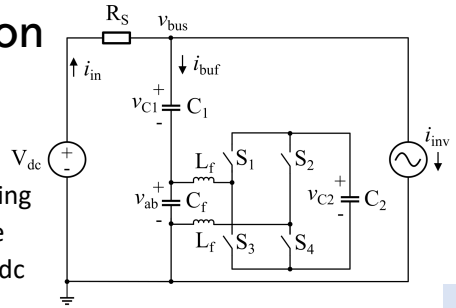
A Charge Injection Loss Compensation Method for a Series-Stacked Buffer to Reduce Current and Voltage Ripple in Single-Phase Systems

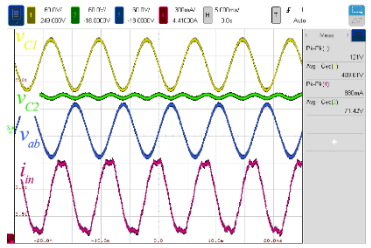
Berkeley Power and Energy Center

Motivation and Application

The Series-stacked buffer (SSB) is an active buffer topology that achieves high energy utilization and greatly decreases the power conversion system volume without comprising efficiency [2]. However, there can be a large amount of residual ac current ripple on the dc bus due to SSB's control methodology that injects real power through the reactive buffer branch. This control is required to charge the C_2 capacitor in the SSB that acts as a dc source for a full-bridge converter. Specifically, this ripple gets is worse in applications with low source impedance, such as battery systems.

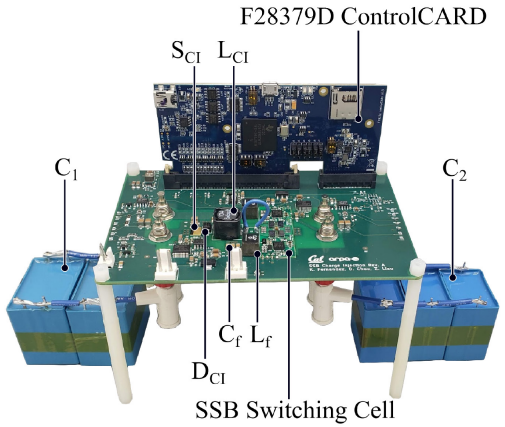


SSB circuit that handles reactive buffering. Real power is injected to charge C_2.



The real power injection causes large ac current ripple along the dc-link i_{in} (24% ac current ripple shown at 1.5 kW at 400 V_{dc}).

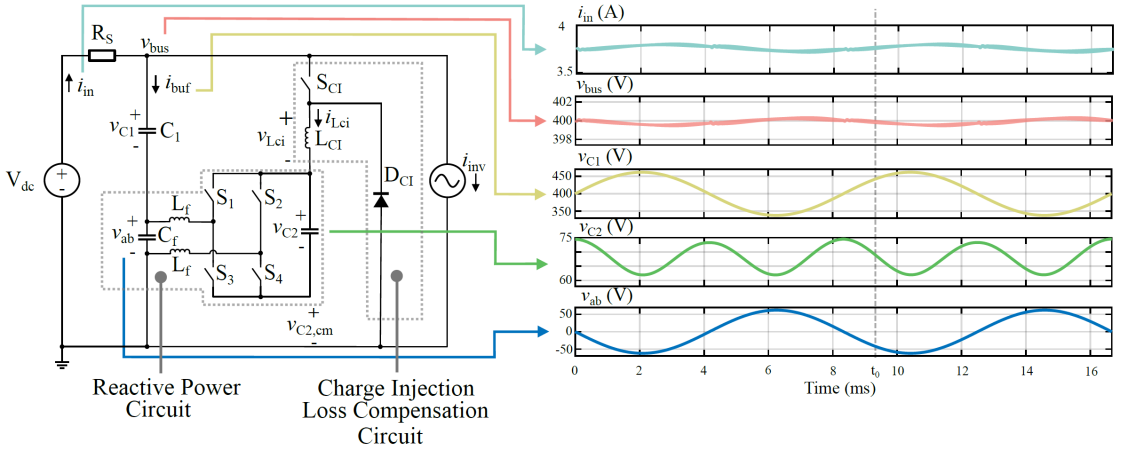
Hardware



Component	Part No.	Parameters
$S_1 - S_4$	EPC2033	150 V, 6 mΩ
S_{CI}	GaN Systems GS66506T	600 V, 2 A
D_{CI}	ON Semiconductor MURS160T3G	650 V, 67 mΩ
L_{CI}	Coilcraft MSS1210-104	100 µH
C_1	TDK B32524Q1686K000	100 V, 68 µF x 3
C_2	TDK B32776G4406K000	450 V, 40 µF x 2

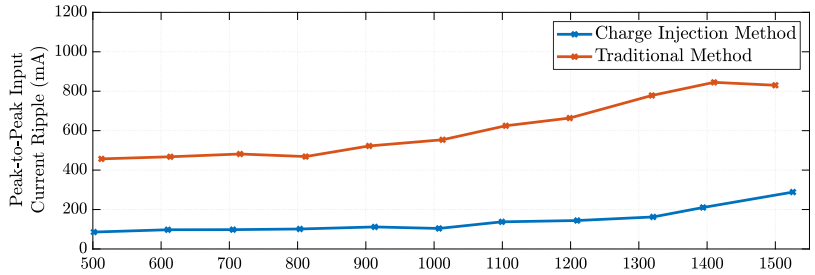
Proof of concept hardware. GaN devices are used for all switches. The volume of this design can be further reduced by using the optimization methodology shown in [3].

Proposed "Charge Injection" Method



The Charge Injection method has a separate branch that handles real power delivery while the rest of the SSB handles the reactive power buffering. As a result, the dc-link current ripple is greatly reduced.

Experimental Verification



The peak-to-peak ac current ripple is reduced:

- By maximum of **5.3x**
- And average of **4.3x**
- **3x** at peak load

Charge Injection method achieves an average **efficiency of 99.4%** across all loads.

References:
[1] K. Fernandez, N. Brooks, T. Ge, Z. Liao, R. C. N. Pilawa-Podgurski, "A Charge Injection Loss Compensation Method for a Series-Stacked Buffer to Reduce Current and Voltage Ripple in Single-Phase Systems" in 2022 Applied Power Electronics Conference (APEC), 2022.
[2] Z. Liao, et al. "A High Power Density Power Factor Correction Converter with a Multilevel Boost Front-End and a Series-Stacked Energy Decoupling Buffer," 2018 IEEE Energy Conversion Congress and Exposition (ECCE), 2018, pp. 7229-7235,
[3] Z. Liao, et al. "Multi-objective optimization of series-stacked energy decoupling buffers in single-phase converters," in 2018 IEEE19th Workshop on Control and Modeling for Power Electronics (COMPEL), July 2018, pp. 1–7.

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