Journal of Energy Storage 15 (2018) 336–344

Contents lists available at ScienceDirect

Journal of Energy Storage

journal homepage: www.elsevier.com/locate/est

The benefits of grid-scale storage on Oahu

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ARTICLE INFO

Article history:
Received 28 August 2017
Received in revised form 6 December 2017
Accepted 7 December 2017
Available online xxx

Keywords:
Energy storage
Reserves
Production cost model
Hawaii

ABSTRACT

The Hawaiian Electric Company intends to procure grid-scale Battery Energy Storage System ("BESS") capacity. The purpose of this study is to determine whether providing contingency reserve or time-of-day shifting is of more benefit to the Oahu grid, and to better understand the relationship between BESS size and level of benefit. This is an independent study by Sandia, and is not being used to support the regulatory case for BESS capacity by Hawaiian Electric. The study team created a production cost model of the Oahu grid using data primarily from the Hawaiian Electric Company. The proposed BESS supplied contingency reserve in one set of runs and time-of-day shifting in another. Supplying contingency reserve led to larger savings than time-of-day energy shifting. Assuming a renewable reserve and a quick-start reserve, and $15/MMBtu for Low-Sulphur Fuel Oil, the 50-MW/25-MWh, 100-MW/50-MWh, and 150-MW/75-MWh systems supplying contingency reserve provided, respectively, savings of 9.6, 15.6, and 18.3 million USD over system year 2018. Over the range of fuel prices tested, these cost savings were found to be directly proportional to the cost of fuel. As the focus is the operational benefit of BESS capacity, the capacity value of the BESS was not included in benefit calculations.

1. Introduction

The Hawaiian Electric Company has requested proposals for grid-scale storage on Oahu [1]. Given that Hawaii has adopted a 100% Renewable Portfolio Standard for electric utilities by 2045 [2], it is clear that the amount of variable generation[1] will only increase. Given its usefulness in integrating variable generation [4], the opportunities for energy storage to play a role in Hawaii will only increase.

Given Hawaiian Electric's intent to procure Battery Energy Storage System ("BESS") capacity, Sandia's[2] motivation for this study was to explore what BESS service would most benefit the system, and to explore how BESS size impacts the amount of benefit. This is an independent study by Sandia, and is not being used to support the regulatory case for BESS capacity by Hawaiian Electric.

A BESS becomes more expensive as the energy storage requirement increases [5]. Therefore the ideal function for a BESS to perform would be one that adds a great deal of value while requiring a small energy storage component. One such function may be the provision of Contingency Reserve. A Contingency Reserve is set aside in the event of an unforeseen unit trip (often called a 'forced outage'), and is typically a spinning reserve. It usually takes hours to repair a unit that has experienced a forced outage. A BESS with a small energy storage capacity could provide this reserve, provided that additional generation could be brought on line before the battery's reserves are exhausted. This generation would need to be brought on line fairly quickly, hence we term it a "Quick Start" Reserve.

Another possibility for savings is having the battery act to provide time-of-day energy shifting, which is often termed "Arbitrage." Generally energy is more costly to produce on-peak than it is off-peak, as less fuel-efficient units may be dispatched at peak times. Having the battery generate on-peak and charge off-peak may save on operational costs, provided that the gap in on-peak and off-peak generation cost is sufficient to overcome the BESS round-trip efficiency losses.

This study builds on previous work studying solar and wind integration in Hawaii [6], as well as the value of energy storage on Maui [7].

Our hypothesis is that Contingency Reserve supplied by the combination of the BESS and a Quick Start Reserve would be less

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[1] Variable generation, such as wind and solar photovoltaic generation, is not dispatchable. For an overview of variable generation in power systems, please see [3].

[2] In this paper, 'Sandia' refers to the authors of this paper. It does not imply a viewpoint or position held by the leadership of Sandia National Laboratories.

https://doi.org/10.1016/j.est.2017.12.009

expensive than employing conventional units to provide the reserve. In addition, the expected benefits from using the BESS (in conjunction with a Quick Start Reserve) to provide Contingency Reserve are greater than from using the BESS to provide Arbitrage.

2. Material and methods

To test this hypothesis, a production cost model of the Oahu grid was created using data supplied by Hawaiian Electric as well as solar data generated at Sandia.

A production cost model captures the costs of operating a fleet of generators, and can consider the transmission constraints of a power system. An optimization is performed to identify the least-cost dispatch given the system load, unit characteristics, fuel costs, and renewable generation [8]. In this case, a Mixed-Integer Linear Programming (“MILP”) model was used. A MILP model will formulate the problem where some variables, such as unit commitment (whether a unit is to be on or off), are integer values, whereas other variables (such as heat rate) are not constrained to be integers [9].

As this study assumes an energy storage facility is operational in 2018 [10], the model was initialized to reflect generation and load as projected for 2018. When conducting a study on a system in the future, it is expected that certain assumptions (such as fuel prices and reserve requirements) may prove to be inaccurate. Therefore, the study team sought to do sufficient scenario analysis to understand what the value of a BESS might be under a variety of conditions. The model runs in this study were conducted in September 2016.

In this study, PLEXOS® (production cost modelling software by Energy Exemplar®) was used. The study team input unit characteristics, load, variable generation output, fuel types and costs, and reserve types and required amounts into PLEXOS®. The software uses this input to formulate the optimization problem, and then passes this problem off to a solver to come up with the solution.

The optimization problem is the least-cost provision of energy and reserve, subject to constraints. The total cost which the model seeks to minimize (while serving load and observing all other constraints) is shown in Eq. (1), where $FuelCost_i$, $StartCost_i$, and $VariableOperatingCost_i$ represent the total fuel, start, and variable operating costs, respectively, in each hour across all units.

$$TotalCost = \sum_{i=1}^{8760} FuelCost_i + StartCost_i + \mathrm{VariableOperatingCost}_i \tag{1}$$

Strictly speaking, PLEXOS® does not attempt to minimize Total Cost in each hour for the whole year at once. Instead, it approximates this through the use of integrated simulation phases that start out with looking at the entire year, and at the default setting end up with performing hourly dispatch (the “dispatch interval”) that is optimized over a 24-h period (the “step size”). While the default setting is used for this analysis, the user can specify both the step size and the dispatch interval. Dispatch can take place every 5 min if desired. Fig. 1 illustrates the integrated simulation phases that the PLEXOS® model performs.[3] Information from each simulation phase is passed down to the next.

First, in the Projected Assessment of System Adequacy (or PASA) phase, the model looks over the entire year, but not for the purposes of hourly dispatch. It is in this phase that the random forced outages of generators (using user-specified probabilities) are assigned. Taking both the assigned generator forced outages and scheduled maintenance into account, the model chooses the optimal time for distributed maintenance (where a certain amount of maintenance must be performed, but a schedule is not specified). Having done this, the model then calculates a Loss of Load Probability (LOLP).

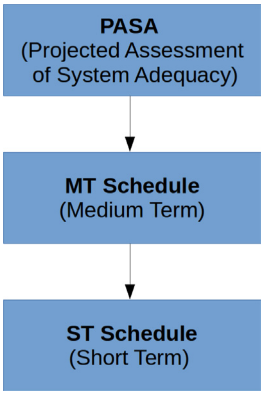

Fig. 1. PLEXOS® flowchart.

Second, the Medium Term Schedule (or MT Schedule) uses temporal simplification to greatly speed execution time. The main purpose of this phase is to decompose medium-term constraints and objectives so that they can be fully accounted for in the chronological Short Term Schedule simulation. An example in this model is that several units have annual minimum fuel consumption amounts.

Last, the Short Term Schedule (or ST Schedule) is a chronological Unit Commitment and Economic Dispatch (UCED) model based on mixed-integer programming. This phase co-optimizes energy and reserves in order to meet the load and reserve specifications for each time period. The window of optimization (or step size) used in this study is 24-h, meaning that unit commitment and dispatch are solved for each 24-h period as one problem. This means that the model has perfect foresight over the 24-h period. An hourly dispatch interval was specified for this analysis.

Reserve Requirements. A Contingency Reserve is power production capacity that is set aside so that it may be used in the event of a forced outage at a generator. It should be able to supply power long enough to either repair the unit with an outage or get a replacement unit on-line. Here we define Contingency Reserve as on-line reserve that can reach nominated output within 10 min and maintain that level of output for at least 2 h. Any conventional unit that is on-line can supply this reserve. The largest single unit on Oahu is the 180-MW AES coal-fired plant. For the purposes of this study, the Contingency Reserve is set at this size. Assuming that 25 MW of demand response will be available at all times reduces the net Contingency Reserve requirement to 155 MW, which is what the study team has modeled.

In order to achieve the same level of reliability as conventional-unit Contingency Reserve, BESS-supplied Contingency Reserve should be able to supply the required duration of output (in this case, two hours). Since the BESS we analyze here is able to supply 30-min of power at full ouput, there should be a Quick Start reserve to provide the power output duration that the BESS lacks.[4] Here we have defined Quick Start Reserve as off-line power generation capacity that can be brought on-line at nominated output within 10-min. We assume that all of the combustion turbines and

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[3] A discussion of the PLEXOS simulation phases is contained in the user manual (only available to subscribers) at: https://wiki.energyexemplar.com.

[4] In cases with a Quick Start Reserve, we have constrained BESS Contingency Reserve participation to the capacity available in Quick Start Reserve.