Energy Storage Technology Advancement Partnership (ESTAP) Webinar

QuEST: Optimizing Energy Storage Tool

Hosted by
Seth Mullendore
Clean Energy States Alliance

November 6, 2019
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Energy Storage Technology Advancement Partnership (ESTAP) (bit.ly/ESTAP)

ESTAP is supported by the U.S. Department of Energy Office of Electricity and Sandia National Laboratories, and is managed by CESA.

ESTAP Key Activities:

1. Disseminate information to stakeholders
   - ESTAP listserv >5,000 members
   - Webinars, conferences, information updates, surveys.

2. Facilitate public/private partnerships to support joint federal/state energy storage demonstration project deployment

3. Support state energy storage efforts with technical, policy and program assistance
Webinar Speakers

Ricky Concepcion
Sandia National Laboratories

Tu Nguyen
Sandia National Laboratories

Seth Mullendore
Clean Energy States Alliance (moderator)
Thank you for attending our webinar

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Upcoming Webinar

Energy Storage 101: Part 3 – Applications and Economics

Tuesday, November 19, 2019 at 1-2 pm ET

This ESTAP webinar will look at when and where energy storage opportunities exist, which services can be effectively “stacked,” how revenue-generating opportunities are sometimes limited due to market rules or utility tariffs, and what future opportunities might arise with changes in market rules and regulations.

Learn more and register at: www.cesa.org/webinars
An Energy Storage Application Suite

PRESENTED BY

Ricky Concepcion, Tu Nguyen
OUTLINE

- QuESt overview
- How to obtain QuESt
- QuESt applications
  - QuESt Valuation
  - QuESt Data Manager
  - QuESt BTM
- Behind-the-meter energy storage systems
- Case study with QuESt: cost savings for large hotel with solar + storage
- Wrap-up and conclusions
OVERVIEW

- Energy storage analysis software application suite
- Developed as a graphical user interface (GUI) for the optimization modeling capabilities of Sandia’s energy storage analytics group
- Version 1.0 publicly released in September 2018
- Version 1.2 available on GitHub
  - github.com/rconcep/snl-quest or sandia.gov/ess (tools)
WHY QUEST?

- For energy storage project stakeholders
  - Accessible and easy-to-use software tool for energy storage valuation

- For engineers and software developers
  - Open source software project
  - GUI design, application design, Pyomo optimization modeling
  - Pyomo models and other code can be adjusted to fit specific needs

- It’s free
  - Released under an open source distribution license

- Current application list
  - QuESt Data Manager - Manages acquisition of ISO market data, US utility rate data, commercial and residential load profiles, etc.
  - QuESt Valuation - Estimate potential revenue generated by energy storage systems providing multiple services in the electricity markets of ISOs/RTOs.
  - QuESt BTM - Estimate the cost savings for time-of-use/net energy metering customers using behind-the-meter energy storage systems.
USING QUEST

- For most users
- Developed for user experience
- No hassle installation

Application/GUI

- For power users
- Use for Python scripting
- More capabilities

API/Library (coming soon)
HOW TO OBTAIN QUEST

- Check the "tools" section of the Sandia ESS website
- The code is hosted on GitHub
  - github.com/rconcep/snl-quest
- General requirements:
  - Windows/OS X/Linux
  - Solver for optimization
HOW TO OBTAIN QUEST

- For Windows 10: we have an executable version of QuESt
  - Fully pre-configured, just run the .exe
  - Still requires an optimization solver
  - Under GitHub releases for each version
QUEST APPLICATIONS
OVERVIEW
Decide what type of analysis to do.

- ISO/RTO value stacking => QuEST Valuation
- Behind-the-meter applications => QuEST BTM

Grab the appropriate data from QuEST Data Manager.

- ISO/RTO market data
- Utility rate structure
- PV profile
- Load profile

Select the appropriate application from the first step.

- Set up the analysis and run it
- View and process results
Given an energy storage device, an electricity market with a certain payment structure, and market data, how would the device maximize the revenue generated and provide value?

- Market area
- Revenue streams
- Historical dataset to study
- Energy storage model parameters
Describe the type of energy storage device to be used.

Energy storage devices come in many forms and technologies. In this application, they are mainly modeled according to their power and energy ratings. Select an energy storage device template and/or customize your own.

- **Li-ion Battery**
  - Advanced Lead-acid Battery
  - Flywheel
  - Vanadium Redox Flow Battery

- Li-Ion Phosphate Battery

- **self-discharge efficiency (%)**
  - 100.0

- **round trip efficiency (%)**
  - 90.0

- **energy capacity (MWh)**
  - 24.0

- **power rating (MW)**
  - 36.0

- **Li-Ion Battery**
  - Modeled after the Notrees Battery Storage Project in western TX.

- **Market area**
- **Revenue streams**
- **Historical dataset to study**
- **Energy storage model parameters**
Here's how the device generated revenue each month.

Revenue was generated based on participation in the selected revenue streams. The gross revenue generated over the evaluation period was $3,064,793.94. The gross revenue from arbitrage was -$526,420.06, an overall deficit. This implies participation in arbitrage was solely for the purpose of having capacity to offer regulation up services.

- Revenue by month
- Revenue by revenue stream
- Frequency of participation in each available revenue stream
We use publicly available APIs, posted market data, and crowd-sourced data.

- LMPs, frequency regulation performance/capacity clearing prices, etc. posted by ISOs/RTOs
- U.S. utility rate structures sourced and validated by OpenEI.org
- Commercial and residential hourly load profiles for all TMY3 (typical meteorological year) locations in the U.S. by OpenEI.org
- Hourly photovoltaic power profiles by PVWatts
LMPs, frequency regulation performance/capacity clearing prices, etc. posted by ISOs/RTOs

Use operator-provided APIs

Use web crawling libraries to parse marketplace data portals
OpenEI.org hosts a database for U.S. utility rates

- Time-of-use energy rate schedules
- Peak demand and flat demand rate schedules
OpenEI.org also hosts simulated hourly load profiles for a typical meteorological year:
- Residential (base, low, high)
- Commercial (16 reference building types by DOE)

PVWatts by NREL

- Uses data from the National Solar Radiation Database and a solar panel system model to simulate hourly power output

A collection of applications for behind-the-meter energy storage. The first application estimates cost savings for time-of-use and net energy metering customers.

- Incorporate specific utility rate structures (energy TOU schedule and rates, etc.)
- Use location-specific simulated load and photovoltaic power data

- Utility rate structure for time-of-use energy rate schedules, demand rate schedules, net metering, etc.
- Load profile based on building type
- PV profile if solar + storage configuration
- Energy storage system parameters
- Utility rate structure for time-of-use energy rate schedules, demand rate schedules, net metering, etc.
- Load profile based on building type
- PV profile if solar + storage configuration
- Energy storage system parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy capacity</td>
<td>The maximum amount of energy that the ESS can store.</td>
<td>80 kWh</td>
</tr>
<tr>
<td>Power rating</td>
<td>The maximum rate at which the ESS can charge or discharge energy.</td>
<td>20 kW</td>
</tr>
<tr>
<td>Transformer rating</td>
<td>The maximum amount of power that can be exchanged.</td>
<td>1000000 kW</td>
</tr>
<tr>
<td>Self-discharge efficiency</td>
<td>The percentage of stored energy that the ESS retains on an hourly basis.</td>
<td>100 %</td>
</tr>
<tr>
<td>Round trip efficiency</td>
<td>The percentage of energy charged that the ESS actually retains.</td>
<td>85 %</td>
</tr>
<tr>
<td>Minimum state of charge</td>
<td>The minimum ESS state of charge as a percentage of energy capacity.</td>
<td>0 %</td>
</tr>
<tr>
<td>Maximum state of charge</td>
<td>The maximum ESS state of charge as a percentage of energy capacity.</td>
<td>100 %</td>
</tr>
<tr>
<td>Initial state of charge</td>
<td>The percentage of energy capacity that the ESS begins with.</td>
<td>50 %</td>
</tr>
</tbody>
</table>
Here's the total bill with and without energy storage for each month.
The total bill is the sum of demand charges, energy charges, and net metering charges or credits. It looks like the ESS was able to decrease the total charges over the year by $1,712.70.

- Compare monthly bill with and without energy storage
- Peak demand reduction to decrease demand charges
- Time-shifting to reduce time-of-use energy charges
- Net metering credits
Compare monthly bill with and without energy storage
Peak demand reduction to decrease demand charges
Time-shifting to reduce time-of-use energy charges
Net metering credits
• **Behind-the-meter** refers to the systems that are located at the customers’ sites (homes, commercial and industrial facilities). BTM systems are usually owned by customers and intended for customers’ use.
**UTILITY RETAIL RATES**

- **Energy Charge**: a charge to customers for the amount of energy consumed, $/kWh.
- **Demand Charge**: a charge to customers for their peak power, $/kW.
- **Other Charges**: meter and basic customer fees are independent of consumption, $/month.

![Load Profile and Energy Consumption Diagram](image)

<table>
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<tr>
<th></th>
<th>Energy Charge</th>
<th>Demand Charge</th>
<th>Other Charges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Customers</td>
<td>Yes</td>
<td>Yes/No*</td>
<td>Yes</td>
</tr>
<tr>
<td>Commercial Customers</td>
<td>Yes</td>
<td>Yes/No*</td>
<td>Yes</td>
</tr>
<tr>
<td>Industrial Customers</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Demand charge is often applied to large commercial customers
• **Fixed rate**: or often called tiered rate is the rate structure where a constant price is applied to each tier of energy consumption.
• **Dynamic rate**: includes the rate structures where energy and demand prices are time dependent.

• **Utilities’ motivations for dynamic-price rate:**
  • Increase customer satisfaction with options to reduce energy bill.
  • Encourage load growth.
  • Reduce peak demand by load shifting.
  • Comply with statutory or regulatory mandate
• In TOU pricing, energy and demand prices are set in advance for different time periods.

• Time schedules for TOU:
  • Hour: peak, part-peak, and off-peak hours.
  • Day: weekdays, weekends, and holidays.
  • Month: summer and winter

Southern California Edison – Schedule TOU-D-A
UTILITY RATE STRUCTURES – DYNAMIC RATE

ENERGY DEMAND

MEGAWATTS

Critical event e.g. heat wave
Typical daily demand

PRICING OPTIONS

CENTS PER KILOWATT-HOUR

Real-Time Pricing (RTP)
Fluctuates hourly based on generation cost

Time-of-Use Pricing (TOU)
Fixed periods based on typical daily demand, critical event has no effect

Variable Peak Pricing (VPP)
Fixed periods based on typical daily demand, peak price varies based on generation cost

Critical Peak Pricing (CPP)
Elevated pricing during critical times

Critical Peak Rebate (CPR)
During critical events, customer is paid this amount for each kWh reduced below a baseline quantity

Source: Environmental Defense Fund (EDF)
• Net metering (NEM) programs allow customers who own renewable energy systems to export their excess energy to the grid.
• The net energy exported to the grid will be used to offset the customers’ consumption. At the end of the true-up period, the customers will be charged/credited for the net energy usage/surplus.
To benefit from dynamic rate structures, the customers must be able to change their loads in a manner that lowers their electricity bills without interrupting their operations (commercial and industrial customers) or sacrificing their conveniences (residential customers).

**HOW CAN UTILITY CUSTOMERS BENEFIT?**

- **Renewable Time Shift**
- **Time-of-use Management**
- **Demand Charge Reduction**
MINIMIZING ELECTRICITY BILLS FOR UTILITY CUSTOMERS

• The objective is to minimize the electricity bill such that the physical limits of energy storage device and the inverter are satisfied.

$$\min\{C^m_E + C^m_N + C^m_D\}$$

s.t. energy storage and inverter constraints

- $C^m_E$ is the energy charge of period $m$
- $C^m_D$ is the demand charge of period $m$
- $C^m_N (\leq 0)$ is the net metering charge of period $m$.

• The decision variables are the charge and discharge power of the energy storage device at each hour
This is a behind-the-meter energy storage problem, so we will use QuESt BTM.

First, we head to QuESt Data Manager to get what we need.
For this analysis, we need:
- Utility rate structure
- Load profile for the property
- PV power profile
• Our hotel’s utility is Pacific Gas & Electric.

• The applicable rate structure for our property is “E-19 Medium General Demand TOU (Secondary, Voluntary)”.

• We’ll need an API key for this tool and the PV profile downloader. There’s a help prompt to get you started with that short process.
• Verify that the energy and demand rate schedules are correct.
### CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE

- Verify that the energy and demand rate schedules are correct.
• Save the rate structure for later.
• Now we’ll obtain the load profile for the building.
CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE

• Now we’ll obtain the load profile for the building.
Now we’ll obtain the load profile for the building.
• Finally, we’ll grab the PV power profile for our property.
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Now that we have all the data that we need, we can return home and start using QuESt BTM for the analysis.

We’ll use the Time-of-Use Cost Savings wizard.
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Proceeding through the wizard, we select the data that we had just downloaded when prompted.

Our proposed energy storage system is 400 kWh/100 kW, so we’ll enter that in.
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**CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE**

Proceeding through the wizard, we select the data that we had just downloaded when prompted.

Our proposed energy storage system is 400 kWh/100 kW, so we’ll enter that in.
• Once everything’s setup, we’ll click “Next” to initiate the model building and solution process.

• In the background, the specified data is being loaded, the optimization models are being constructed, and the models are being solved.

• After a brief wait, a prompt will notify you that the computation is complete.
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• After a brief wait, a prompt will notify you that the computation is complete.
We can now view the wizard’s report of results and view several summary graphics.

Based on the calculations, the addition of the energy storage system reduced annual charges by about $36k.

This was mostly due to demand charge reduction.

Peak demand each month was reduced by about 100 kW.
CASE STUDY: LARGE HOTEL WITH SOLAR + STORAGE

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• We can also create a summary report that includes formulation details and the results.
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We can retry the wizard with different energy storage system parameters. Or we can try different PV/load profiles, rate structures, etc.

Is the energy storage system worth it? It will depend on the financials of acquiring and operating it... but we have an estimate on its performance value potential.


5. F. Wilches-Bernal, R. Concepcion, R. H. Byrne, “Participation of Electric Storage Resources in the NYISO Electricity and Frequency Regulation Markets,” accepted for the 2019 IEEE Power and Energy Society General Meeting, Aug 2019, Atlanta, GA.


FUTURE PLANS AND WRAP-UP

- Develop new applications
  - Integrated resource planning tools
  - Optimizing with costs
  - Resilience
  - More value streams
  - RFP templates
- Release API/Library
- Webinars, tutorials, workshops
- Integrate user feedback and requests
Acknowledgements

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