Battery Energy Storage Systems

Components and *Use Cases*

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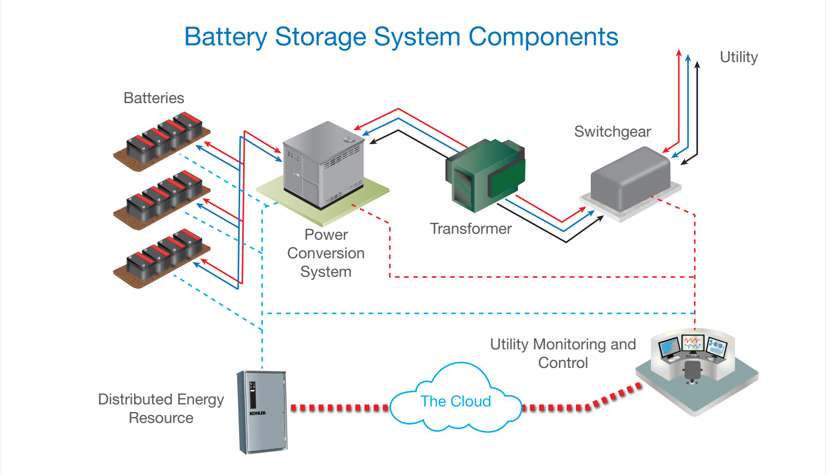
INTRODUCTION

Power outages, utility frequency or voltage briefly out of tolerance, and soaring utility bill costs are some of the problems critical infrastructure facilities are facing today. With technology rapidly evolving, there are new opportunities for these customers. Battery energy storage systems are an option to leverage for utility bill cost reductions and fast power injection to combat utility power stabilization issues.

Battery storage systems are getting a lot of attention. The United States government recently passed the Inflation Reduction Act (IRA) which incentivizes the manufacturing of battery storage components and the installation of these systems, see Figure 1. There are three primary consumers of battery storage: residential, utility, and commercial/industrial applications. For this paper, we will focus on commercial/industrial consumers and applications.

Figure 1



BATTERY STORAGE SYSTEM COMPONENTS

Battery storage systems convert stored DC energy into AC power. It takes many components in order to maintain operating conditions for the batteries, power conversion, and control systems to coordinate the discharging and charging the batteries. See Figure 1.

The following section will review the major system components.

ENCLOSURE

An enclosure serves an important role within the battery storage system to protect the batteries. Protection comes in two primary forms: first in keeping wildlife out, and second by maintaining the temperature of the cooling system. Batteries must maintain a very specific temperature range in order for optimal performance.

Another important aspect of the enclosure is safety. Battery cells can experience thermal events, which are an internal short. When a thermal event happens, batteries can catch fire and the fire can spread to other batteries. If not properly mitigated, the fire can spread throughout the entire system.

Battery manufacturers design batteries with redundant safety measures to prevent thermal runaway, but unfortunately it is still possible. The final safety feature for the enclosure is a fire suppression system that will activate based on the enclosure temperature or gas detection.

INTERCONNECTION OF DC BUS

An important design factor for systems with multiple battery enclosures are for interconnection of the DC bus from section to section. This is important to minimize the installation time of the system and decrease the overall installation cost.

The battery racks within the enclosure connect from the battery management system (BMS) terminals to the DC bus internal to the enclosure.

Enclosures have been designed with external DC bus connections from either side to allow for quicker installations.

COOLING SYSTEM

LITHIUM-ION BATTERY COOLING

An instrumental component within the energy storage system is the cooling. It is recommended from battery manufacturers of lithium-ion batteries to maintain a battery temperature of 23ºC +/- 2. Fluctuations in temperature can affect the battery performance and life cycle.

Drops in temperature below the 23 degrees affect the discharge capacity of the batteries, seen in `Figure 2`

TWO TYPES OF COOLING SYSTEMS

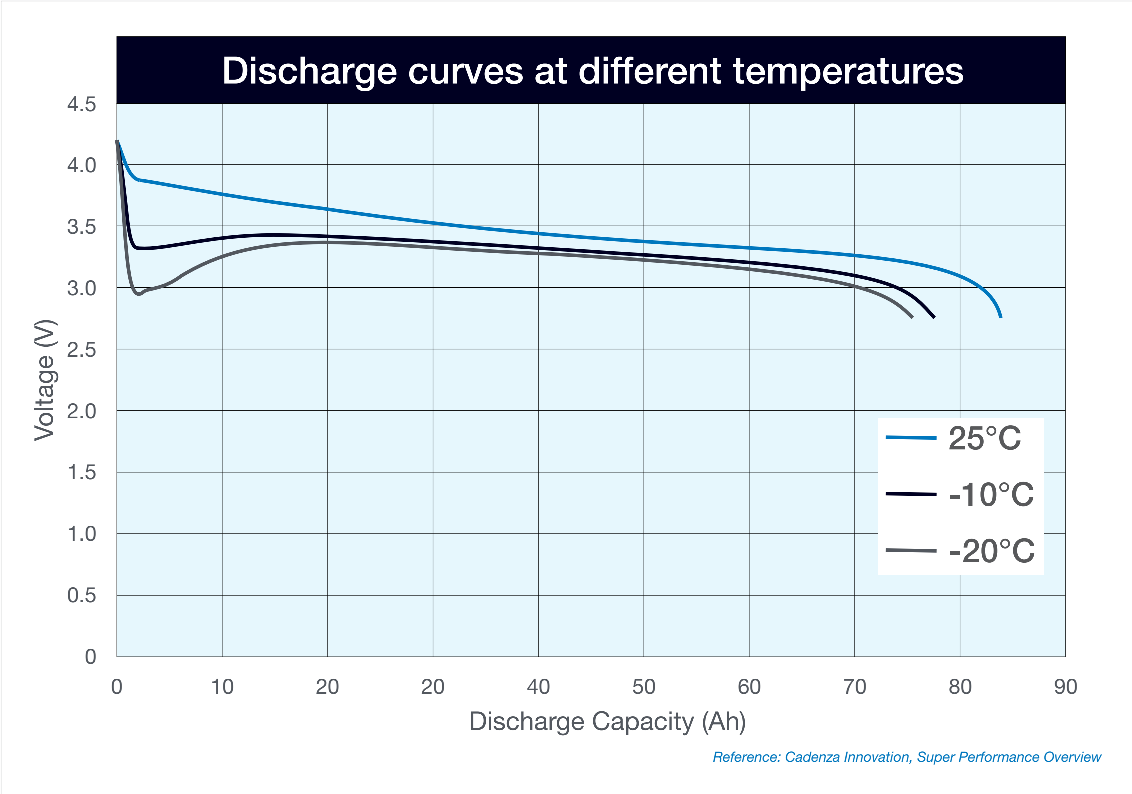
There are two types of cooling systems, forced-air and liquid-cooling.

Forced-air cooling dominated early battery storage designs due to its low cost and relatively easy design. Forced-air did a reasonable job keeping the batteries around their recommended temperatures. But as the early systems started to age, the batteries performance started to decline.

In order to mitigate the decrease in performance and extend the life of the batteries, battery storage system providers began developing liquid-cooling technology. This technology is able to get closer to the batteries and does a better job of cooling the batteries.

The liquid-cooling technology is the primary cooling method in the industry today. It uses glycol as the liquid and can last for ten years without the need to be replaced. As part of the O&M process, the glycol level should be measured once a year.

`Figure 2`



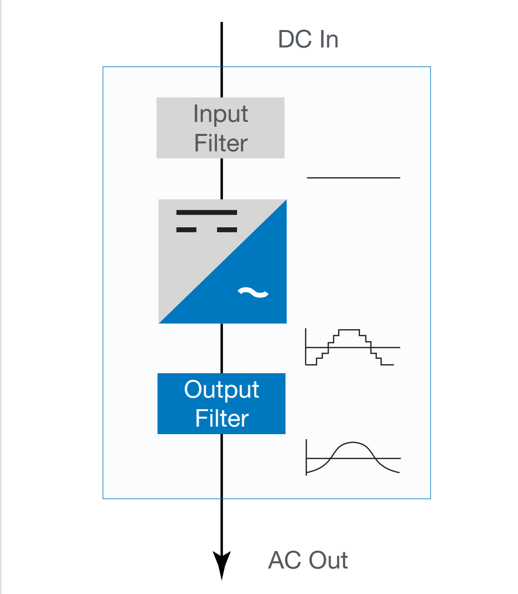
INVERTER

CONVERTS STORED DC ENERGY TO AC POWER

The inverter is the key component that converts stored DC energy to AC power. The conversion process happens by turning transistors on and off to create the AC waveform, this process is also known as pulse width modulation (PWM).

This inverter typically resides outside of the battery storage enclosure and the battery output from the battery management system (BMS) will connect to the input of the inverter (DC In). See Figure 3.

Figure 3



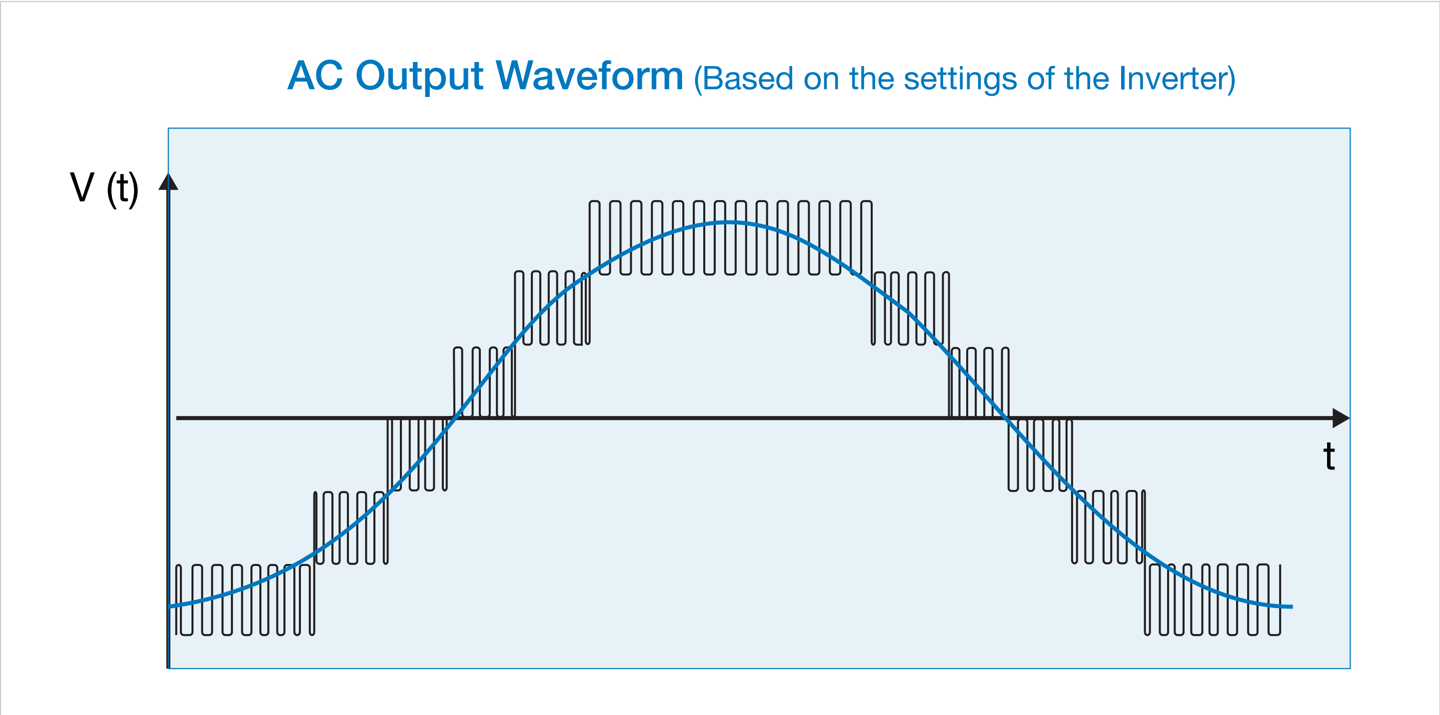
INVERTER MODES

An inverter has two distinct modes, grid following and grid forming.

In grid following mode, the inverter will match it's output to the AC reference signal input. The AC input is typically the utility.

In grid forming mode, the inverter will create the AC output waveform based on the settings of the inverter. This mode activates without the presence of the AC reference signal input. See Figure 4.

Figure 4



TRANSFORMER

MEDIUM VOLTAGE APPLICATIONS

Transformers are required for medium voltage applications, in which the voltage needs to be increased to meet the needs of the customer power system.

Transformers, although not required for low voltage, are great options for point of interconnection between the two power systems since they will not propagate faults. Also they provide a means for filtering the power but add extra cost. The inverter output would connect to the transformer.

CONTROL SECTION

ENERGY–MANAGEMENT SYSTEM

The control section serves as a hub for energy-management system components and the means to transmit any battery information to the cloud for advanced processing or reporting.

Below are the following components that may be utilized in the control section:

- Cellular Router: Responsible for transmitting the data obtained from the energy-management system to the cloud where the energy-management software developer can utilize the data to generate reports or execute system use cases.
- Energy-Management Hardware: Responsible for executing the system-designed use cases.
- Power Meter: Responsible for understanding how much power the battery storage system is exporting during system use cases.
- Network Switch: Responsible for communication between devices within the system. Protocols can vary but Modbus or CAN are common.

CONTROLS AND OPTIMIZATION PLATFORM

Heila Technologies, a Kohler company, produces distributed energy control solutions that work as a controls and optimization platform for BESS-connected projects.

Heila's innovative decentralized controls platform allows BESS to optimize for customers' economic and resiliency goals. The controls and optimization platform uses game theory-based algorithms and state-of-the-art forecasting methods to optimize value streams such as energy and demand shifting during high time of use rates, scheduled demand response, and solar clipping recapture.

These optimization goals are also adjustable as utility tariff structure and market incentives shift over time.

A vendor agnostic platform is important for adding new energy resources (such as PV, fuel cell, generators, etc.) in the future to avoid reprogramming the entire controls architecture or writing custom code. This flexibility allows the customer to add energy resources over time as electrification and EV charging inevitably increases the facility's consumption. Customers will naturally elect to have on-site generation resources rather than needing to oversize utility services and transformers. Heila's monitoring and analytics platform can also recommend optimum size of PV, BESS, or other energy assets over time, changing rates, and incentive structures. This recommendation uses the same algorithms that are used to dispatch energy assets like BESS in the future that simplifies the precommissioning process and streamline post-deployment optimization and support.

BATTERY STORAGE SYSTEM USE CASES

PURCHASE ASPECTS

Customer executives review all aspects to purchase a battery storage system. These can include financial, power resiliency, diversification of power sources, and decreasing their carbon emissions.

DECISIONS DRIVEN BY FINANCIAL ASPECT

Even though all factors are considered for battery storage systems, the main driving force is the financial aspect.

In order for the battery storage system to make financial sense, each use case must be considered, although not all are applied to the system.

The system designer will work with the customer requirements in order to maximize the financial benefits. This generally comes in the form of utility bill reduction and minimizing customer downtime from utility failures.

The selected use cases are important for the battery design because the batteries can be designed for high power output or longer sustained power. Having both high power and long duration can add a lot of cost to the system so it is important defining the system use cases.

MAIN USE CASES OF COMMERCIAL/INDUSTRIAL CUSTOMERS

DEMAND CHARGE REDUCTION

Demand charge is a monthly fee that is applied to customer utility bills.

The purpose of the fee is for utility infrastructure maintenance. The fee is calculated by taking the customer's monthly maximum kilowatt consumption and multiplying it by the utility demand charge multiplier.

The utility calculates the maximum kilowatt by continuously monitoring the customer's load profile from a utility grade meter every 15 minutes. The highest value from this polling will set the demand charge kilowatt. See `Figure 5`.

Customers with a large load profile and high-demand charge multiplier are perfect for this use case.

It is common for developers to target financial savings of 30%–50% of the customer's total utility bill. The batteries would need to be sized accordingly depending on the kilowatt peak and would need to last between two to four hours.

DEMAND RESPONSE

Utility companies offer a program in which they will request the customer's facility be removed from utility power. This can be an automated request or a telephone call.

When the customer receives this request, they must transfer from utility power to another power source—this can be generators or batteries. The batteries would have to be sized accordingly to ensure they can maintain the load demand for the predetermined duration of the request. The customer could also do a combination of batteries and generators for the duration of the request. The customer receives utility bill relief for participating in the demand response program.

FREQUENCY REGULATION/ VOLTAGE RESPONSE

Frequency regulation and voltage response are two use cases that leverage the battery storage system to ensure the voltage and frequency of the bus is maintained within tolerance to prevent tripping of critical loads. For frequency regulation, the battery storage system will inject real power during frequency dips to maintain 60 Hz operation. For voltage regulation, the battery storage system will inject or absorb reactive power to maintain the system rated voltage. Generally, these use cases are used more for critical load panels than the full facility.

PV SELF–CONSUMPTION

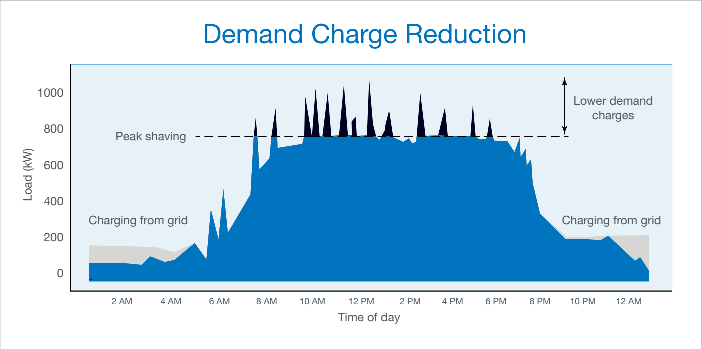
Peanut butter and jelly, solar and batteries—some things are perfectly paired together. Due to the variability nature of solar energy, batteries can offset some of this variability and allow the customer to have a renewable resource on demand.

Since batteries cannot generate their own power, oversizing and storing the excess production of solar energy in batteries is a great way for customers to have resilience or utilize utility bill optimization to save some money.

BACKUP POWER

When power fails, customers can leverage the batteries to provide power to the critical loads for the duration agreed upon in the requirements. The duration tends to be two to four hours.

`Figure 5`



CONCLUSION

Battery energy storage systems are most applicable to customers with highly variable utility rate structures, load spikes with high-demand charges, or in areas that lack utility power stability.

These systems, along with generators, are imperative to provide customers with energy resilience.

As costs continue to decline and other technologies begin to emerge, it will be commonplace for critical infrastructure facilities to closely resemble microgrids.

ABOUT THE AUTHOR

Michael Kozich is a Sr. Staff Engineer at Kohler Co. He has worked for the company's Energy division since 2007 and specializes in control systems programming and design for critical infrastructure customers. He most recently completed a stretch assignment to research battery storage systems. Kozich has a bachelor of science in electrical engineering from the University of Wisconsin-Milwaukee.

ABOUT KOHLER ENERGY

Kohler Energy, a global leader in energy resilience solutions, brings bold design and powerful impact to the energy systems that sustain people and communities everywhere around the world. It is an integral part of Kohler Co., with solutions across home energy, industrial energy systems, and power train technologies. Leveraging the strength of its portfolio of brands – Power Systems, Home Generators, Kohler Uninterruptible Power, Clarke Energy, Heila Technologies, Curtis Instruments, and Engines. With more than a century of industry leadership, Kohler Energy builds resilience and goes beyond functional, individual recovery to create better lives and communities. For more details, please visit KohlerEnergy.com.

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PRINTED IN U.S.A. WF373984 G26-48 8/23