Applications And Markets For Electricity Storage In California

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INTRODUCTION

The California Energy Commission and (CEC) the U.S. Department of Energy's (DOE) Electric Energy Storage Program have developed a benefit- and market-based framework for selecting energy storage demonstration projects in California. A very important facet of program has been to encourage demonstrations for applications with "significant" nearterm (ten year) market potential, based on actual benefits.

In support of that effort, Distributed Utility Associates has estimated the benefits associated with a diverse set of electricity storage applications. Applications addressed include some uses of storage within the utility infrastructure and others that are "on the customer side of the meter." Some of the benefits are readily monetizable under current tariffs, rules and practices; others will require regulatory approval before they can be realized but the benefit estimates are nonetheless as realistic as possible, assuming such revised regulation.

For each application estimates were made for a) lifecycle financial benefits ($/kW of equivalent capital cost) and b) market potential (MW) for energy storage in California. No estimates were made of storage costs except where ranges of operations and maintenance costs were needed to optimize storage dispatch. It is left to the reader to compare the costs of storage devices to the benefits estimated herein.

Benefit calculations were made using projected hourly wholesale energy prices and using existing utility rates as appropriate for a given application. The estimates are for storage systems whose discharge duration are assumed to match the needs associated with a given application. (Discharge duration is maximum length of time during which a storage plant can be discharged at full rated power output without being recharged.) Also addressed were opportunities to use individual energy storage systems for more than one application and/or benefit stream. The objective was to identify plausible, near-term, high value uses of storage for utility applications that require limited or no technological advances.

BENEFITS DETAILS

Several benefits from energy storage for utility applications are well known: reduced financial losses due to poor power quality and power outages, energy price arbitrage involving charging with low priced "off-peak" energy for use later when energy cost and price is high, and utility ancillary services.

Over the last ten to twenty years several other possible benefits from energy storage have been proposed, evaluated and in some cases demonstrated. For example, the class of benefits called "distributed" benefits (that accrue based on the location of storage capacity), and benefits associated with superior performance of the transmission system.

One of the most comprehensive, publicly available listings of benefits from electricity storage was developed for the California Energy Commission (CEC) and the U.S. Department of Energy (DOE) in support of an energy storage-related RFP.[1]

In many cases more than one benefit is required from storage for benefits to exceed cost. However, careful consideration of operational, technical, and market details are required before benefits may be added. The subject of combining benefits from energy storage is an emerging R&D topic.

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This work is sponsored by the U.S. Department of Energy Storage Systems Program and managed by Sandia National Laboratories.

Deferred T&D Upgrade Investment and T&D Life Extension

The single year transmission or distribution deferral benefit is the financial value associated with deferring a utility T&D upgrade for one year. It is the financial carrying charges that are avoided because the upgrade is not undertaken immediately.
Consider an upgrade to a 9 MW distribution system. Typically 3 MW will be added, a 33% increase, after the upgrade the distribution system can serve 12 MW of load. Using an average annual carrying cost of $50 per kW in California for distribution capacity added, the annual (single year) carrying charges for the upgrade are $150,000. [1]

To defer an upgrade for one year it is assumed that the energy storage plant's power output must be equal to the expected load growth for the next year. Continuing with the example above: if load growth on the circuit is 2.5% per year, during the next year then load growth is expected to be 9 MW * .025 = 225 kW. In theory, a storage plant rated at 225 kW could allow the utility to defer the distribution upgrade for one year, for a one time, single year benefit of $150,000 / 225kWstorage = $666/kW (of storage capacity, if installed). If the storage system can be installed for that amount or less, then the storage plant pays for itself in one year.

Similarly, storage used to extend the life of T&D equipment may provide a benefit comparable to that for T&D deferral.

Transmission Support

It is possible to use energy storage to improve the performance of the transmission system. For any given location, to the extent that energy storage support increases the load carrying capacity of the transmission system, a benefit accrues if additional load carrying capacity defers the need to add more transmission capacity and/or additional T&D equipment.

Transmission Access and Transmission Congestion Charges Avoided

Utilities that do not own transmission facilities pay transmission owners for transmission "service." That is, when non-owners use the transmission system to move energy to and/or from the wholesale marketplace owners must recoup carrying costs and operations and maintenance cost incurred. Related charges are often called transmission access charges. One possible way to allocate transmission capacity when demand is high is to use demand-driven "congestion charges." Storage may be used to avoid these charges.

Energy Price Arbitrage

Arbitrage involves purchase of inexpensive electricity available during periods when demand for electricity is low, to charge storage, so that the low priced energy can be used or sold at a later time when the price for electricity is high.

Reduced Need for Generation Capacity

If the installed base of electricity storage is large enough, the storage could be used in lieu of central generation capacity. If so, costs avoided include cost to own the power plant or cost to "rent" capacity in the wholesale electricity marketplace.

Ancillary Services

It is well known that energy storage can provide several types of ancillary services. These are what might be called support services used to keep the regional grid operating. Two of the more familiar ancillary services are spinning reserve and load following. Another is often referred to as "regulation." Frequency regulation may be especially valuable storage application.

Renewables Value Enhancement

Electricity storage can enhance the value of energy from renewables generation in at least two fundamental ways. Storage can "firm-up" renewables' output so that electric power (kWs) can be used when needed. Similarly electric energy (kWhs) generated during times when the value is low can be "time-shifted" so that the energy can be sold when its value is high. One option would be to charge storage with electricity from the grid as well as from wind generation.

Time-of-use Energy Cost Reduction

For electric utility customers that pay “time-of-use” energy prices, storage may provide means to reduce their overall cost for electric energy. Customers charge the storage during off-peak time periods when their electric energy price is low, then discharge the energy during times when on-peak (time-of-use) energy prices apply. (This differs from arbitrage because a) energy is stored by the end-user and b) transactions are all at the retail level, whereas arbitrage involves energy stored for sale, wholesale or retail.)

Demand Charge Reduction

Energy storage could be used by energy end-users to reduce their overall costs for electric service by reducing demand charges. Demand charges related to the maximum power draw of a facility (rather than the amount of energy used).

Reduced Financial Losses from Improved Electric Reliability

One way to improve the reliability of electric service is to use energy storage systems for important or critical loads. In the event of a power outage lasting more than a few seconds the storage system provides enough energy to a) ride through outages of extended duration, and/or b) complete an orderly shutdown of processes, and/or c) transfer load to on-site generation resources.

Reduced Financial Losses from Improved On-site Power Quality

Improving electric service power quality (PQ) involves use of electricity storage to protect important or sensitive loads against short duration power system anomalies that affect the quality of power delivered to electric loads.

Some manifestations of poor power quality which may damage or affect operation of electric loads and that could be reduced or eliminated by energy storage include:

- variations in voltage magnitude
- variations in the primary 60 cycles/sec frequency at which power is delivered
- low power factor
- harmonics

Other Quantitative and Qualitative Benefits

Other quantifiable (monetizable) benefits and some qualitative benefits may also be attributed to energy storage.

Reduced Cost for T&D Losses

This benefit accrues if there is a differential between T&D resistive (I^2R) losses on-peak when storage is discharged, versus losses off-peak when storage is charged. As an example, if T&D I^2R losses are 8% on-peak and 5% off-peak the avoided losses are 3%. That reduces fuel use and related air emissions and reduces the need for generation and transmission capacity.

T&D Life Extension

Similar to T&D deferral, storage may be used to reduce maximum loading on T&D equipment such that the life of the T&D equipment may be extended. If so, the financial benefit could be similar in magnitude to that for T&D deferral.

T&D Asset Utilization

If storage is charged at night and then discharged during the day one effect may be that the T&D system is used, on average, more that if storage was not deployed. This could result in improved returns on the respective capital investment.

Environment

In some cases use of storage could reduce overall air emissions, depending on the generation plants and fuels used to generate charging electricity for storage and on generation plants and fuels not used when storage discharges.

MARKET POTENTIAL

Based on these benefits and on market potential estimates for California Distributed Utility Associates developed storage "demand curves" for California. Figure 1 shows the total MW of storage that might be profitably installed in California as a function of storage device capital cost. Each data point represents the benefits of each application per kW, and the step sizes are the market potential estimated by the authors for each individual benefit. The market sizes are shown as cumulative (from the right to the left), as storage costs decrease additional applications become financially viable.

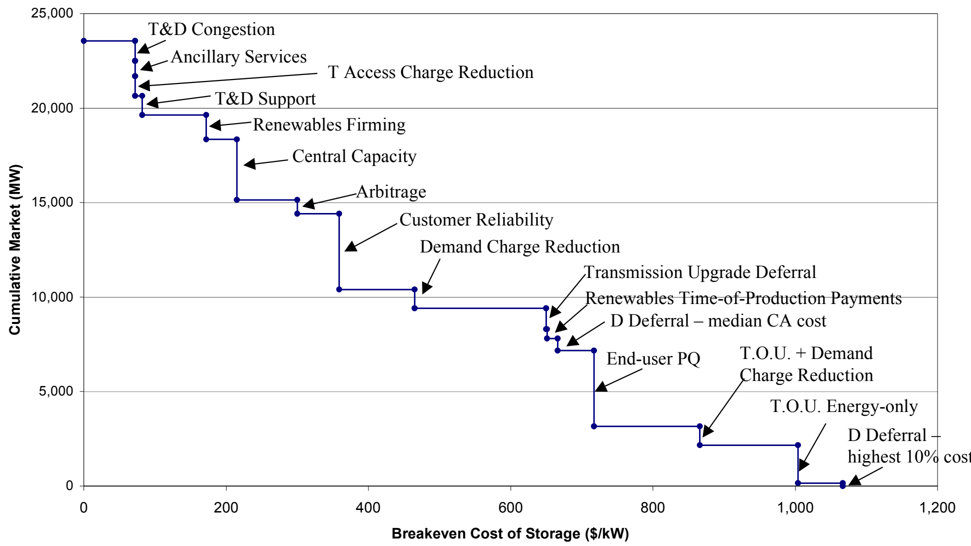

Figure 1. California Storage Demand

Consider three examples plotted in the lower right quadrant of the plot in Figure 1.: storage systems costing less than $800/kW would be cost-effective for any of these circumstances: 1) distribution (D) deferral benefit is in the top 10th percentile, 2) a utility customer uses storage to reduce time of use energy (TOU) energy charges, or 3) a utility customer uses storage to reduce time of use energy charges and demand charges.

The most valuable use of storage is distribution deferral for the most expensive 10% of locations in California; being worth approximately $1,060/kW, and having a ten-year market potential of less than 200 MW, but yielding a theoretical profit of about $260/kW. Lower benefits and profits per kW (but higher market potential) would arise from the other two most valuable applications. The TOU energy-only application has 2,000 MW of market potential and the TOU-plus-demand-charge benefit applies to 1,000 MW of load. The remaining benefits on the chart are not in and of themselves cost effectively solvable with this storage system (costing $800/kW). In real situations storage would likely be used so that two or more of these benefits accrue, making storage even more cost-effective. Readers are urged to consider feasible combinations of benefits.

Matching results are presented in Figure 2 for the ten year lifecycle benefits (within California) for storage. The location of the steps in terms of $/kW are identical to the market potential chart, but the size of each step is now the raw benefits to California of the installation of storage. This causes the chart to flatten out at low benefits per kW.

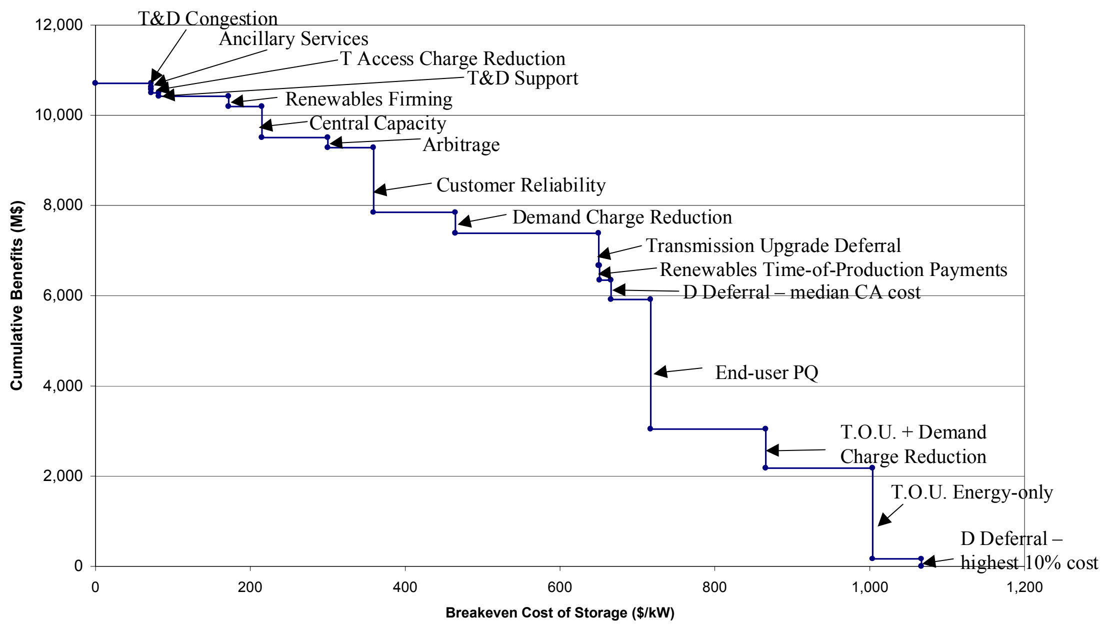

Figure 2. California Storage Benefits

These storage demand charts should help storage system developers determine the most likely market "significant," near term, high value market opportunities. Results also illuminate the relative importance of system efficiency, life, variable O&M and other factors (with respect to the near term market opportunities). Results will differ for other states due to utility tariff differences and avoided utility costs.

This work was sponsored by the US DOE and managed through Sandia National Laboratories, in close collaboration with the California Energy Commission; details are provided in Reference 1.

RESEARCH DIRECTIONS

This analysis of the leading storage applications and market potential in California is part of a longer term analysis of this topic sponsored by the U.S. Department of Energy Storage Systems Program.

Distributed Utility Associates' (DUA) earliest storage market analysis efforts for DOE and Sandia National Laboratories were to step "outside the box" to evaluate innovative market niches and applications areas were defined therein.[1] A natural follow-on to that scoping work was a numerical ranking of the four best niches and applications. That led to selection of one or more for further analysis. [2] Finally, a more detailed evaluation of the leading candidate (combined arbitrage with transmission and distribution deferral) was undertaken; it included extensive feedback from members of the storage business community on the feasibility of pursuing that combined application. [3]

The California benefits and market quantification was created as a working document in support of the recent Request for Proposals from the California Energy Commission and the Public Interest Energy Research (PIER) Program entitled Electric Energy Storage Demonstration Projects in California. The benefits and market section of that document is Attachment 14. [1] DUA is in the process of creating a similar document with a national perspective, for publication within a few months.

In the coming months the CEC solicitation should present several opportunities to confirm or to revise the estimated benefits from storage in real applications in California.

In addition Distributed Utility Associates will create a more robust storage sizing algorithm (MW and MWh) for transmission and distribution deferrals. That exercise will also include analysis of risk associated with use of storage and with traditional transmission and distribution upgrades, to estimate and compare risk-adjusted costs. A national workshop on storage cost and benefits is also expected.

REFERENCES

[1] California Energy Commission and the Public Interest Energy Research (PIER) Program, Electric Energy Storage Demonstration Projects in California, Request for Proposals (RFP) #500-03-501. Attachment 14: Electric Energy Storage Benefits and Market Analysis.

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