IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 5, Issue 1, May 2025

Impact Factor: 7.67

Design and Control of a Bidirectional DC–DC Converter for Electric Vehicle Battery Charging and Regenerative Braking Systems

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Abstract: *Electric vehicles (EVs) have gained substantial attention as a sustainable alternative to internal combustion engine-based transportation. One of the key technologies that enhances the efficiency of EVs is regenerative braking, which captures kinetic energy during deceleration and stores it back into the battery system. This paper presents the design, modeling, and control of a bidirectional DC–DC converter that supports two primary operations: forward power transfer during battery charging and reverse power flow during regenerative braking.*

The converter uses a buck–boost topology to handle wide voltage variations on both input and output sides, ensuring flexibility with different battery chemistries and motor controller demands. A microcontroller-based control strategy dynamically switches between buck and boost modes based on real-time current direction and system voltage levels. The proposed system includes a digital PID controller for current regulation and voltage stabilization, along with integrated protection mechanisms against overcurrent and voltage overshoots.

Extensive simulations were conducted using MATLAB/Simulink to evaluate converter behavior under different driving and braking scenarios. Results demonstrate improved energy recovery efficiency—exceeding 90% under optimal conditions—alongside stable and ripple-free charging characteristics. The converter also ensures smooth and automatic mode transitions, thereby improving system responsiveness and battery safety. The proposed converter architecture serves as a practical and efficient solution for next-generation EV platforms, offering both enhanced energy utilization and extended battery life..

Keywords: Electric vehicles