INTL 015 Ultrahigh Efficiency Bidirectional DC-DC Converter for Energy Storage and Super Charger Applications

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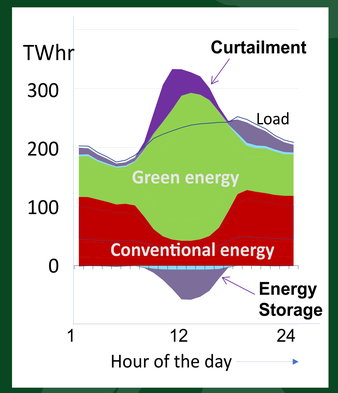
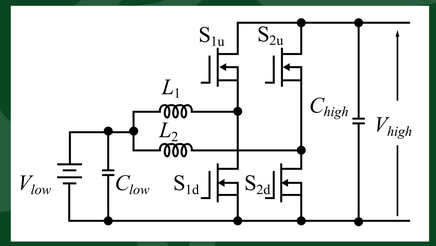
Creative motivation:

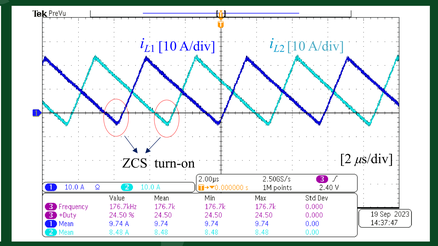
- In order to achieve the 2050 global NET-ZERO goal, the majority world energy must come from “Green Energy,” Due to unpredictable energy output and mismatch between renewable generation and load demand, the excess “Green Energy” needs to be stored for curtailment.
- Currently the battery charging/discharging round trip energy efficiency of commercial product is below 90%, which needs to be significantly improved to help expedite the CO2 reduction goal. Recently with wide bandgap semiconductor device available, and the battery voltage level moving up to 1 kV range, it is possible to design a battery charging system with round-trip efficiency higher than 99.5% range, or a significant 10% saving on battery charging/discharging for energy storage and EV supercharging systems.



Research process:

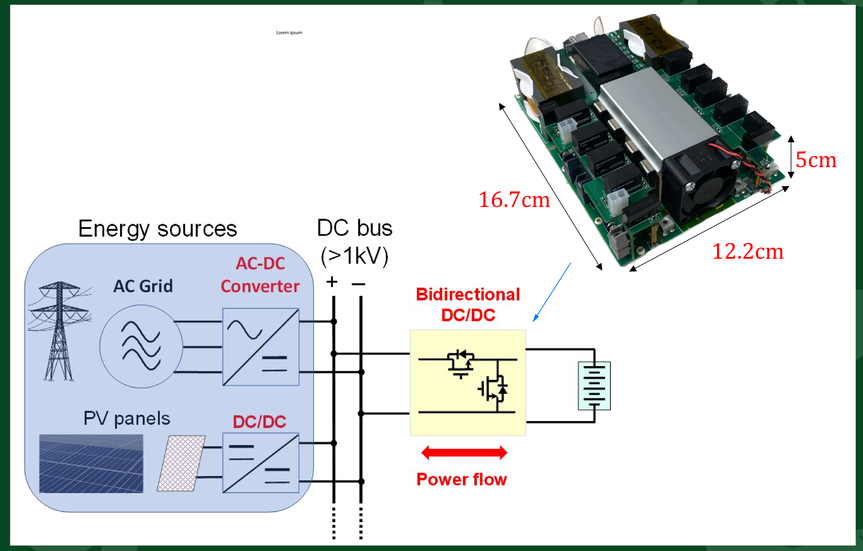
- There are two major loss components in a power conversion system. One is the switching device, and the other one is magnetic component. The switching device losses come from conduction voltage drop and switching losses. The voltage drop can be reduced by paralleling devices, but the switching loss reduction is nontrivial.
- Our approach is to eliminate the switching loss by a smart computation to eliminate the switching loss under multiple device or converter paralleled condition and to move up the switching frequency to reduce the magnetic component size and loss.
- The switching method is called “synchronous conduction mode” (SCM) or transition mode (TM), which produces a triangular current that contains a negative portion to produce sufficient energy to discharge the semiconductor junction capacitance during switching to eliminate the switching loss. As a result, we achieved 99.8% power conversion efficiency, while reducing the size and cost substantially.





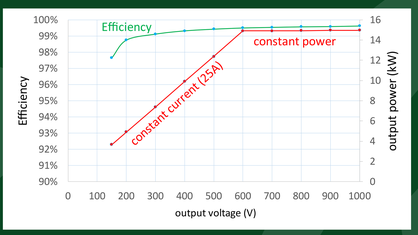
Project brief:

- The proposed system consists of (1) energy sources including renewable energy source, (2) a common DC bus with kilo-volt level, and (3) a bidirectional DC-DC converter.
- The key development here is the “ultrahigh efficiency” DC-DC converter, which is now widely used in energy storage and EV super chargers. The input is 1 kV, and the output is a battery with 800-V nominal. The project goal is to increase the efficiency while reducing the size and cost.



Efficiency:

- The peak full-load efficiency occurs under 1kV/15A condition. Its efficiency measurement is shown below. Meter reading P1 is the measured output power, P2 is input power, and the measured efficiency is 99.821%.
- The full-voltage and full-load efficiency under the entire charging range is illustrated as following. From 600V to 1kV, the converter runs in constant power mode with output of 15 kW. Below 600V, the converter runs in constant current mode with a current of 25A. from 250V to 1kV, the efficiency maintains 99% and higher.



Broad Impact:

- The first aspect of energy saving impact area is in energy storage applications. Using US Energy Information Agency (EIA) data, the annual green energy generation is 9000TWh in 2022. Assuming 10% of this energy needs to be stored, it will amount to 900 TWh. As an average, each 500-MW coal-fire power plant produces 3-TWh electricity per year, the use of our ultrahigh efficiency bidirectional DC-DC converter will help save at least 160 coal-fire plants.
- The second aspect of energy saving area is in EV super charging applications. According to International Energy Agency (IEA), the number of fast charger stations reached 2.7 million at the end of 2022 with 5% growth annually. Assume each charging station is rated 100 kW and operate 10 hours a day in average. The global energy usage will be 2.7 TWh per day, and the annual energy saving will be 49 TWh. With the use of our ultrahigh efficiency DC-DC converter, the amount of coal-fire power plant elimination will be 16.
- A total of 176 coal-fire plants will be eliminated with our 5% loss reduction.

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