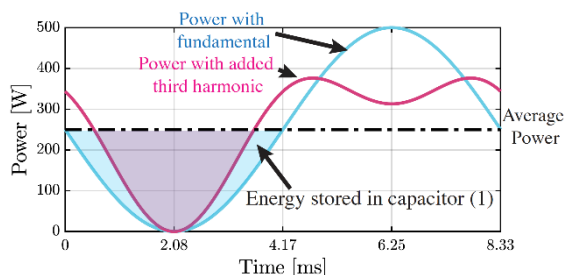


Utilizing Harmonic Injection to Reduce Energy Storage in a Single-Phase Active Energy Buffer



Motivation

- Single-phase power converters rated for high power applications require reactive buffering on the dc bus to maintain a constant and clean dc power input or output. Often this is a bulky electrolytic capacitor.
- [1] found that buffer storage requirements for a passive buffer could be reduced 56% for the addition of allowable 3rd and 5th harmonics
- We apply this harmonic injection method for energy storage reduction in the capacitors of the series-stacked buffer (SSB), which is a power-dense alternative to the conventional capacitor solution.

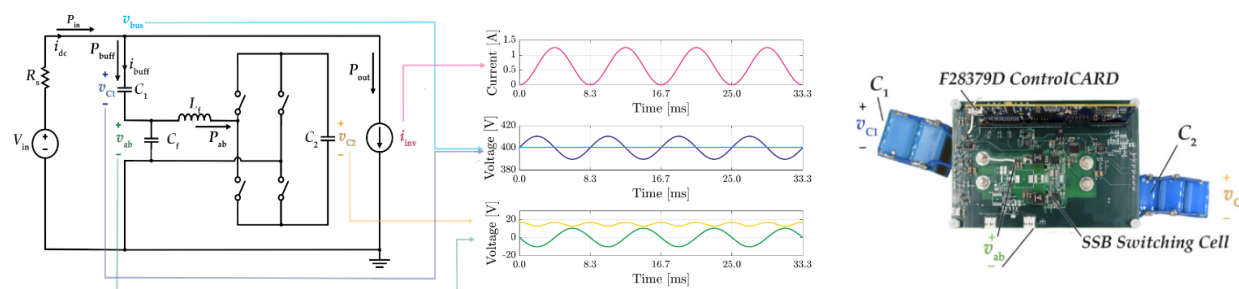


Energy storage in buffer during a twice-line frequency cycle.

$$W_{store} = \int_0^{T_{2l}} P_{buff}(t) dt$$

$$W_{store} = \frac{1}{2} C V_{max}^2 - \frac{1}{2} C V_{min}^2$$

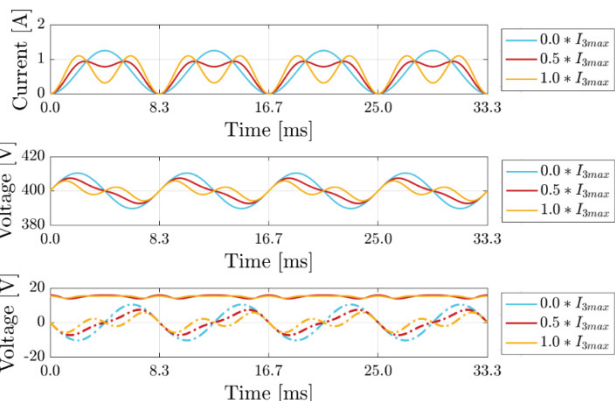
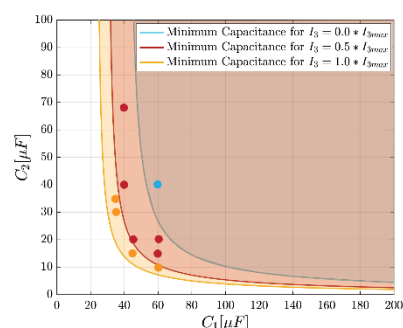
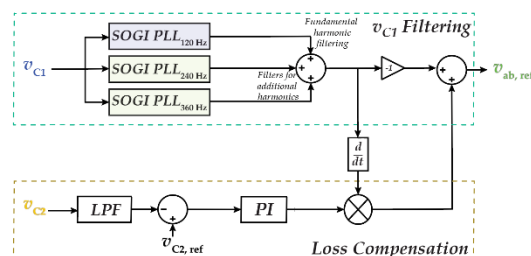
Circuit Topology and Hardware



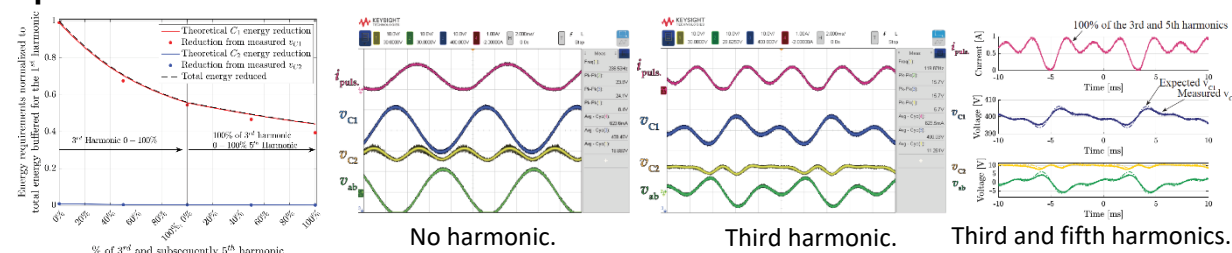
The SSB is an active buffer that combines a primary energy buffer capacitor with an H-bridge. This permits a larger voltage ripple across the main energy storage capacitor maximizing the amount of energy buffered, and subsequently the energy utilization ratio [2].

Challenges and Control

- Determining the expected voltage ripple on each of the capacitors is nontrivial.
- Figure out how to control an active buffer when additional harmonics are added to the system.



Experimental Verification



55% reduction in required energy storage split between two capacitors. In an example case, C_1 can be reduced from $60\mu F$ to $34\mu F$, and C_2 from $27\mu F$ to $20\mu F$ for same dc-bus voltage ripple [3].

References:
[1] A. J. Hanson, A. F. Martin, and D. J. Perreault, "Energy and Size Reduction of Grid-Interfaced Energy Buffers Through Line Waveform Control," *IEEE Transactions on Power Electronics*, Nov. 2019
[2] N. C. Brooks, S. Qin, and R. C. N. Pilawa-Podgurski, "Design of an active power pulsation buffer using an equivalent series-resonant impedance model," in *2017 IEEE 18th Workshop on Control and Modeling for Power Electronics*, Jul. 2017
[3] F. Giardine, N. C. Brooks, K. Fernandez and R. C. N. Pilawa-Podgurski, "Utilizing Harmonic Injection to Reduce Energy Storage and Required Capacitance in an Active Series-Stacked Energy Buffer for Single-Phase Systems," *2022 IEEE 23rd Workshop on Control and Modeling for Power Electronics*, 2022

