ENERGY STORAGE UPDATE

US Energy Storage Projects and Prospects Guide 2016

The guide focuses on the Borrego Springs, Tehachapiand and Notrees energy storage projects and examines the long-term impact that they will have on the future project pipeline in the United States

The whitepaper covers:

- Storage applications that made sense for some of the major utilities and why they have deployed certain technologies over others
- How to mitigate risks during your development cycle to avoid significant losses
- Business strategies used by Southern California Edison, SDG&E and Duke Energy to lower upfront capital costs

Featuring insights from

Southern California Edison

San Diego Gas and Electric

Duke Energy

Introduction

Energy storage enjoys a privileged position in the US. According to the Energy Storage Association's US Energy Storage Monitor, 60.3 MW of storage was deployed in the third quarter of 2015, a twofold year-on-year increase (fig. 1). Much of this tremendous impetus comes from the early adoption of electrical energy storage. The US has pioneered the use of batteries for grid-scale storage applications, for example.

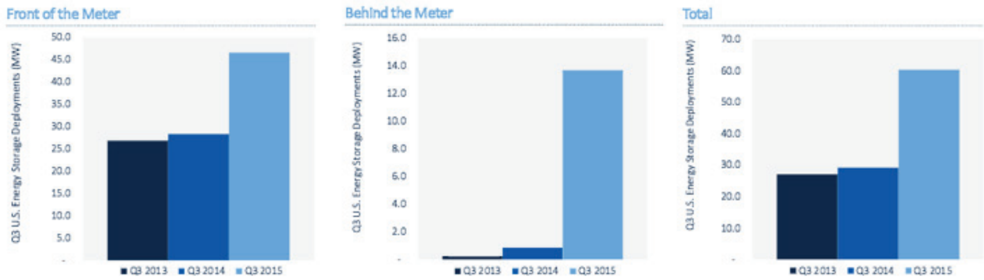

Fig. 1: Q3 2015 energy storage deployments in the US. Source: Energy Storage Association/GTM Research.

Responding to regulation in what is arguably the world's foremost market for energy storage, California, utilities started commissioning significant projects as far back as 2012. And increasingly other states, from Hawaii to New York, are emerging as key markets for grid-scale energy storage, with utilities there initiating projects, too.

In fact, it is probably fair to say that the US now has more and longer experience of grid-scale electrical energy storage than any other country in the world. This experience is critical going forward because one of the big challenges facing electrical storage deployment is not just how to follow best practice now, but also what to expect in future.

Few grid-scale projects have the operating history to offer insights into this complex topic. Of those that do exist, some of the most significant are in the US. Thus, in the run up to Energy Storage Update's forthcoming conference in the US, we felt it would be important to review a number of pioneering US projects and assess how their performance has lived up to expectations.

The three projects chosen for analysis in this report all belong to investor-owned US utilities and have significant operational experience. They are:

- The Borrego Springs microgrid project owned by San Diego Gas & Electric (SDG&E) in California.
- The Notrees wind storage demonstration project owned by Duke Energy in Texas.
- The Tehachapi wind energy storage project owned by Southern California Energy (SCE) in California.

A brief summary of key characteristics of each project is provided in table 1.

Table 1: Comparison of Borrego Springs, Notrees and Tehachapi projects.

Name	Battery chemistry	MW	MWh	Commissioned	Location	Owner
Borrego Springs	Lithium nickel cobalt aluminum	1.6	4.7	Jul 12	Borrego Springs, California	SDG&E
Notrees	Advanced lead-acid/ Lithium ion (Li-ion)	36	24	Oct 12	Goldsmith, Texas	Duke Energy
Tehachapi	Li-ion	8	32	Jun 14	Tehachapi, California	SCE

Note: Borrego Springs MW/MWh figures are aggregated values for substation, community and home energy storage systems.

Borrego Springs: a successful microgrid

Borrego Springs is a leading microgrid project designed to show how utility storage assets could help to stabilize output from third-party-owned distributed generation assets, predominantly solar, in a remote community. The Borrego Springs community is served by a single sub-transmission line and SDG&E chose to install a microgrid there to improve the reliability of electricity supply while avoiding the need for additional transmission capacity.

The microgrid features a mix of technologies, including two 1.8 MW Caterpillar diesel generators, about 700 kW of rooftop PV and 125 home area network systems. The storage portion of the microgrid is also heterogeneous, initially comprising a 0.5 MW/1.5 MWh battery system for peak load reduction at the local substation, plus three 25 kW/50 kWh community and six 4 kW/8 kWh residential battery systems.

This initial configuration was subsequently enhanced, with the substation storage capacity rising to 1.5 MW/4.5 MWh. A summary of the key features of the project is shown in table 2.

Table 2: Borrego Springs key data.

System operator	Battery supplier	Power electronics	Project lifespan (years)	Applications
California Independent System Operator (CAISO)	o Saft (sub-station storage) o S&C Electric (community storage)	o Parker Hannifin (sub-station storage) o Kokam (community storage)	15	o Load following o Renewables capacity firming o Transmission congestion relief o Distribution upgrade deferral

Financials

The project initially cost a total of USD$12.4 million, not including a project extension grant in 2015 (see below). Of this, $7.5 million was in federal funding from the DoE and $4.1 million was from SDG&E. Other project partners, including Lockheed Martin, IBM, Advanced Energy Storage, Horizon Energy Group, Oracle, Motorola, Pacific Northwest National Laboratories and the University of California, San Diego, put in $800,000.

The total project cost represents an investment of almost $7.3 million per megawatt hour of capacity, although this figure may significantly overestimate the cost of storage since the microgrid includes a number of other elements.

Operational highlights

SDG&E started planning the Borrego Springs microgrid in 2007 after wildfires caused a two-day outage across the community, which has a peak load of about 14 MW and is surrounded by the Anza-Borrego State Park. The microgrid initially served 1,060 customers in the community, and in September 2013 managed to maintain a power supply to users during the hottest hours of the day following an outage caused by flash floods.

In 2015, SDG&E received a $5 million California Energy Commission grant to extend the infrastructure across the entire Borrego Springs metered customer base of 2,800. The expansion is due for completion in mid-2016 and involves the integration of a nearby PV plant, the 26-MW Borrego Solar project owned by NRG.

SDG&E says the current battery capacity should be enough to run the community purely off solar power during the day, using traditional generation just for backup at night. "If a large outage were to impact the whole town, the microgrid can switch from running in parallel with the main grid to 'islanding' mode, when [it] runs on onsite generation resources," says SDG&E in a press release issued February 2015.

SDG&E demonstrated the full capability of this islanding mode shortly afterwards, in May 2015, when the community was due to suffer a 10-hour outage while the utility replaced poles carrying the distribution line. In the event, Borrego Springs was switched over to the power supply from the NRG solar plant, which provided more than half the energy needed for the entire community, with the rest coming from the microgrid's batteries and gensets.

"It's the first microgrid that has responded to an emergency situation in the whole country," says Hanan Eisenman, communications manager for SDG&E.

Notrees: adapting battery chemistry to applications

Duke Energy developed Notrees alongside a 153 MW wind power project in partnership with the Energy Reliability Council of Texas (ERCOT) and the DoE. The project is notable for being one of the biggest battery installations in the country. A summary of the key features of the project is shown in table 3.

Table 3: Notrees key data.

System operator	Battery supplier	Power electronics	Project lifespan (years)	Applications
Ercot	o Xtreme Power (phase 1) o Samsung SDI (phase 2)	Younicos	10	o Ramp control o Electric energy time shift o Renewables capacity firming o Frequency response o Voltage control

Financials

The project initially cost $43.6 million , $22 million of which came through a DoE grant. This equates to about $1.8 million per megawatt hour of capacity. Subsequently, Duke Energy has commissioned a significant upgrade (see below) for an undisclosed fee.

Operational highlights

When Notrees was completed, in December 2012, its main intended purpose was to provide renewable integration services such as frequency response, ramp control, voltage support and energy time shifting for the wind farm next to it. It was expected that the advanced lead-acid batteries supplied by vendor Xtreme Power would be appropriate for these use cases.

However, according to Younicos, which bought Xtreme Power out of bankruptcy in April 2014 , lead-acid proved a poor fit for a growing trend towards the provision of grid services, such as frequency regulation, at Notrees. This prompted Duke to announce an upgrade in battery technology in June 2015 .

A first phase of the repowering project, completed in 2015, involved replacing 18 MW of the 36 MW of lead-acid batteries with Li-ion. This is now being run in parallel with the remaining lead-acid-based storage. A second phase, due for completion before the end of 2016, will see the entire facility converted to Li-ion.

Operation of both lead-acid and Li-ion technologies is managed automatically by a control system installed by Younicos, which takes signals from ERCOT and from the wind farm. "The experience at Notrees underscores the need to consider carefully which applications you will be developing before you choose a particular battery chemistry for your project," says Younicos spokesman Philip Hiersemenzel.

It also shows "the advantage of a robust controls system which manages system operation as cost-effectively as possible, and with the configuration flexibility to maximize system value as technology and market conditions evolve," he says.

Tehachapi: dealing with integration issues

Tehachapi is nominally a wind energy-related project attached to the 4.5 GW Tehachapi Wind Resource Area, although in actual fact the plant was conceived as a two-year test bed for a wide range of potential grid applications. When it opened, in September 2014, it was credited with being the largest battery storage project in North America, with 604,832 Li-ion cells housed in 10,872 modules. Table 4 summarizes the project.

Table 4: Tehachapi key data.

System operator	Battery supplier	Power electronics	Project lifespan (years)	Applications
Casio	o LGChem	ABB	2, with possible extension to 10	o Electric supply capacity o Renewable capacity firming o Transmission congestion relief o Distribution upgrade deferral o Voltage support

Financials

The capital expenses for Tehachapi were almost $50 million, including close to $25 million from the DoE's ARRA Smart Grid Demonstration Program. This represents an investment of just over $1.5 million per megawatt-hour of capacity.

Operational highlights
SCE has encountered a number of challenges in the development of Tehachapi. It was created in response to a DoE demonstration project request and the design parameters were consequently constrained by the DoE's requirements. The utility was originally only able to find one vendor, A123 Systems, which could meet the project specification for grid-scale Li-ion technology at the right price.

Before implementation, however, A123 Systems went into receivership as a result of manufacturing problems, forcing SCE to source alternative vendors.
By the time of its second request for proposals, SCE was able to source five vendors that could meet its technical requirements "within the cost envelope," according to Mark Irwin, director of technology development.

The company chose LGChem to provide the batteries and overall energy storage system. But for the power conversion and system integration work it was necessary to bring in ABB. The integration work was arduous, says Irwin. SCE opted to create a 'mini system' based on two racks of cells only, but with all the integration components in place. To get this to work properly took several months and 11 versions of the control software.

And even after commissioning, the system has been subject to problems. Issues with the design of the system led to the catastrophic failure of one of its four transformers, which required all of them to be replaced over a period of around five months.

These problems mean Tehachapi's actual operating experience has been much less than originally expected, since it has only been functioning on a continuous basis since around mid 2015. Nevertheless, SCE is currently considering extending Tehachapi's original two-year lifespan to 10 years and using the facility for commercial applications. Which applications these might be is still unclear.

As part of its demonstration remit, the project is being used to evaluate 13 applications and eight separate use cases. This evaluation is still underway and in the first half of 2016 SCE expects to test multiple applications simultaneously at the facility.

In the meantime, SCE is using its experience from Tehachapi to inform the development of other storage projects, including a 2.4 MW/3.9 MWh plant that is due to be awarded during 2016.

Significantly, too, says Irwin, most of the problems in Tehachapi's development have been "nothing to do with storage. The transformer problem was due to mistakes with design and the integration problems had to do with it being the first of a kind."

Conclusions

As might be expected from a brief selection of pioneering projects, the experiences presented in this report are highly diverse and make it difficult to draw hard-and-fast conclusions. However, there are a number of significant points that can be made:

- Problems with the Notrees and Tehachapi projects illustrate that getting grid-scale energy storage right is a complex affair. This issue is likely to wane with growing storage portfolios, but underscores the need for experienced project partners.
- It is notable that Notrees and Tehachapi also both suffered from the loss of their first-choice battery vendors. This highlights the widely held wisdom of sticking to diversified, mainstream suppliers with strong balance sheets and track records.
- As might be expected, federal funding has played a significant part in bringing all these projects to fruition. Government loans amounted to around half of all funding in two cases, and even more at Borrego Springs.

Finally, the wide range of investment levels, from $7.3 million to $1.5 million per megawatt-hour of capacity, is provided above for illustrative purposes but may in practice not be that significant. The pilot nature of these projects means they were unlikely to have been fully cost optimized and, in any case, what counts is not how much each project costs but how much value it delivers.

On this front, our research reveals two significant findings. First, none of the utilities listed in this report has published a return-on-investment calculation for its project. And second, all are pressing ahead with further storage plans.