High-Bandwidth Control of Unfolding-based AC-DC Converters

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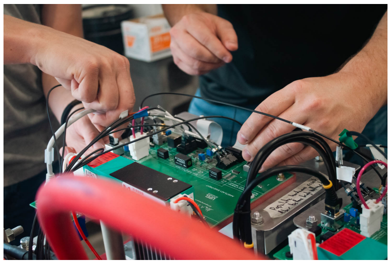

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Electrical and Computer Engineering

Abstract

This work presents a comprehensive examination of the challenges associated with achieving high-bandwidth control in T-type bridge-based dc-dc converters used in unfolding-based ac-dc systems. High-bandwidth control is essential for maintaining grid-side power factor correction and improving output power regulation, but can be challenging to implement without affecting the stability of the converter. This technology introduces a software-implementable control method that actively damps LC resonance and enables high-bandwidth control.

Problem

LC resonance limits high-bandwidth control for grid-side power-factor correction and output regulation by reducing phase margin and causing instability. Passive damping is used to fix this but adds cost, bulk, and reduces power density.

Solution

A software-implementable active-damping controller for T-type bridge dc–dc converters eliminate bulky passive damping networks, improve stability and dynamic performance in unfolding-based ac–dc systems, and boosts control bandwidth.

Value Proposition

Software-configurable active damping removes bulky passive damping networks in unfolding-based converters, boosting control bandwidth and allowing tailored LC resonance, yielding higher power density, lower cost, and improved performance.

Benefit

High-bandwidth control is vital for preserving grid-side power factor correction and enhancing output power regulation but achieving it can be challenging to implement without affecting the stability of the converter. LC resonance adversely affects closed-loop control, reducing the phase margin and rendering the closed-loop system unstable. Conventionally, large passive damping networks are employed to address this issue, but they substantially raise system cost and reduce power density — problems that worsen at higher power levels.

To eliminate reliance on bulky passive damping networks, this work introduces a software-implementable control method to actively damp LC resonance and enable high-bandwidth control. Simulation studies and hardware tests show that the proposed controller can increase achievable bandwidth by an order of magnitude compared to the undamped case. The approach is aimed at improving the stability and dynamic performance of T#type bridge dc–dc converters in unfolding-based ac–dc systems, particularly for power factor correction and output power regulation, while avoiding the size, cost, and power#density drawbacks of conventional physical damping networks.

This technology unlocks wider adoption of efficient unfolding-based converters by eliminating bulky passive damping networks, while simultaneously boosting control bandwidth. By enabling software-configurable active damping and allowing adaptation of permissible LC resonance for different applications, it delivers higher power density, lower system cost, and improved dynamic performance.

Market Application

This innovation targets the power conversion equipment market. As governments, businesses, and consumers accelerate adoption of electrification and green technologies, demand for uninterrupted power solutions is growing, increasing the need for advanced rectifiers and converter systems. By improving performance while reducing size and cost, this technology can help power-conversion manufacturers meet rising market demand and support broader electrification efforts.

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Publications

- A. Zade, S. Gurudiwan, D. Maksimovi# and R. Zane, "High-Bandwidth Control of a 20-kW Single-Stage Unfolding-Based AC–DC Converter Using the Extra Element Theorem and Current Emulation Technique, " in#IEEE Transactions on Power Electronics, vol. 39, no. 11, pp. 14411-14429, Nov. 2024, doi: 10.1109/TPEL.2024.3423705.
- A. Zade, C. R. Teeneti, S. Gurudiwan, S. Poddar, M. Mansour and R. Zane, "Analysis and Mitigation of Sector Transition Distortions for Unfolding-based Grid-tied AC-DC Converters," 2023 IEEE Applied Power Electronics Conference and Exposition (APEC), Orlando, FL, USA, 2023, pp. 1945-1952, doi: 10.1109/APEC43580.2023.10131393

Intellectual Property

Status: Granted

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