

Integration of Energy Storage Technology
White Paper – Identification of Issues and proposed Solutions
May 22, 2008

Introduction

This white paper describes the issues on integrating different types of energy storage technology on the electric power grid. The November 2007 California ISO publication “Integration of Renewable Resources” contained a chapter that described some of the available technologies. A copy of that material is reproduced as Appendix A to this paper. In the November report, the ISO described the potential value of storage to help with the integration of large amounts of intermittent resources such as wind and solar generation. The purpose of this paper is to continue that initial discussion, identify outstanding issues and barriers to the successful deployment of storage facilities, and ultimately to determine the optimum solution to the issues.

Background

The overall process to be used will be stakeholder driven. The proposed steps and initial timeline are:

- May 29th, 2008 – Web cast with stakeholders to identify the major issues.
- June 2-10– Rewrite of the white paper to further describe the issues and post the paper for stakeholder review.
- June 17 – Stakeholder meeting at the ISO in Folsom to discuss the issues and proposed solution alternatives.
- June 18-30 – Write paper on proposed solutions.
- July – Perform additional analytical studies as required to analyze proposals
- July-August – Date to be determined – 2nd Stakeholders meeting to discuss proposals and results of the studies.
- August-September– Write detailed description of recommendations and alternatives
- September – Post for comments
- October – Respond to comments and revise proposal as necessary
- TBD - Presentation to ISO Board -

The ISO currently has 20,000 MW of wind generation and 20,000 MW of solar generation in the generator interconnection queue. While it is doubtful all of these renewable energy projects will be built, the ISO expects that over 7,000 MW of wind generation will be connected to the system by 2011. We also expect to have at least 1500 MW of solar generation. The forecast for 2020 is for 12,000 MW of wind generation and 6,000 MW of solar. The variability of these renewable resources creates an opportunity for new storage technology. Storage facilities can provide ancillary services (regulation and operating reserves) as well as a way to shift energy delivery from off-peak periods to delivery during peak load periods.

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The ISO participated in a California Energy Commission sponsored research project in 2005-6 to evaluate the use of a high-speed flywheel system for regulation services. A 100 KVA high-speed flywheel was located at the Distributed Utility Integration Test Facility (DUIT) in San Ramon, CA. The ISO sent a real-time regulation signal to the unit to verify its ability to follow a control signal from the ISO Energy Management System. For this test, the ISO used an ACE (Area Control Error) and Frequency signal to drive the flywheel instead of a traditional AGC (Automatic Generation Control) signal. This type of a signal creates many more charge and discharge cycles for a ten minute period and is more compatible with the operating characteristics of a storage system. An AGC signal to a generating plant can often drive the unit up or down from its operating set point for an extended period of time, from several minutes to 10 to 20 minutes, so a traditional AGC signal may not be compatible with some storage technology. The use of an ACE/Frequency signal worked well and the project was a success. The longer term question that still must be resolved is how to blend an AGC regulation signal that fits both generation and non-generation facilities and provide the system control required to meet NERC and WECC standards.

There currently is no market or tariff to pay a facility for providing a pure frequency regulation service. The Western Interconnection (WECC) has been working on a frequency response standard for several years. The ISO has anticipated that if a 30 second frequency response standard is finally approved, the ISO will probably have to create a new market for procurement of a frequency response service. New storage facilities will probably find this a very attractive market. The current projection for approval of the proposed frequency response standard is sometime in 2009.

FERC Order 890 has directed the ISO/RTO's to modify their tariffs to reflect the fact that non-generating resources can provide ancillary services. The ISO's proposed tariff language changes have been filed with FERC to meet this requirement. There are still numerous issues that need to be discussed and alternative solutions proposed to assist with the integration of storage technology on the grid.

Interconnection issues

One of the first issues is what is the process and procedures for interconnecting a new storage facility. There are at least five potential locations:

- S1 – Customer sites
- S2 – Distribution substations
- S3 – Sub-transmission substations
- S4 – Transmission substations
- S5 - Generating stations

Diagrammatically this can be illustrated as shown below:

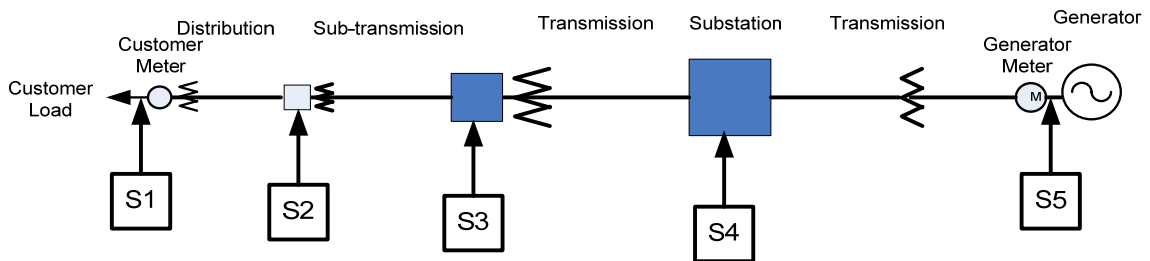


Figure 1

The storage facility could also be interconnected to the transmission line, sub-transmission, or distribution circuit which potentially adds to the complexity of the interconnection. The facility would have to be included in circuit protection schemes and its rapidly changing injections of energy and load on the circuit could impact other automatic control devices such as automatic voltage regulators. Other transmission or distribution circuit customers could experience voltage flicker problems. For the purposes of this initial discussion of interconnection of storage facilities, let's limit the discussion to the potential interconnection points S1 to S5.

Storage can provide a variety of services at each of these locations and the types of services it provides will determine how it is treated financially. Some of the options are:

1. Transmission device – voltage support, VAR source, mitigation of transmission loading, etc. – and therefore storage is financed through transmission rates.
2. Distribution device – power quality improvement, voltage support, load relief, load leveling, etc. – included in distribution rates.
3. Customer device – demand peak reduction, power quality, uninterruptible power supply, plug-in hybrid vehicles, etc. – paid for by the customer or a curtailable load provider.
4. Market services – Ancillary Services such as regulation and operating reserves, arbitrage of energy prices (shifting of energy from low cost periods for deliver during higher cost periods). Obviously these services are financed through the energy and capacity markets.

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Customer Storage (Location S1) is behind the meter and subject to National Electric Code regulations. An example could be a traditional UPS device with a large amount of battery storage and a backup generator. It could also be a Plug-in Hybrid Electric Vehicle (PHEV). If the customer also has Distributed Generation (DG) behind the meter, then CPUC's Rule 21 regulations will apply if the system is capable of reverse power flow on the distribution system. The question is whether Rule 21 would apply for a large storage device on the customer side of the meter.

Storage connected to the distribution system (Location S2) could be owned by either the local distribution company or it could be merchant service. If it is owned by the utility and is used to support the distribution system, then it would be financed by distribution rates. It probably would not be used to sell ancillary services to the ISO. If it is merchant based, then would the utility treat it as a DG facility or would they have to negotiate a performance based contract for the services? If it is merchant based, could the operator sell Ancillary Services to the ISO? The distribution system would probably be impacted by a 10 MW storage device that was providing fast regulation service acting like an extremely variable \pm MW load. Obviously this option needs to be discussed with the utilities to determine if it is realistic to have independently owned storage devices plugged into the distribution system.

Storage connected to the Sub-transmission system or non-ISO transmission (Location S3) could provide both transmission services to the Transmission Owner (TO) and ancillary services to the ISO. The acceptable size of a storage device would depend on the voltage level and the robustness of the sub-transmission system. The owner of such a storage device would have to apply to the transmission company for an interconnection study and approval. A storage owner could potentially negotiate with the transmission company to set up a contract for transmission services and then sell ancillary services to the ISO. The big question is whether such a hybrid method of financing a storage device is feasible and practical. If the device is used to support the sub-transmission system and it is owned by the transmission company, then they would need CPUC approval to include it distribution rates or FERC approval to include it in transmission rates.

Storage connected to the ISO Transmission network (Location S4) could provide both transmission services and market based services in the energy and capacity markets. The owner of the storage facility would apply to the ISO for an interconnection study and approval. The ISO currently has a Large Generator Interconnection Process (LGIP) and a Small Generator Interconnection Process (SGIP) that is described in detail on our web site <http://www.aiso.com>. Currently the ISO is using the SGIP rules for storage facility applications. The question is: does this process need to be formally changed to recognize it applies to both small generators and storage facilities? Is there any compelling reason to design a new process that is just for storage facilities?

Storage connected to the ISO Transmission network from a Generating Plant site (Location S5) is very similar to the SGIP procedure described above. If this is an existing generating plant or a wind farm, there may already be sufficient transformer and transmission capacity to handle the additional energy from a storage system. Storage at

this location would probably be a market based service and financed as a merchant facility.

Energy Market

Storage participation in Forward Energy Market and Real Time Energy Markets can be useful to shift energy delivery from off-peak periods to on-peak periods. This would be particularly useful with large amounts of energy production from intermittent resources such as wind and solar generation. Storage would add to the nighttime load on the system when excess wind generation is often available. It could also absorb energy from the concentrated solar generation facilities which are expected to ramp up to maximum daily energy production in the morning hours between 6 am to 7 am while the morning load pull is just starting. Storage then can become the “shock absorber” by being the energy source and sink for the mismatch of wind and solar generation with the system load.

The key question is whether the storage facility can operate at a profit by buying energy from the market when the price is low or negative and sell it back to the market when the price is high. For this strategy to be successful, it would be useful to have

- significant volatility in real-time energy prices,
- a volume of energy storage that is at least 3 times the capacity rating of the unit (a 10 MW facility should have at least 30 MW Hrs of storage capability),
- a very efficient storage technology with low round trip energy losses, and
- a capital cost per MW of energy storage that is below \$1Million.

Figure 2 below is an example of real-time energy prices. Prices vary from -\$30 at 6 am to \$80 at 6:30 am. Although there are at least 5 periods of significant price variation, the low or negative price periods may not last long enough for the storage device to absorb very much energy at the low price. This only an example of one day’s prices and the question is whether this is a typical pattern for prices.

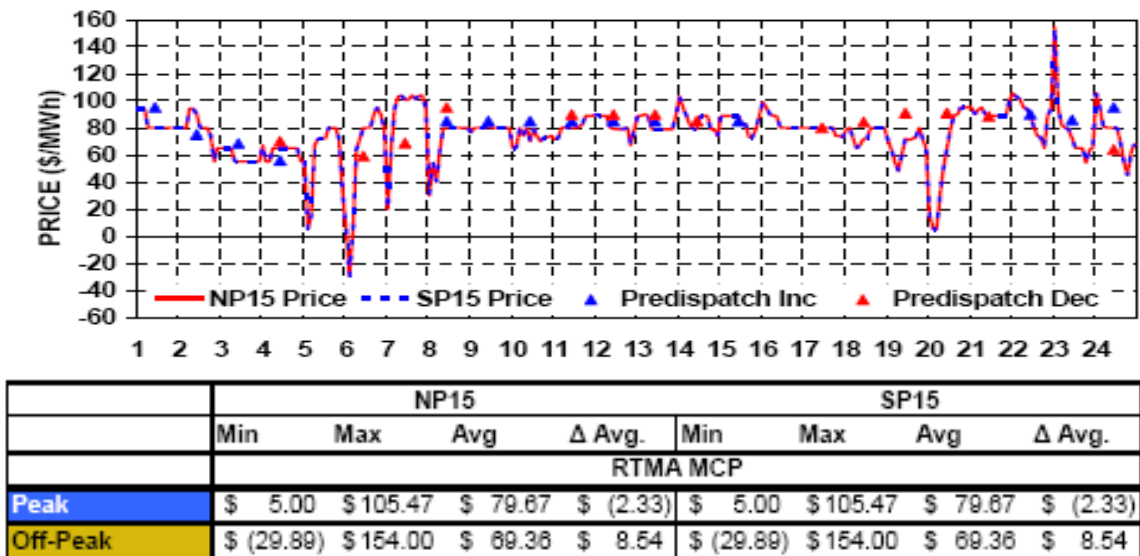


Figure 2

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A more detailed study on the variability of real-time energy prices has been done and the results will be discussed at the June Stakeholder meeting on Integration of Storage Technology. There is an additional issue: the use of historical pricing data may not be a good indicator of future price variability once the new market system MRTU goes into operation in the 4th quarter of 2008. One of the MRTU design objective is to have day-ahead energy generation schedules that more closely match load schedules and forecasts. If this objective is achieved, then real-time prices may be less volatile. On the other hand, the large increase in wind and solar generation on the system by 2011 and 2012 may significantly increase the variability of generation energy supplies and this could result in an increase in real-time price volatility.

Storage technology typically has losses that range from 10% to as high as 40% or greater. For a device with a 10% loss rate (round-trip efficiency of 90%), then for every 10 MW-Hrs of energy stored in the facility, only 9 MW-Hrs of energy are recovered and sold back into the market. If the price of energy at the time of the energy injection into the storage system was \$5/MW-Hr, then the energy cost was \$50. If the energy price at the time of the sale back into the market was \$50, then gross profit is \$450 (9x\$50) for a net profit of \$400. If this process could be repeated many times per day, then the amount of net profit would probably exceed the operating costs and provide sufficient return on capital to justify the investment in the storage facility

The capital cost for all storage technologies still appears to be greater than \$1 Million a megawatt. The hope is that this cost will decline as volume production of batteries, flywheels and other storage devices ramps up. Energy tax credits would help with the financing of new storage facilities and to get the industry started. The question is how this can be accomplished on the state and federal level.

Large Energy Ramps

Large Energy Ramps were identified in the November Renewables Report as a major operating issue for the future. Today's 1000 MW to 2000 MW per hour energy ramps for three hours during the morning load pick up and corresponding rapid energy ramp down in the evenings are expected to increase by approximately 1000 MW for number of months of the year. A storage facility that could either charge or discharge for three to five hours could be a significant help with the large ramps. Pump storage, flow based batteries and compressed air storage would seem to fit this criteria the best. Perhaps NAS and LI battery storage systems can be designed to meet this longer charge/discharge cycle. At the present time, the ISO depends on the Supplemental Energy Market for this ramping capability so the ability of storage technology to bid into the Supplemental Energy market could provide a valuable additional resource. A future issue will be the need to grow the depth of the INC and DEC bids in the Supplemental Energy Market.

Over Generation Mitigation

An issue identified in the November Renewables Report was the problem of the mismatch of generation schedules with scheduled loads. In 2006, there were at least 50 occurrences where the ISO had to declare an over generation problem existed and there

was a market appeal for more DEC bids to reduce the amount of scheduled generation and energy imports to match the forecasted load. The new MRTU market system should help to ensure that more accurate generation and import schedules are produced. The forecasted wind generation energy production will also be included in the scheduled energy production. Again storage facilities could help to mitigate significant mismatches between energy production schedules and forecasted loads.

Ancillary Services Markets

As per FERC Order 890, the ISO has been directed to submit tariff changes to allow non-generation resources such as storage to participate in Ancillary Services Markets. The ISO’s proposed tariff changes are shown in Attachment B.

Storage participation in capacity markets – Regulation, Spinning Reserve and Non-spinning reserves

Many potential investors and operators of storage facilities are very interested in providing regulation services and/or spinning reserves. These capacity markets can significantly increase the profitability of a storage facility. For example, if the market clearing price for regulation was \$21/MW for UP regulation and \$19 for DOWN regulation; a 10 MW stage facility successfully bidding into this market, they would be paid \$210 for UP regulation ($\$21 \times (+10\text{MW})$) and \$190 for DOWN regulation ($\$19 \times (-10\text{MW})$) for a total capacity payment of \$400 for that hour. If the unit had a 90% round-trip efficiency and the market clearing price for energy was \$50/hr for 1 MW, then the 10 MW unit might consume 1 MW of energy from the real-time energy market so its profits would be reduced by \$50 to a net profit of \$350 for the hour. If the unit delivered net energy to the market during the hour (used some of the energy previously stored), they it would be paid the market price for the energy.

The market clearing price for Spinning Reserve is typically significantly less than the regulation market so the attractiveness of bidding into the Spinning Reserve market may be relatively low. Market clearing prices can be quite variable as seen in Figure 3 below.

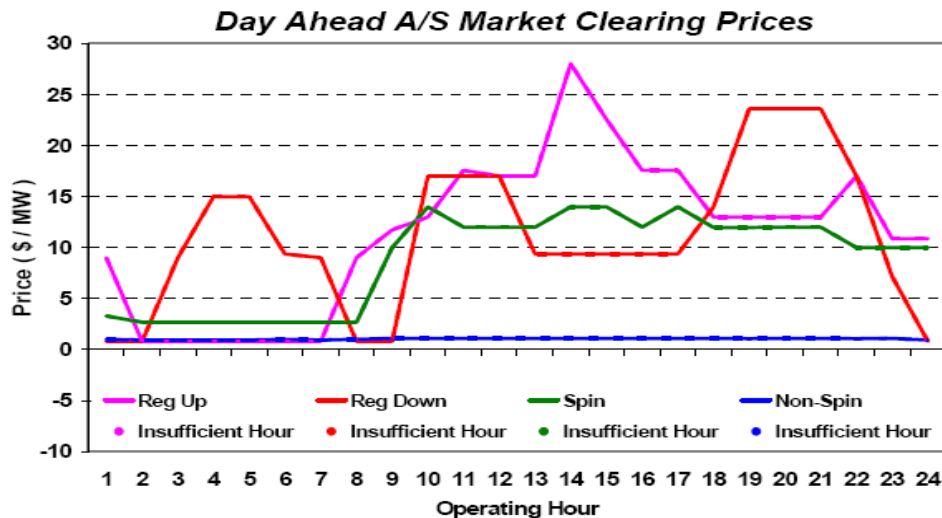


Figure 3

Some storage facilities such as batteries and flywheels have the unique characteristic of ramping from full discharge to full charge in only several seconds. They have argued that very fast regulation services should be paid a premium over the normal market clearing price for regulation. Initial studies have shown that fast regulation units such as hydro generation facilities do most of the regulation work so there is some merit to this argument. Additional studies are needed to verify this initial finding and if there is justification for a premium payment for fast regulation, then who pays for this premium services? Is it paid for by reducing the total amount of regulation and, if so, how confident is the ISO that it can meet NERC operating standards with less regulation?

Certification of storage for Regulation and Spinning Reserve

ISO Procedure G-213 Generator Certification Testing on the CAISO web site <http://www.caiso.com/docs/2000/09/08/200009081011018455.pdf> describes the current procedure for testing and certifying generation, loads, and system resources for ancillary services such as regulation and operating reserves. This procedure should be updated to include the procedure for testing and certifying storage facilities for suppliers of ancillary services.

Frequency Regulation

The ISO currently does not have a specific market product for frequency regulation. The Automatic Generation Control (AGC) signal that is used to rebalance the system is a combination of Interchange error ($I_{SCH} - I_{ACT}$) plus a frequency deviation term, plus an off set term for automatic time error correction and an Hourly Inadvertent Energy Payback term. The traditional AGC

dispatch for generating facilities may be a less than optimum solution for the future with large amounts of storage available for fast regulation. A potential project is being discussed that would explore the use of a new ASC (Automatic Storage Control) signal and a ALC (Automatic Load Control) signal in addition to an AGC signal. A future control system might look something like the following Figure 4:

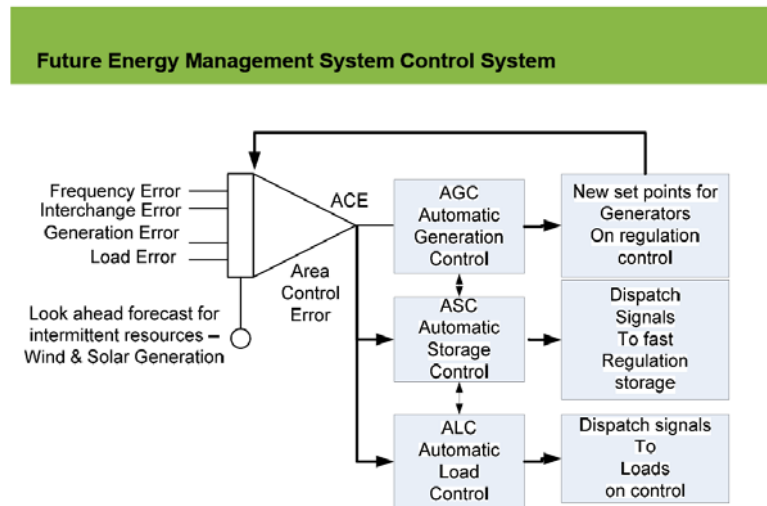


Figure 4

Communication requirements

The communication requirements to a generating unit in the ISO area is described in detail in the interconnection agreement and participating generator agreement documents. Essentially the ISO requires 4 second real-time data from the facility and the ability to communicate with the facility on a 24/7 basis. The normal communications interface device between the generator and the ISO is a RIG (Remote Intelligent Gateway) or a DPG (Data Processing Gateway). A RIG is required for the unit to provide ancillary services. A similar communication requirement will be essential for a storage device to provide ancillary services. These requirements will be reviewed with storage to determine if there is anything uniquely different about storage versus a generator or a load. The initial expectation is that the operator of the storage facility will have to manage the amount of energy stored in the system and that is not an ISO responsibility.

Plug-In Hybrid Electric Vehicles (PHEV)

PHEVs are a major potential load and energy storage on the grid. They are like regular hybrids vehicles but with larger batteries and the ability to re-charge the battery from an electric connection to the grid. Ideally they can travel for the first 30 miles or further on the energy stored in the battery and not have to start the gasoline engine in the vehicle. This would be within the commute range for many drivers and it could significantly lower the amount of air pollution from vehicles.

The stability of the grid could be enhanced if the charging units for the PHEV's were designed to be frequency sensitive. As long as the electric system frequency was above 59.95 Hz, the units would charge as normal. If the frequency drops below 59.95 Hz, they would reduce by 50% and help the system frequency recover. If the frequency drops below 59.9 Hz, they would stop charging all together until the frequency recovers to 59.95 Hz. Once the frequency has recovered to 59.95 Hz or higher, then they would have a random amount of seconds' delay (0 to 30 seconds) before they would start charging again so all the charging load would not hit the grid at once. This would help the grid recover from a major frequency event such as the loss of a major generating unit and would have little direct impact on the PHEV and their ability to fully charge the battery. Such logic could easily be added to the PHEV on-board computer system that manages the charging of the batteries.

Summary

This white paper and the accompanying Frequently Asked Questions document attempt to frame some of the issues associated with integrating storage facilities on the power grid. The details and solution alternatives are expected to develop during discussion with stakeholders over the next several months.