Technical And Market Aspects Of Innovative Storage Opportunities

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Introduction

Phases I [1] and II [2] of this study involved identifying, characterizing and evaluating promising new market opportunities for energy storage. By design they involved consideration of energy storage applications beyond conventional uses, such as improved power quality, to take advantage of "buy-low, sell-high" opportunities, or as UPSs. The goal was to identify a technically viable application with significant economic market potential.

The purpose of this paper is to summarize results from Phases I and II, to describe progress to date in Phase III and to elicit other researchers' opinion. For Phase III many assumptions from Phases I and II of the study will be refined. In particular the study will address storage duration requirements for energy storage systems used to provide benefits associated with electricity transmission and distribution (T&D) capacity and with electricity price volatility (buy low – sell high). Also needed are: Testing of the premise that high storage round-trip efficiency is important and a better characterization of regulatory and business considerations.

Background

Phase I involved development of nine high-level "Stretch Scenarios" under which innovative use of energy storage could lead to attractive storage market opportunities (SMOs) and to significantly higher demand for energy storage systems. The goal was to characterize viable SMOs for further consideration, ultimately five were identified.

Notable Stretch Scenarios considered included: 1. Very Inexpensive and Efficient Storage, 2. Fluctuating Energy Prices, and 3. Extreme Deregulation and Competition.

A synthesis of implications associated with the scenarios lead to the following observations:

- It is most attractive to locate storage at the point of use, allowing for baseloading of "upstream" electric systems.
- Energy services companies (ESCOs) wishing to serve infrequent but lucrative markets with energy price-spikes care more about first cost and reliability than efficiency or recharge rates.
- Regulatory structures that allow innovative approaches will lead to increased opportunities for storage. These include: performance based rates (PBR), competition, and marginal costing.
- There may be opportunities to use low-efficiency but low first-cost storage technologies.

The most interesting storage market opportunities identified were

1. Enhanced Environmental Externalities
2. Power Price Volatility
3. Customer Siting for Transmission and/or Distribution System Benefits
4. Storage System Packaging Breakthroughs
5. Combined Heat and Power Output Smoothing

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Phase II of the study was a detailed evaluation of those five SMOs to identify and characterize the "most promising" one for further study. A key part of the process involved screening out the least viable SMOs, based on institutional, market, or technical criteria. Those remaining were ranked based on a transparent quantitative scoring methodology. "Success criteria" used are listed in Table 1. below.

Table 1. Storage Market Opportunity Success Criteria

Storage Value Metric	*$/kWh* *(of storage)*
10 year Power/Output Potential	*GW*
10 Year Energy Storage Potential	*GWh*
10 Year Economic Benefits Potential	*$*
Environmental Benefits	*score*
Technology Innovation Opportunity	*score*
Scenario Likelihood	*score*

During Phase II the authors concluded that the most promising application is grid-tied energy storage for situations characterized by both high utility transmission and distribution (T&D) cost and high energy cost volatility. Key benefits are associated with storage's load carrying capacity during peak demand periods and with the ability to take advantage of price differentials between electric energy purchases made during on-peak and during off-peak price periods. Depending on the circumstances specific energy storage plant installations may also yield benefits for power quality and electricity service reliability enhancements.

The authors estimated that energy storage used for the enhanced T&D/high energy price volatility application could be competitive for tens of gigawatts (GW) during the years 2001 to 2010. For the study five hours of storage was assumed to be sufficient, leading to a market potential of over one-hundred gigawatt-hours. Distributed Utility Associates' preliminary estimate was that the potential gross benefit associated with that energy storage capacity was over twenty-five billion dollars, with a predicted value of over $200 per kWh of energy storage capacity.

Phase III, Developing the Business Case

In Phase III more rigorous estimates are being made of benefits ($) and market potential (kW and kWh) associated with energy storage use for the high value application identified in Phase II.

Another facet to the Phase III investigation is development of technical requirements for a storage system that can serve the high value application. Other criteria include: round trip efficiency, ramp rates, power output quality, reliability, and perhaps most importantly, the duration (number of hours) of full load storage discharge required.

The project team will distill these technical requirements into a specification to be shared with storage system and subsystem vendors. In consultation with vendors, the specification will be reconciled with technical characteristics of existing and emerging storage technologies. Initial estimates of equipment installed cost and lifecycle cost will be made for qualifying storage systems. Those cost estimates will be reconciled with the total benefits achievable to determine necessary storage system cost reductions.

Two distinct types of suppliers will be considered: 1. established suppliers with a track record reflecting successful utility-related experience, and 2. newer, possibly less experienced companies with promising new technology. Storage types include: conventional and advanced electrochemical batteries, flywheel energy storage, compressed air energy storage (CAES), and superconducting magnetic energy storage (SMES).

Economic Viability Assessment

Perhaps the most important design criterion for battery systems used for the application being considered is the total discharge duration (duration) needed. As illustrated conceptually in Figure 1., benefits for applications being investigated tend to increase significantly with increased duration and to level off for longer durations. Storage System Type 1 is indicative of a system with low capacity cost ($/kW$_{output}$) and higher energy storage "reservoir" cost ($/kWh). Storage System Type 2 has higher capacity cost with lower energy cost. While both system types can be cost-effective, in this illustration the optimal system size and dispatch strategy would probably differ.

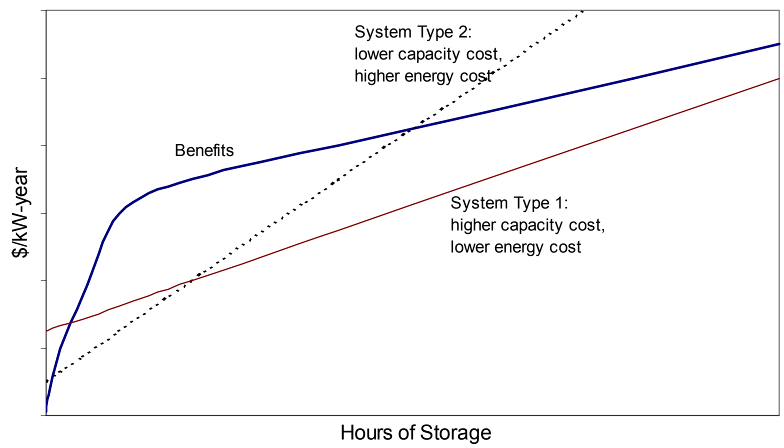

Figure 1. The Continuous Discharge Duration, Benefits Relationship

A more concrete example is illustrated in Figure 2. It reflects results from a study for the portion of the Central Power and Light (CP&L) system in Laredo Texas[3]. The area has relatively high capacity and energy costs and significant Summer air conditioning load. Benefits accruing to the utility for various load curtailment durations are shown.

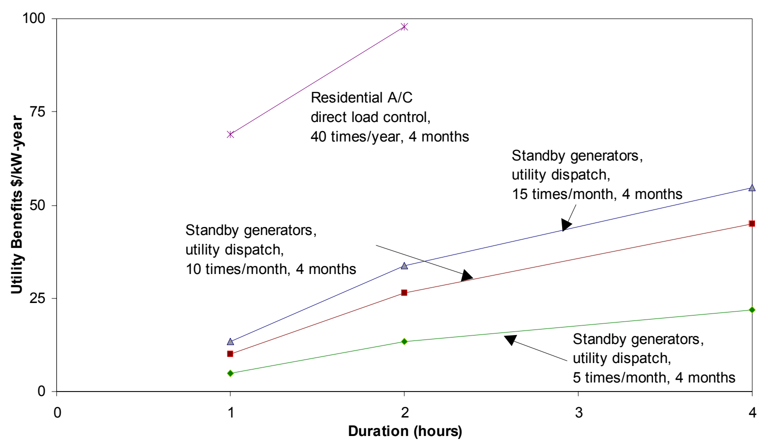

Figure 2. Utility Benefits versus Duration of Customer Participation

These results provide a strong indication of the duration/benefit relationship for storage in Laredo as they reflect the value to utilities if customers shed load (via direct load control) or provide energy to the grid using standby generators that are dispatched by the utility. If customers (or the utility itself or energy services companies) used storage to serve on-site demand then power requirements from the grid can be reduced. Or, storage could provide energy to the grid as did the standby generators.

Another important facet to the investigation is analysis of the relationship between net benefits associated with energy storage system use and the tradeoff between energy storage plant capital cost and round trip efficiency. This is important because authors believe that there may be market opportunities for which energy storage with relatively low capital plant cost and relatively low round trip efficiency (e.g., 40% to 60%) could provide attractive net benefits.

Figure **3**. provides an illustration: There are two plots, one for 200 hours per year of energy storage discharge and one for 1,000 hours per year. The target cost is defined as being equal to the net benefits accruing.

Consider the curve for 200 hours per year of discharge. It indicates a relatively modest change in system target cost across a wide range of system round trip efficiencies (i.e., there is relatively little financial gain for large improvements in efficiency). For the range of round trip efficiencies from 25% to 75% each increase in efficiency of 1 percentage point is worth an average of $2.5/kW in increased net benefits, or about $125/kW.

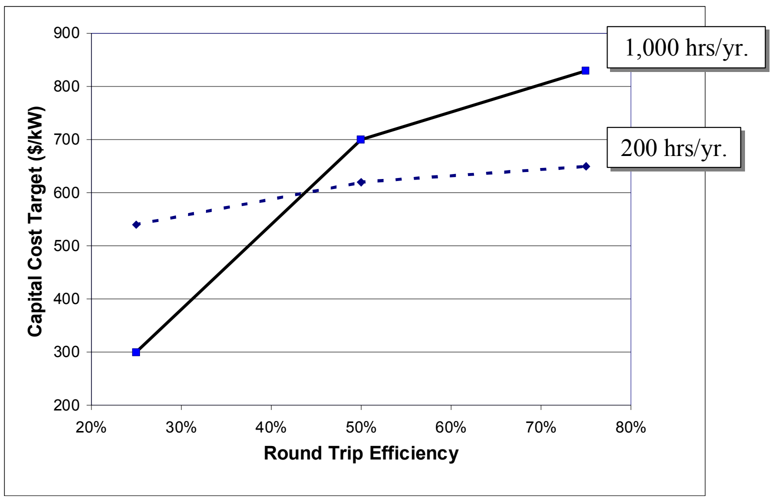

Figure 3. Energy Storage Round Trip Efficiency versus ystem Capital Cost Target

For 1,000 hours per year of energy storage discharge doubling efficiency from 25% to 50% increases benefits (and target cost) by $400/kW. Each increase in efficiency of 1 percentage point is worth an average of $16 in increased net benefits. By contrast, for the range of 50% to 75%, each increase in efficiency of 1 percentage point is worth an average of $5/kW, or $125/kW total.

Emerging Regulatory and Business Conditions

The Federal Energy Regulatory Commission (FERC) is developing a policy that requires "locational," real-time pricing for transmission capacity[4]. This is a market-based approach to allocating resources, especially during times when transmission congestion leads to constraints on energy deliverability. This policy is part of FERC's recent efforts to facilitate "open access" to transmission lines whereby utilities and non-utility entities can use power transmission capacity to buy or to sell electric energy.

There is some speculation that similar requirements could eventually apply to power distribution systems. This is part of a larger interest in enabling more and more varied electric resources, including demand management and distributed generation and storage, by providing means to participate in the greater energy marketplace.

The implications of extending this logic and authority for generation, storage, and demand management would be significant.

Most importantly market-based real-time price signals from a locational marginal pricing (LMP) scheme provide very local time-specific financial incentives to end users to reduce load when the distribution system is constrained. If high marginal energy and transmission prices prevail at the same time as high distribution marginal costs then savings could be significant. Load reduction could involve shutting off equipment or could be accomplished by using on-site generation or energy storage to serve some or all customer load.

Such a development could lead to the opportunity for owners of energy storage located downstream from a given distribution price node (distribution pricing area, or DPA) to enter into bilateral contracts with end-users in the same DPA. Storage owners could also to partner with the local distribution utility by allowing the utility to dispatch the storage, for consideration.

If utilities are allowed to charge marginal cost for capacity they may have the incentive to use utility-owned storage to optimize capital outlays and asset utilization in constrained DPAs. Conversely without the means to recover actual marginal cost to serve additional load in a given DPA utilities may not have the financial incentives to either upgrade the distribution system or to use storage to optimize service quality and quantity.

Conclusion

Based on the envisioned attributes of each storage technology and the technical requirements associated with benefits, a market vision (encompassing the market opportunity) is being defined. Given the market opportunity definition and the market potential, the marketable "product" will be defined. The remaining market challenges will be assessed and defined. Market challenges that can be addressed by the federal government will be identified and specific federal roles will be suggested.

Citations

[1] Iannucci, J., Schoenung, S.: Energy Storage Concepts for a Restructured Electric Utility Industry, a report for Sandia National Laboratories, July 2000, SAND2000-1550.

[2] Iannucci, J., Eyer, J.: Innovative Business Cases for Energy Storage In a Restructures Electricity Marketplace, a draft report for United States Department of Energy and Sandia National Laboratories, August 2001.

[3] Orans, R.; Woo, C. K.; Greenwell, C.: Designing Profitable Rate Options Using Area-and Time- Specific Costs, a report to Electric Power Research Institute, November 1994.

[4] Fernandez, A., Mead, D., Withnell, D., Wolfman, A.: Working Paper on Standardized Transmission Services and Wholesale Electric Market Design, a presentation for the Federal Energy Regulatory Commission (FERC) commission meeting, March 2002.
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