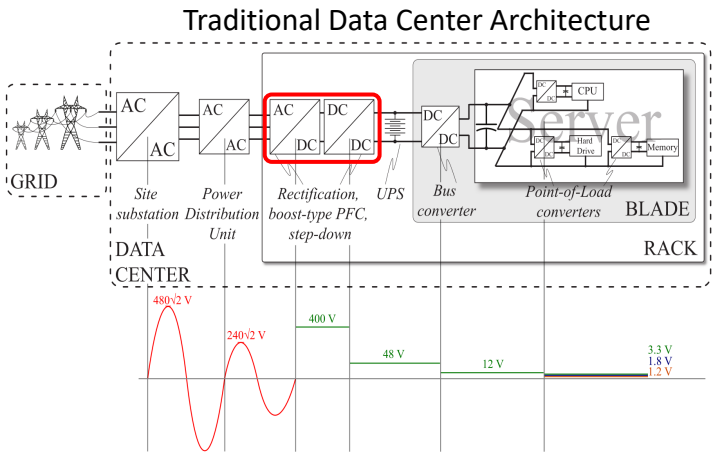
High Efficiency 240 Vac to Load Data Center Power Delivery Topologies and Control

Berkeley Power and Energy Center

Motivation and Application

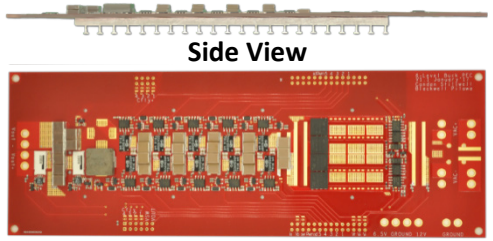


Traditional data center power factor correction (PFC) units boost voltage before rectification and step-down

Proposed: A one-stage single-phase ac-dc converter (240 Vac to 48 Vdc) with PFC

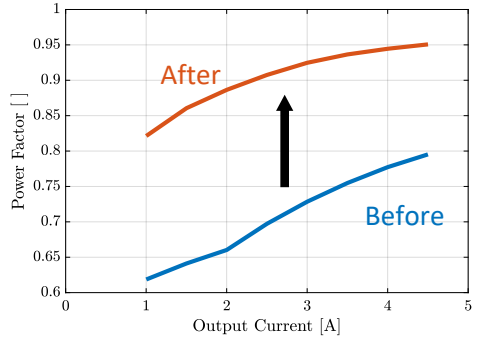
Metrics	Existing	Proposed
Peak Efficiency	94 %	97.8 %
Power Density	0.33 kW/L	7.5 kW/L

Hardware Prototype



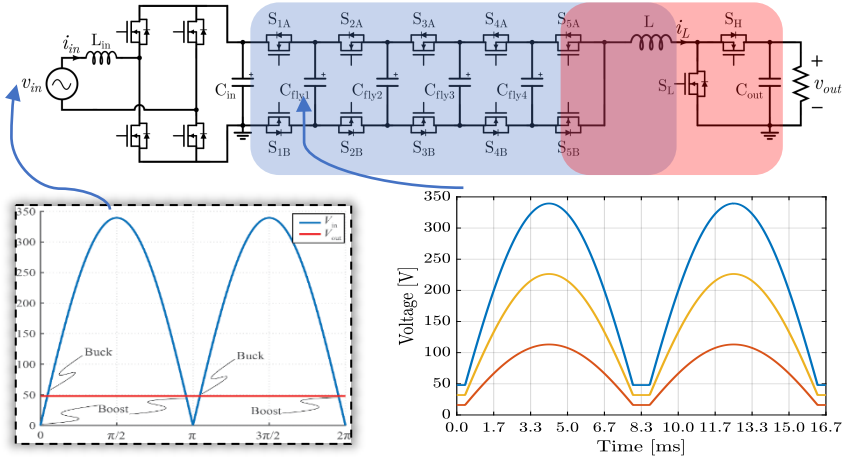
Operating Parameters	
Number of Levels	6
Switching Frequency	40 kHz
Output Current	4.5 A

Current Compensation to Improve Power Factor



Displacement current from C_{in} and C_{fly} leads to a phase shift in the input current, degrading the power factor. Our improved control algorithm compensates for this current to improve power factor [1].

Challenges and Solutions



Converter will buck or boost depending on point in AC input line cycle

Flying capacitor voltages vary with ac line cycle → unique challenges with capacitor balancing

Buck: S_H ON, S_L OFF; $S_{\{1,2,3,4,5\}A}$ and $S_{\{1,2,3,4,5\}B}$ modulate

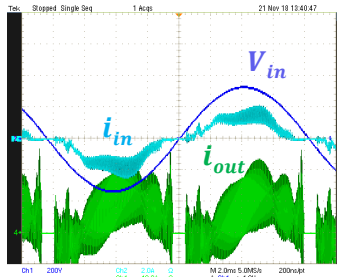
Boost: $S_{\{1,2,3,4,5\}A}$ ON, $S_{\{1,2,3,4,5\}B}$ OFF; S_L and S_H modulate

Preliminary prototype tests buck functionality, so that the converter is off when $|V_{in}| < V_{out}$.

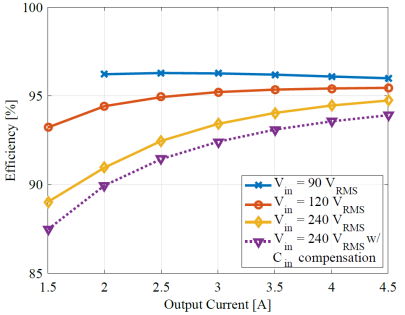
The converter relies on a stiff 48 V at the output (i.e. the UPS)

Experimental Verification

Operating Waveforms



Efficiency Curves



Performance Specifications	
Efficiency	94.8% at 240 Vac, 250 W
Volume (Box)	2.45 in³
Power Density	163 W/in³ (w/o heatsink) 79 W/in³ (w/ heatsink)

References:

[1] E. Candan, A. Stillwell, N. Brooks, R. Abramson, J. Strydom, R. C. N. Pilawa-Podgurski, "A 6-level Flying Capacitor Multi-level Converter for Single Phase Buck-type Power Factor Correction," in *Proceedings of 2019 IEEE Applied Power Electronics Conference and Exposition (APEC)*, March 2019.

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