Control of DC-DC Power Converters with Battery Cell Inputs and Series and Parallel Outputs

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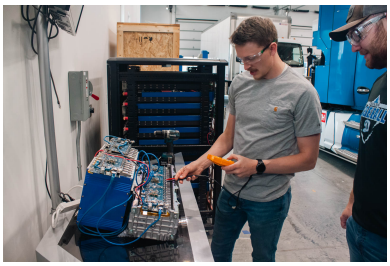

Control of DC-DC Power Converters with Battery Cell Inputs and Series and Parallel Outputs

Electrical & Computer Engineering

Abstract

USU researchers have developed a control scheme that eliminates the drawbacks of conventional control architectures in battery packs. One aspect of the invention permits stable operation of the battery pack in both charging and discharging conditions. Another aspect of the invention allows cell-level control to force the degradation of individual cells. This technology allows for hot swapping of battery cells to increase modularity and flexibility regardless of battery chemistry.

Problem

Lithium-ion batteries, common in grid applications, produce a relatively low voltage limited to parallel operation of battery packs or cells. A high voltage must come from a lithium-ion battery series, which can be difficult to regulate.

Solution

This technology regulates the input and output voltages to bring the same charge across each battery cell. This creates the necessary voltage for the batteries through what is called a variable droop.

Value Proposition

This invention permits stable operation of a battery pack in both charging and discharging conditions, provides modularity and scalability, and allows cell-level control of battery cells for life extension and balancing.

Benefit

USU researchers have developed a control scheme that eliminates the drawbacks of conventional control architectures in battery packs, specifically related to output voltage sharing among series-connected battery modules in a plug-and-play (PnP) DC microgrid. Traditional voltage regulation approaches are not suitable for PnP systems due to their variable output voltages. Instead, USU researchers provide a current regulation strategy that utilizes existing cell current sensors to improve modularity and eliminate the need for additional output current sensors. Research introduces an I-V droop control method to address asymmetries between charging and discharging modes, ensuring effective voltage sharing across modules. Experimental validation on a 1.5 kW system demonstrates successful voltage and power sharing, with minimal voltage differences among modules during operation. This invention aims to improve the modularity and scalability of battery systems by regulating input current rather than output voltage, while addressing stability concerns in series-connected converters.

This allows for improved performance in high-capacity applications while minimizing complexity and cost. Experimental results confirm its effectiveness in maintaining balanced charge levels across different battery configurations.

Market Application

Businesses that work with large scale battery management systems, switches for battery packs, and lithium battery manufacturing will benefit from functionalities offered by this technology.

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USU Reference No. C20022

Intellectual Property

U.S. Non-Provisional Patent No. 11,735,782, “Voltage Sharing of Series Connected Battery Modules in a Plug-and-Play DC Microgrid,” issued August 22, 2023

U.S. Continuation-in-Part Patent No. 12,230,982, “State-of-Charge Balancing with Parallel and Series Output Connected Battery Power Modules,” issued February 18, 2025

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