricing will encourage resources with the lowest costs to provide Regulation movement (ramp-rate) to enter the market and give rate-payers the benefit of new, low-cost resources.

  Each resource should be paid a price-per-MW movement multiplied by its actual amount of MW movement, up and down, during each hour. However, instead of stating ramp rate in MW-minute, Beacon suggests changing this to MW/AGC-dispatch cycle (4 seconds).

  This basis would be better aligned with the true ramp-rate capability of the types of resources likely to provide service in the new Regulation market and the use of Regulation to manage 4-second system imbalances. For example, Beacon Power's 20 MW commercial-scale flywheel storage plant can provide its full output within one dispatch cycle, i.e. 20 MW/AGC cycle, while over a minute it has an equivalent ramp-rate of 300 MW/min, even though it has a maximum bi-directional capacity of 20 MW.

- ***Regulation procurement methodology:*** The Proposal did not specify how the proposed multi-part pricing structure would be used in the Regulation procurement methodology, other to state that Regulation will be procured based on bid price and resource ramp rate. We offer our suggestions below on that topic.

  Using each resource's bid-in ramp-rate and total capacity offered, the CAISO can determine, based on its dispatch method, how much movement each resource could provide relative to its capacity offered. For example, it could determine that a 20 MW resource bidding a 4 MW/min ramp-rate could provide 200 MW of movement that hour, while a 20 MW resource bidding a 300 MW/min ramp rate could provide 900 MW of movement.

  Thus, a two-part bid structure will let CAISO assess the additional value that a faster-ramping resource can provide over a slower-ramping resource per MW of capacity offered, and use that data in its selection algorithm to determine the least-cost set of resources to provide Regulation.

  This method of bidding, selecting, and compensating resources should also allow the CAISO to send the right market signals for resources to offer a higher amount of capacity and ramp-rate. Since frequency is a function of both the amount of MWs of imbalance on the grid *and* the speed of the imbalance correction, it is appropriate to select and compensate Regulation providers based on both the amount of MWs capacity made available *and* the speed at which it can deliver that capacity in response to a CAISO control signal.

  Alternatively, the CAISO could use a single bid to set the price for both the capacity and performance payment, as ISO-NE does today, as long as it pays resources commensurate with the service they provide. ISO-NE has a performance payment mechanism that pays resources based on the amount of MW movement, up and down, that each resource provides in response to the control signal, but it uses a single-bid approach ($/MW) to set the clearing prices for both the capacity and performance payment.

  The ISO-NE Regulation performance credit is the product of the $/MW clearing price, the unit's Regulation Service megawatts (the sum of the absolute value of up and down movement in response to the ISO's control signal) and the Capacity-to-Service Ratio set at 0.1 (a value calculated by the ISO to based on their finding that the average regulation resource in their market provides 10 MW of movement per 1 MW of capacity). This structure ensures that:

- A resource dispatched to provide an average amount of Regulation movement in the market will have a 50/50 split between its capacity and performance payment;
- A resource dispatched to provide more work (MW-movement) will be paid more than average; and
- A resource dispatched to provide less work (MW-movement) will be paid less than average.

The ISO-NE Regulation market design does not enable real-time optimization between the amount of capacity and amount of performance to select the least-cost portfolio of resources, like a two-bid market. However, it clearly sends the right market signals for resources to bid in as high a ramp-rate as possible, because resources deployed more to provide Regulation are compensated more.

Over time, ISO-NE has been able to administratively lower its average regulation capacity procurement as a percentage of average system load. ISO-NE procured 120 MW of Regulation capacity (0.8% of load) in 2008, 94 MW of Regulation capacity (0.66% of load) in 2009, and 70 MW of Regulation capacity (0.47% of load) in 2010. Moreover, in all three years, ISO-NE procured the least amount of Regulation per average system MW of load than all other ISOs.

- ***Regulation net energy settlement:*** The Proposal would eliminate the net energy settlement, based on the expectation that up-and-down movements would net each other out for the new bi-directional service. Beacon cautions the CAISO to study this further.

  Although the signal may be energy-neutral, storage resources have conversion losses and thus are still net consumers of energy. Either the CAISO's "null point" for each resource must provide an offset for each storage resource's conversion losses, reflecting the resource's round-trip efficiency, or the CAISO should continue to maintain net-energy payments. Energy settlements also provide desirable incentives for efficiency.

  This issue was heavily discussed during the REM initiative. Thus, we seek clarification on how the new Regulation market will work with the recently designed Regulation Energy Management (REM) tariff.

ISO's proposed schedule and timeline

Beacon applauds the steps that the ISO is taking to fully utilize the capability of fast-ramping technologies and to implement pay-for-performance. However, we are concerned about the length of time to implement these changes. (i.e., 2014-2015 timeframe).

As discussed above, the CAISO 20% RPS study showed significant need for additional Regulation capacity and ramp-rate to integrate 20% and 33% renewable resources. For example, the maximum Regulation Up requirements estimated for summer 2006, 2012, and 2020 were 278 MW, 455 MW, and 1444 MW, respectively. Similarly, the maximum Regulation Up ramp-rates estimated for summer 2006, 2012, and 2020 were 75 MW/min, 118 MW/min, and 528 MW/min, respectively.

To encourage faster ramping capability in the market – through improvements to the Regulation response of existing resources and/or entry by new, fast Regulation resources – the CAISO should implement the proposed new Regulation payment structure as soon as possible. This least-regrets action would do the following:

- ***Send the necessary market signals*** to encourage investment in new storage resources that can provide critically needed renewable integration services.
- ***Reduce or eliminate the need for increased CAISO Regulation procurement*** due to higher intermittent renewable resource penetration, thereby lowering the cost to ratepayers for attaining 20% and 33% renewables on the California grid.

Postponing implementation of the new Regulation design until 2014-2015 will significantly delay investment in new storage technologies that are "grid-ready" and operating in other regions of the country today. If implementation is delayed, the CAISO should at least implement interim measures in the existing Regulation market, including "pay-for-performance" compensation and structuring the Regulation dispatch signal to take advantage of fast-response regulation resource ramping capabilities.

(See Appendix A, which provides information on a dispatch methodology that would split the Regulation signal into a slow and fast signal and that could be utilized in today's Regulation market prior to implementation of the CAISO's proposed Regulation and RTIS market changes.)

Other potential products and issues – automatic unit response

Beacon Power supports the CAISO proposal to create a product for Inertia and Frequency Response. The procured Energy, Ancillary Services, and Unit Commitment services may not provide enough natural Frequency Response and Inertia to accommodate the integration of variable energy resources. Moreover, it may be difficult and/or costly for VERs to acquire the ability to provide primary frequency response.

This type of new market product would enable the CAISO to procure Inertia and Frequency response from other resources, such as flywheel energy storage, with the capability to provide synthetic inertia and primary frequency control. Storage provides a very fast response, could always be available and proportionate in response, and does not require an underlying amount of either generation or load to be operational.[3]

The primary source of frequency response today is generation. However, generation-based frequency response can only be provided by a subset of the generation fleet, and only when the generation is operating and below its maximum output. A market that enables storage resources to provide Frequency Response and Inertia would greatly expand the pool of resources available to the CAISO for managing this critical reliability function. Furthermore this market product would ensure that the CAISO has sufficient Inertia and Frequency Response during any hour of the day.

[3] Flywheels' capability to provide frequency response was proven as part of the Beacon Power's demonstration program conducted within the New York ISO in 2006.

APPENDIX A

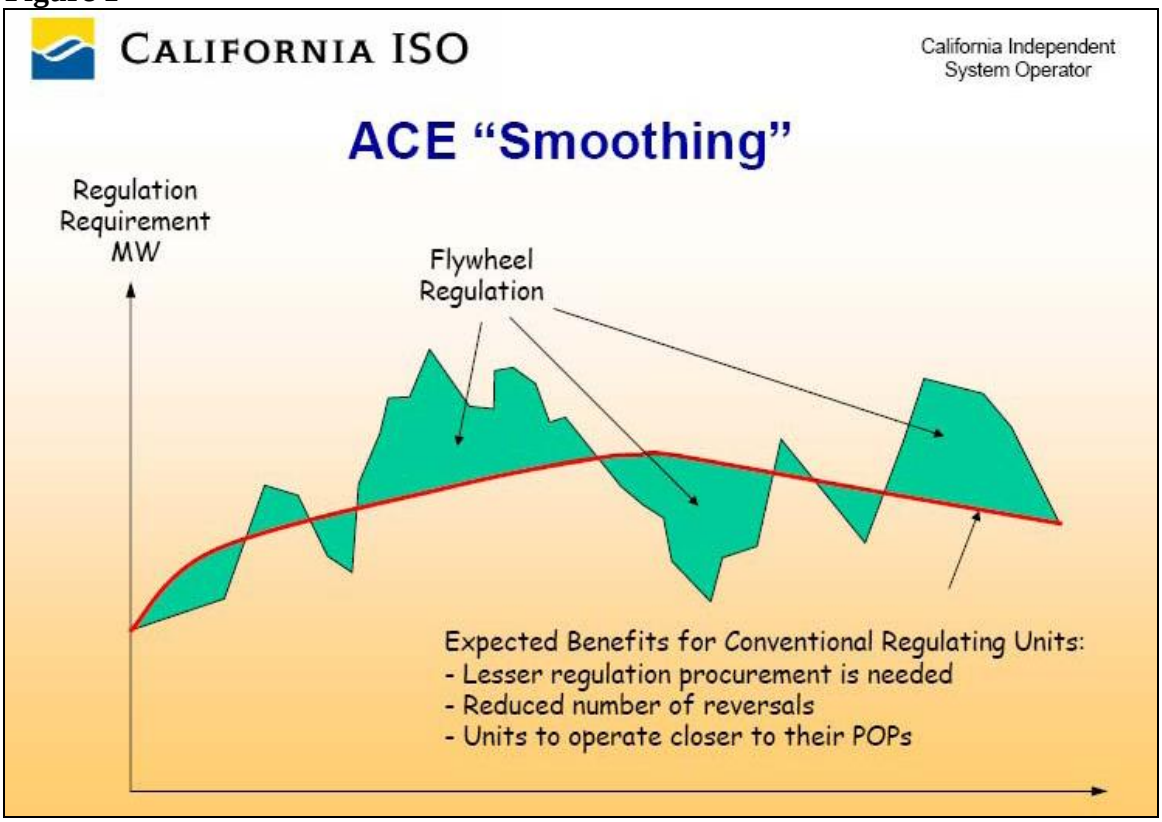
CAISO ACE Smoothing Dispatch

In 2005, in conjunction with Beacon Power and the California Energy Commission (CEC), the CAISO developed a new dispatch algorithm to take advantage of flywheels' fast response capability.

Most regulation dispatching algorithms intentionally damp the rapidly moving instantaneous ACE, so the participating generators movement and directional changes are minimized. During the flywheel technology demonstration project, the CAISO developed a new algorithm, called ACE Smoothing, to maximize the benefit of these fast moving resources to the ISO.

The ACE Smoothing dispatch mechanism divides the work of correcting the ACE into two distinct roles: 1) conventional generation (ramping in the 5-10 MW/min range) provides the corrective action necessary to correct imbalances that occur over tens of minutes; and 2) fast responding resources (ramping in the 100's MW/min range) provide the corrective actions required to react to instantaneous changes in ACE. Figure 1, taken from a February 2005 CAISO presentation to the CEC, shows graphically the goal of correcting the majority of the ACE with fast-responding resources and leaving an easier task of following the slower signal to the slow responding resources.

Figure 1



The signal given to the slower ramping units is derived from a rolling average of the ACE (Equation 1). This slower signal is easier to follow and cycles less frequently, so those generators could run at a lower heat rate[4] and incur lower operating and maintenance costs. When a slow-ramping unit follows a fast signal and does not control accurately, that inaccurate control creates the need for even more control actions. This is known as over-control. Allowing slow-ramping units to react to the slow portion, or smoothed portion, of the ACE limits the amount of over-control, allows for the system to be more effective and uses less Regulation to provide the same level of reliability.

Equation 1:

$$ACE\ Smoothing\ Slow\ Signal\ =\ ACE_m \times MW_{capacity_i}/MW_{capacity_{total}}$$

Where

$ACE_m\ = 10\ minute\ rolling\ average\ of\ ACE$

$MW_{capacity_i}\ =$ the Regulation capacity of the conventional regulation resource i

$MW_{capacity_{total}}\ =$ the total Regulation capacity of all the conventional regulation resources

The signal to the faster ramping units is the difference between the instantaneous ACE and the rolling average (Equation 2). This part of the signal changes direction very often, taking advantage of those resources' ability to ramp quickly and limiting the amount of energy necessary to provide this service. The fast signal also tends to be energy-neutral, because it does not contain any of the ACE long-term trends. All these properties combined make the fast portion of ACE Smoothing ideal for Energy Storage, V2G, or SmartGrid applications.

Equation 2:

$$ACE\ Smoothing\ Fast\ Signal\ =\ (ACE_m\ -\ ACE) \times MW_{capacity_i}/MW_{capacity_{total}}$$

Where

$ACE_m\ = 10\ minute\ rolling\ average\ of\ ACE$

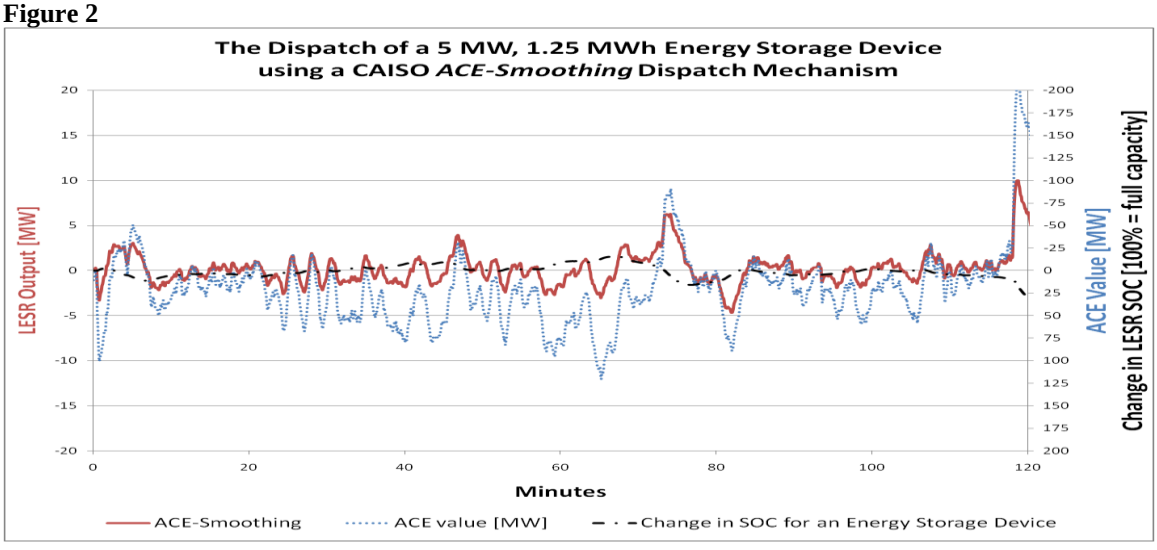
$ACE\ =\ Instantaneous\ Area\ Control\ Error$

$MW_{capacity_i}\ =$ the Regulation capacity of the fast responding resource i

$MW_{capacity_{total}}\ =$ the total Regulation capacity of all the fast responding resources

Figure 2 shows ACE data, the resulting fast signal from the ACE Smoothing dispatch method, and the change in LESR SOC responding to the dispatch. Note that the change in SOC is less than 25%, i.e., the resource has more than sufficient energy storage capacity to provide this service. The signal is well-matched to this resource's characteristics with respect to ramp rate and energy duration.

Figure 2



[4] Heat rate is the number of British Thermal Units of Fuel that is used to produce one kW of electricity

Our CAISO demonstration also developed an easy solution to the current problem of inability to send a negative signal to participants. This problem was resolved by CAISO sending raw signal data to Beacon that was scaled on a 0 to 65000 counts basis, where 0 to 32500 counts equaled minus full scale output to zero output, and 32500 to 65000 counts equaled zero output to full scale output.

The final results[5] produced by the CAISO suggested that combined approach of the ACE Smoothing algorithm provided twice the regulation benefit of traditional AGC resources driven by traditional dispatching algorithms.

ACE Smoothing Advantages for the Grid

- Less Regulation Procurement
- More effective and tighter control – reduces amount of over-control
- Fewer emissions associated with Regulation

ACE Smoothing Advantages for Energy Storage, V2G, SmartGrid

- Takes advantage of the ramp capabilities
- Energy neutral signal increase utilization of the resource's capacity

ACE Smoothing Advantages for Ramp-Limited Resources

- Allows generation to cycle less frequently and operate closer to their preferred operating point
- Less O&M for Generators

[5] California Energy Commission. (2007, January 10th). *News Releases.* Retrieved February 2nd, 2009, from California Energy Commission: http://www.energy.ca.gov/releases/2007_releases/2007-01-10_Beacon_Power.html