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Power couples: The synergy value of battery-generator hybrids

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ABSTRACT

Battery hybrids—a battery system paired operationally with a generation system—can often provide more value than the individual systems alone. We identify and describe eight value streams that battery hybrids can provide. Additionally, we identify the trends of increasing renewable energy, demand for resilience, need for flexibility, and the increasing economics of hybrid systems of standalone diesel generation as supporting increased battery hybridization in the future.

1. Introduction

Battery storage is becoming a relevant part of the electricity grid. Declining prices are spurring rapid growth in battery storage installations. Lithium-ion battery prices fell by more than 65% from 2007 to 2014, decreasing by 14% annually (Nykvist and Nilsson, 2015). Furthermore, battery prices are forecasted to decline another 50% from 2016 levels by 2020 (D'Aprile et al., 2016), and total capital costs for battery storage projects are estimated to decrease by 38% between 2016 and 2021 (Lazard, 2016a). Projects that only a few years ago would have been uneconomic are now in some cases providing enticing returns. U.S. battery capacity is forecasted to grow 22-fold in the next six years (Greentech Media Research, 2017).

Batteries have several qualities that are useful for providing electricity services. They are dispatchable, have fast response times, have zero end-use emissions, can be installed quickly, and face fewer siting restrictions than most conventional generation. Thus, battery storage can provide value to both utilities and customers through a number of generation, transmission, and distribution applications (Akhil et al., 2015; Fitzgerald et al., 2015). The wide range of applications for battery storage implies a large market potential for storage projects.

Batteries may be paired operationally with a generator to create a battery hybrid. Battery hybrids can reduce costs, increase revenue and provide services that the battery and generator cannot alone provide. The additional value streams that battery hybrids can provide indicate that the market potential for battery hybrids may be even bigger than for standalone battery storage.

The rest of this paper discusses the uses of battery hybrids, provides a framework for understanding how pairing a battery with a generator can decrease costs and increase value, and discusses the future of battery hybrids. We focus on how synergies between a battery and a generator allow battery hybrids to provide services more efficiently and provide services which neither battery nor generator alone could. We first discuss the potential benefits of hybridization, and show how synergy value can be created from the strengths of the battery or generator negating a weakness of the other. We then discuss the important value streams that battery hybrids can provide. We finally discuss the future of battery hybrids.

2. The motivation to hybridize

Hybridization has three primary benefits. Hybrid projects have lower costs, can leverage hybrid-specific policy incentives, and can increase revenue compared to separately built battery and generator projects. While we focus on synergies between batteries and a generator, technology cost reductions and hybrid-specific policy measures are important motivators for hybridization.

A hybrid project can share soft costs such as planning, labor, and customer acquisition, and in some cases can share costs for hardware such as transmission lines, controllers, and inverters between the battery and the generator. Co-optimized hybrid system costs can be lower than the cost of building a generator and battery separately (Ericson et al., 2017). Installing a separate residential solar photovoltaic (PV) and battery system is an estimated 18% more expensive than

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simultaneous installation (Ardani et al., 2017).[1] Coupling batteries with PV at the utility-scale can also reduce costs, with estimated savings of up to 8% of total project costs (Denholm et al., 2017).[2]

Battery hybrids, especially batteries paired with wind or solar generation, benefit from several tax incentives in the U.S. Storage paired with renewable energy qualifies for a better depreciation schedule and a 30% investment tax credit (Elgqvist et al., 2017). Even in situations where the generator and battery would generate more revenue when independently sited, the tax credit and reduced construction costs may make it more profitable to hybridize. Thus, even in the absence of direct synergies, the economics may drive an increasing number of battery hybrid projects.

The third potential benefit of hybridization is an increase in value due to operational synergies between batteries and a generator. Batteries and generators each have specific strengths and weaknesses. Synergy occurs when the battery complements a strength or negates a weakness of the generator; or when the generator complements a strength or negates a weakness of the battery.

Batteries have multiple strengths. Batteries are dispatchable, have fast response times, have zero end-use emissions, are always synchronized with the grid, can be located behind-the-meter, can be installed quickly, and face fewer siting restrictions than most conventional generation. Fast ramping makes battery storage well suited to provide ancillary services such as frequency regulation and spinning reserves (Akhil et al., 2015). Zero end-use emissions allow batteries to be located in cities with emission restrictions. Storage may be sited downstream of transmission nodes to reduce congestion and defer transmission upgrades. Storage can also provide behind-the-meter power to customers when it is needed most. This allows batteries to provide resilience during blackouts and reduce demand and time-of-use charges to customers.

Battery storage also has several shortcomings. First, batteries have limited discharge duration, which means energy may be unavailable when needed.[3] Common battery durations range from 30 min to 4 h. This range reflects current market regulations; 30 min meets requirements for frequency regulation and 4 h meets requirements for capacity markets (Johal et al., 2016). Since adding duration adds to system costs, battery storage becomes increasingly costly as the required length of service increases. Battery storage alone is therefore unsuited for applications that require sustained discharge for longer than a few hours. Energy can be stored and discharged for longer time periods in water reservoirs, as compressed air, as heat, and as primary fuel supply such as coal and natural gas storage. Battery storage also suffers from relatively high capital costs. While battery costs are rapidly falling, current high capital costs of battery storage make batteries less economic than other forms of energy storage for some applications.

Similar to the strengths and weaknesses of battery storage, each generator has specific strengths and weaknesses as well. For example, solar panels may be installed quickly, have zero marginal costs and zero end-use emissions, and can provide distributed generation. However, solar is not dispatchable and does not produce energy at night. Natural gas combustion turbines have relatively low capital costs and can be started quickly, but have generation costs that depend on highly variable fuel costs and cannot be synchronized to the grid while offline. Diesel generators have low capital costs, are dispatchable, and can provide distributed generation, but have high fuel costs, are inefficient while ramping or generating at part load, and are subject to air quality restrictions (Anderson et al., 2016).

While many of the services hybrids provide can be provided by a standalone battery or generator system, synergies between the battery and generator can lead to instances where a hybrid system is able to provide the service more effectively than separate systems could. Hybridizing a battery with a generator can increase the battery effective discharge duration and can reduce total capital costs by allowing requirements to be met with a smaller battery. Hybridization can also reduce variability issues related to renewable generation and increase the effective ramp rate of turbines.

In the next section, we discuss applications where batteries and a generator can effectively complement each other. For each application, the combined characteristics of the battery hybrid are better suited to provide the service than the individual characteristics of the battery or generator can.

3. Battery hybrid value streams

Battery storage and battery hybrids have a wide variety of possible value streams. Akhil et al. (2015) details 18 distinct services energy storage can provide, spanning every aspect of electricity production, distribution, and consumption. Here, we focus on eight applications that are especially important for battery hybrids. The eight value streams we identify as especially important to battery hybrids are:

1. Energy arbitrage
2. Spinning reserves
3. Ramp control
4. Generation capacity
5. Transmission benefits
6. Demand charge reductions
7. Resilience and reliability
8. Island and off-grid generation

For each application, we provide instances where the technical requirements of each application can be more effectively met by a battery hybrid than a generator or battery alone. An in-depth analysis of each value stream can be found in Ericson et al. (2017).

3.1. Energy arbitrage

A battery participating in energy arbitrage stores energy when prices are low and sells energy when prices are high. For energy arbitrage to be profitable there must be enough of a difference between low and high prices to generate sufficient return on investment after covering efficiency losses and wear and tear.

Periods of high production from variable generation increase line congestion and may exceed line capacity, leading to low or even negative localized prices. Hybridization can avoid these low or negative cost regimes by charging the battery during congested periods. Furthermore, storage paired with solar photovoltaics (PV) can charge with energy that would otherwise be clipped due to generation exceeding inverter capacity (Denholm et al., 2017).[4] Finally, in areas without full net metering laws, a paired battery can charge during periods when self-generation exceeds load which reduces effective charging costs.

3.2. Spinning reserves

To maintain grid reliability in the case of an unexpected plant

[1] Estimates are for a 5.6 kW PV and a 3 kW, 6 kWh solar-storage system. All-in cost estimates were $27,703 for simultaneous installation and $32,786 for separate installation.

[2] The project that was analyzed consists of a 65 MW fixed-tilt solar farm with a 50 MW inverter and a 30 MW, 120 MWh lithium-ion battery.

[3] Battery storage is rated both in terms of power and energy. Rated power is measured in kilowatts and is based on inverter size. Rated energy is the maximum kWh of energy that can be stored. Duration is the amount of time the storage system can output at its rated power, and is equal to rated energy divided by rated power.

[4] As solar panels seldom produce at maximum capacity, PV systems generally have higher panel capacity than inverter capacity. A battery paired with solar on the DC side of the inverter can charge when panel output exceeds inverter capacity.

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