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# Enhancing Battery Energy Storage Systems Through Silicon Carbide (SiC)


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Batteries can be used to store the energy produced from renewable sources like solar and wind at peak times, allowing it to be drawn upon when environmental conditions are less favourable for energy production. This article reviews topologies for residential and commercial battery energy storage systems (BESS) before presenting EliteSiC solutions from onsemi, which can improve the performance of BESS as replacement to silicon MOSFET or IGBT switches.

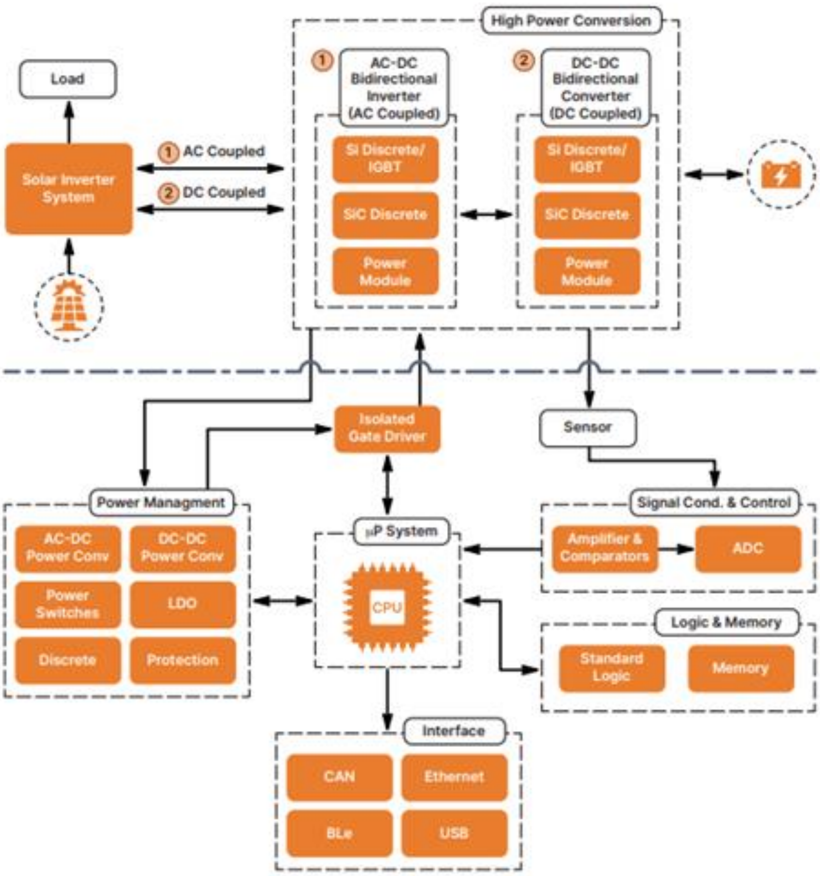


Figure 1: Overview of a BESS implementation

**BESS advantages**

The four most commonly used energy storage methods are electrochemical, chemical, thermal, and mechanical. Lithium-ion batteries, the most recognizable electrochemical storage system, exhibit high power density and efficiency, compact form factors, and modularity. In addition, Li-ion is a mature battery technology making it reliable and low-cost. The continuously falling price of Li-ion batteries contributes to their growing use in energy storage systems. Using on or off-grid solar inverter systems together with battery storage offers many benefits for residential and commercial users, including:

- Pricing: storing energy reduces electricity costs when the price of electricity from utility providers is higher.
- Self-sufficiency: storing energy reduces (or eliminates) dependence on the grid.
- Backup power source: stored electricity offers an alternative in case of a mains power failure.

**BESS Main Building Blocks**

A BESS typically includes four main building blocks, including:

- **Rechargeable battery module**: This comprises rack-mounted battery cells with nominal voltage ranging from 50 V to over 1000 V.
- **Battery management system (BMS)**: The BMS protects and manages rechargeable batteries, ensuring they operate inside safe operating parameters.
- **Power conversion system (PCS)**: The PCS connects the battery pack to the grid and load and is a significant factor in a BESS's cost, size, and overall performance.
- **Energy management systems (EMS)**: This software monitors, controls and optimizes the generation or transmission system.

**Residential BESS**

Power conversion systems used with BESS are categorized by how they couple energy (AC or DC) and also by power level (residential or commercial). A DC-coupled system, or hybrid inverter, requires only one power conversion step. However, while AC-coupled energy storage is an easy upgrade for existing solar or wind generating systems, it requires an additional power conversion step to charge and discharge the battery and therefore, more power can potentially be lost. For example, a residential power conversion system can be added to an existing solar inverter system to allow generated energy to be used to charge a backup battery or power home appliances.

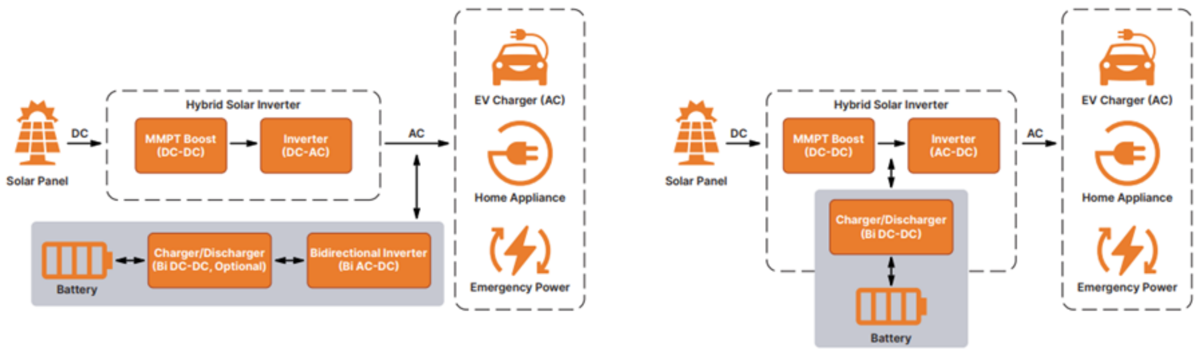


Figure 2: Residential AC-coupled (left) and DC-coupled (right) ESS

A bi-directional DC-DC converter connects a battery pack and the DC link. The bus voltage of a single-phase system is usually less than 600 V while charging and discharging power does not exceed 10 kW. Here, a buck-boost converter is the most common bi-directional DC-DC topology because it requires fewer components and is easy to control. Two 650 V IGBTs or MOSFETs with parallel diodes are adequate in a bi-directional system of this type. For example, onsemi's FGH4L75T65MQDC50 650 V FS4 IGBT with integrated SiC diode offers low conduction and switching losses in this application.

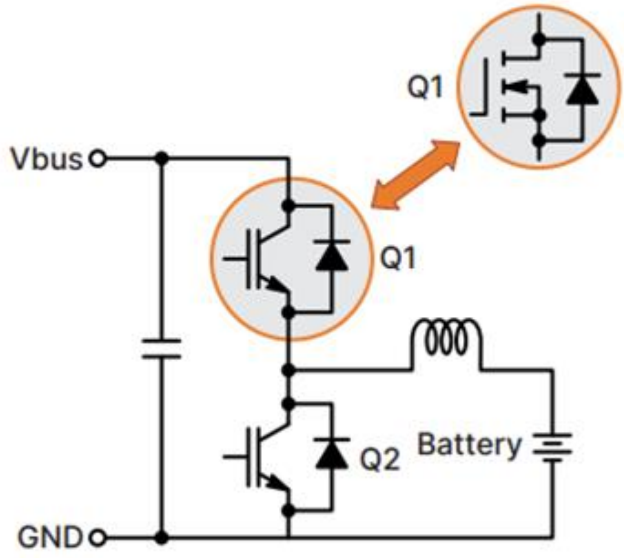


Figure 3: Buck-boost for bidirectional DC-DC

Isolation can ensure the safety of BESS users, and the dual active bridge converter (DAB) or CLLC topologies offer isolated bidirectional DC-DC converter solutions for BESS. A cascaded front-end buck-boost circuit can deliver a broader range of input and output voltages in the event of a significant variation in the battery voltage. This approach also lowers the amount of reactive power and increases the size of the soft-switching zone. The NTP5D0N15MC 150 V N-Channel Shield Gate PowerTrench MOSFET is ideal for these topologies.

Three-phase is the standard power supply in commercial and business premises and homes with higher power demands. Power switches in three-phase applications must withstand operating voltage and currents capable of delivering up to 15 kW and a higher DC-link voltage than residential installations (up to 1000 V). This can be implemented by replacing the 650 V switches considered previously with the 1200 V devices, potentially as part of a three-level symmetric buck-boost topology. This offers lower switching losses as only half of the output voltage appears at the switches and diodes. This also has the advantage of requiring smaller inductors and exhibits improved EMI performance. Unfortunately, this approach requires more components, increasing design complexity, control and system cost.

**Commercial BESS**

A commercial energy storage system's input and output power range is typically between 100 kW and 2 MW. These large installations may consist of several three-phase subsystems ranging from dozens of kilowatts to over 100 kW. Here, the maximum DC voltage, which depends on the bus voltage of the existing solar system or battery voltage, is a critical specification. The DC bus voltage of standard commercial solar inverters is typically 1100 V but can be up to 1500 V in a utility-scale system. For a given power level, increasing the DC-bus voltage reduces the current and therefore lowers the cost of the interconnection cable.

AC-coupled systems are more commonly used in commercial BESS because they can be easily added to an existing design. while DC-coupled systems have relatively high requirements on electrical retrofit especially for commercial cases because they have to be connected to DC bus, which is usually inside the original system and has high voltage and current. The three-level I-NPC is a topology commonly used with inverters in high-power industrial applications. This has four switches, four inverse diodes, and two clamping diodes with a breakdown voltage lower than the actual DC-link voltage meaning 650 V switches are sufficient in an 1100 V system.

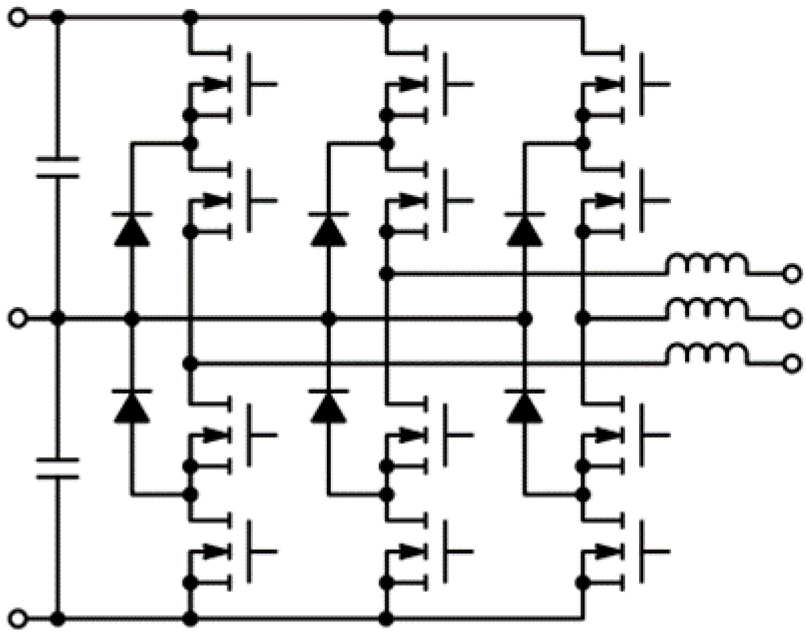

Figure 4: Three-phase I-NPC Topology

There are several advantages to using three-level topologies. Firstly, they have lower switching losses (proportional to the square of the voltage applied to switches and diodes). Secondly, they exhibit lower current ripple and, the peak-to-peak voltage is half the total output, making it easier to filter using a smaller, lower-cost inductor. Finally, conducted EMI, linked to the current ripple, is reduced, as are radiated emissions. Upgrading to an A-NPC topology offers even better performance because it replaces two clamping diodes with two lower-loss active switches. However, for this arrangement, driver pairing and delay matching are critical, which can be a disadvantage in some applications.

**SiC Solutions Improve BESS Performance**

SiC offers superior performance characteristics - like wider bandgap, higher breakdown field strength, and higher thermal conductivity - than silicon. These features enable SiC devices to operate at higher frequencies without the requirement to trade off output power against inductor size. Increased operating efficiency using SiC can also allow natural cooling instead of forced air in some situations. The 650 -V NTH4L015N065SC1 and NTBL045N065SC1 EliteSiC MOSFETs from onsemi are excellent choices for replacing silicon-based switches in energy storage system applications while using the 1200 —V NXH40B120MNQ0 dual boost and NXH010P120MNF1 2-Pack half-bridge, EliteSiC power integrated module can deliver even higher power density in utility-scale systems. onsemi also offers several other components, including gate drivers, current-sense amplifiers and MACPHY ethernet controllers, which can be used in BESS applications.

**ENDS**

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