Control of a Single-Stage Three-Phase Buck-Boost Power Factor Correction Rectifier

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Background

- Novel control strategy proposed for *More Electric Aircraft*
  - Three-phase Buck-Boost Rectifier
  - Capable of tight and fast regulation of output voltage
  - Achieves unity input power factor
  - One Proportional-Integral (PI) Controller
- Existing control strategies must implement PI compensators in both voltage and current loops
  - Greater complexity
  - Less Reliable
  - Slower

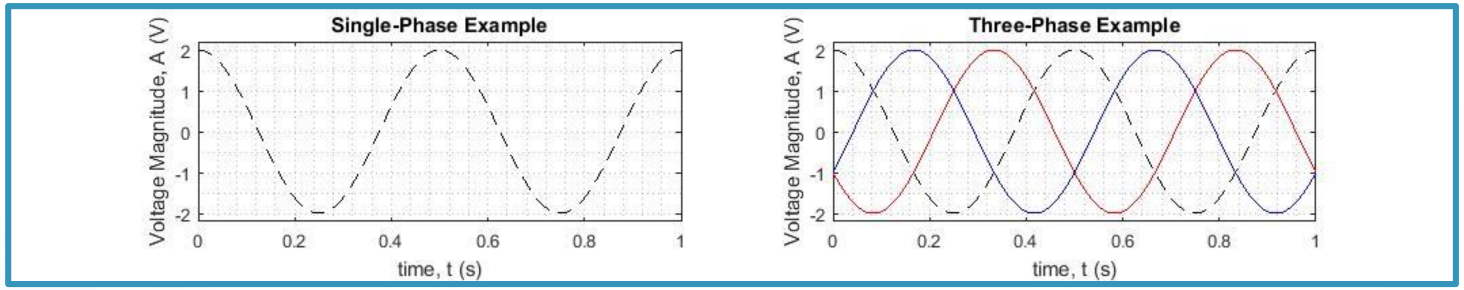
More Electric Aircraft (MEA)

- The Boeing 777 and 787 electric power generation and distribution systems were reviewed and analyzed
- *No-Bleed Architecture* on the 787 is capable of generating twice as much electricity as previous Boeing airplane models
  - Achieves fuel savings of about 3%[1]
  - Extracts as much as 35% less power from the aircraft's engines[1]

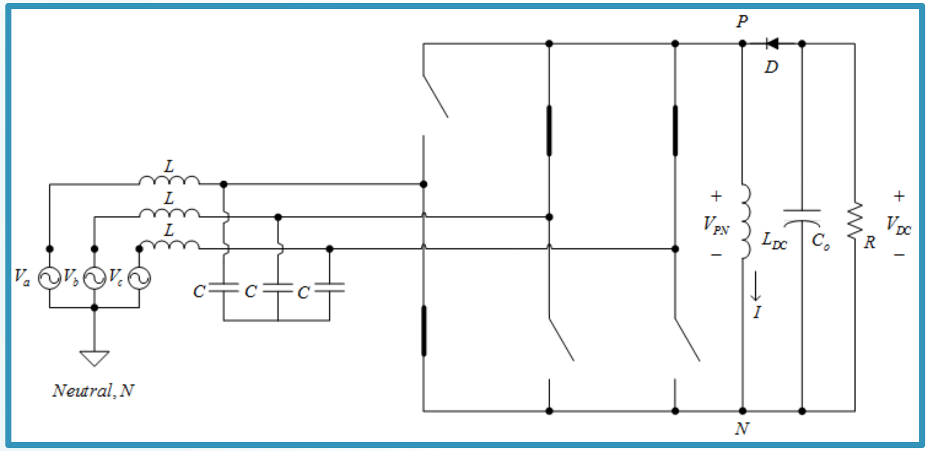
1 M. Sinnett, 'AERO - 787 No-Bleed Systems', *Boeing.com*, 2007. [Online]. Available: http://www.boeing.com/commercial/aeromagazine/articles/qtr_4_07/article_02_1.html. [Accessed: 03- Jun- 2015]

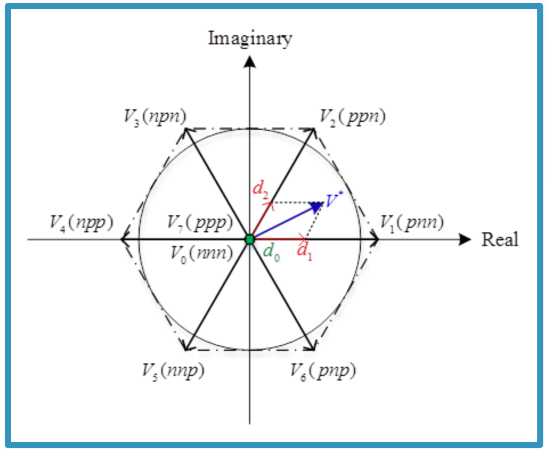
Literature Review

- Comparison of Single-Phase vs Three-Phase Waveforms



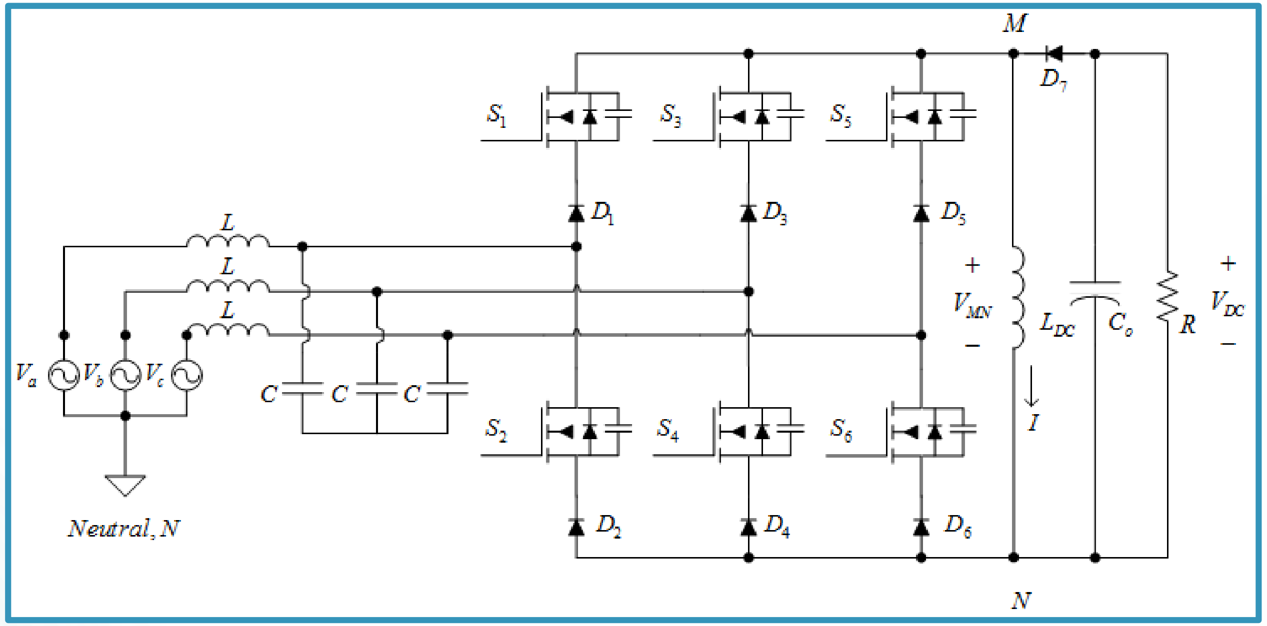
- Principles of Space Vector Pulse-Width Modulation(SVPWM)





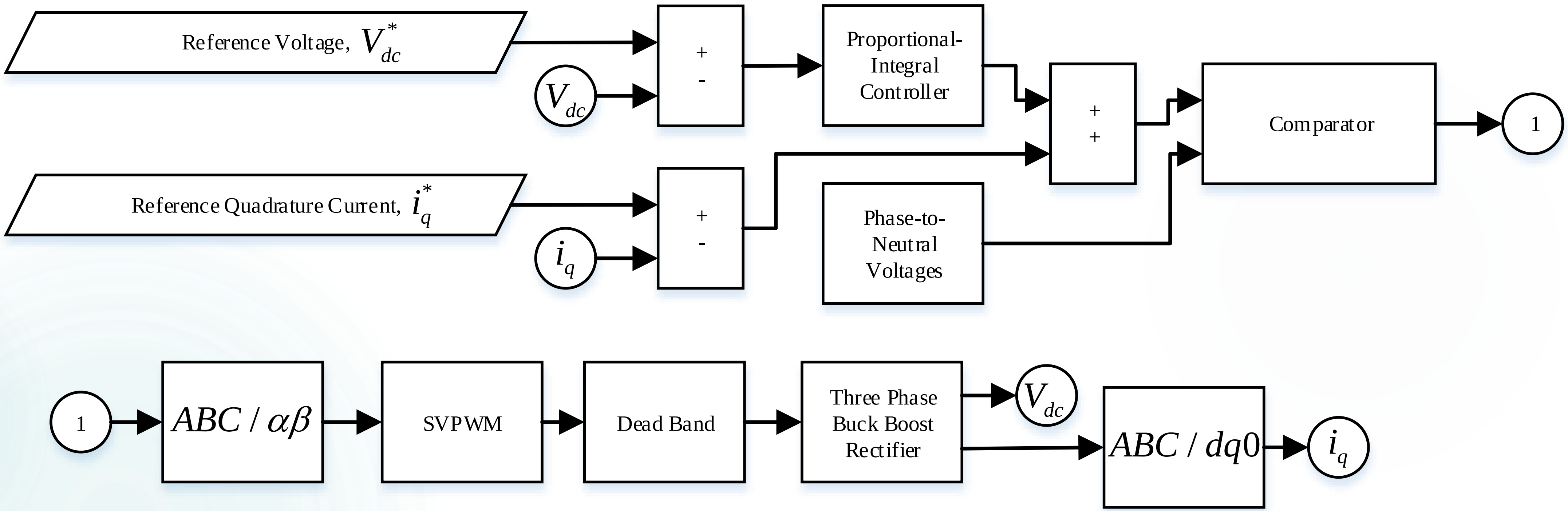
- SVPWM techniques approximate the reference voltage vector (V^*)
  - Combine switching states: $d_0 + d_1 + d_2 = 1 \quad d_1 \cdot V_1 + d_2 \cdot V_2 = V^*$

Buck-Boost AC/DC Rectifier



- Resembles a Buck-Type Rectifier at the input voltage
- Similar to a DC/DC Buck-Boost converter towards output
- Basic DC/DC converter relationship
  - Implies perfect PFC: $$i_{1,avg}(t) = \frac{D^2 T_s}{2L} \cdot v_1(t)$$
- Zero of the system: $$s = \frac{V_{DC}(1-D) + V_{MN}(D-1)}{I \cdot L_{DC}}$$

Control Strategy



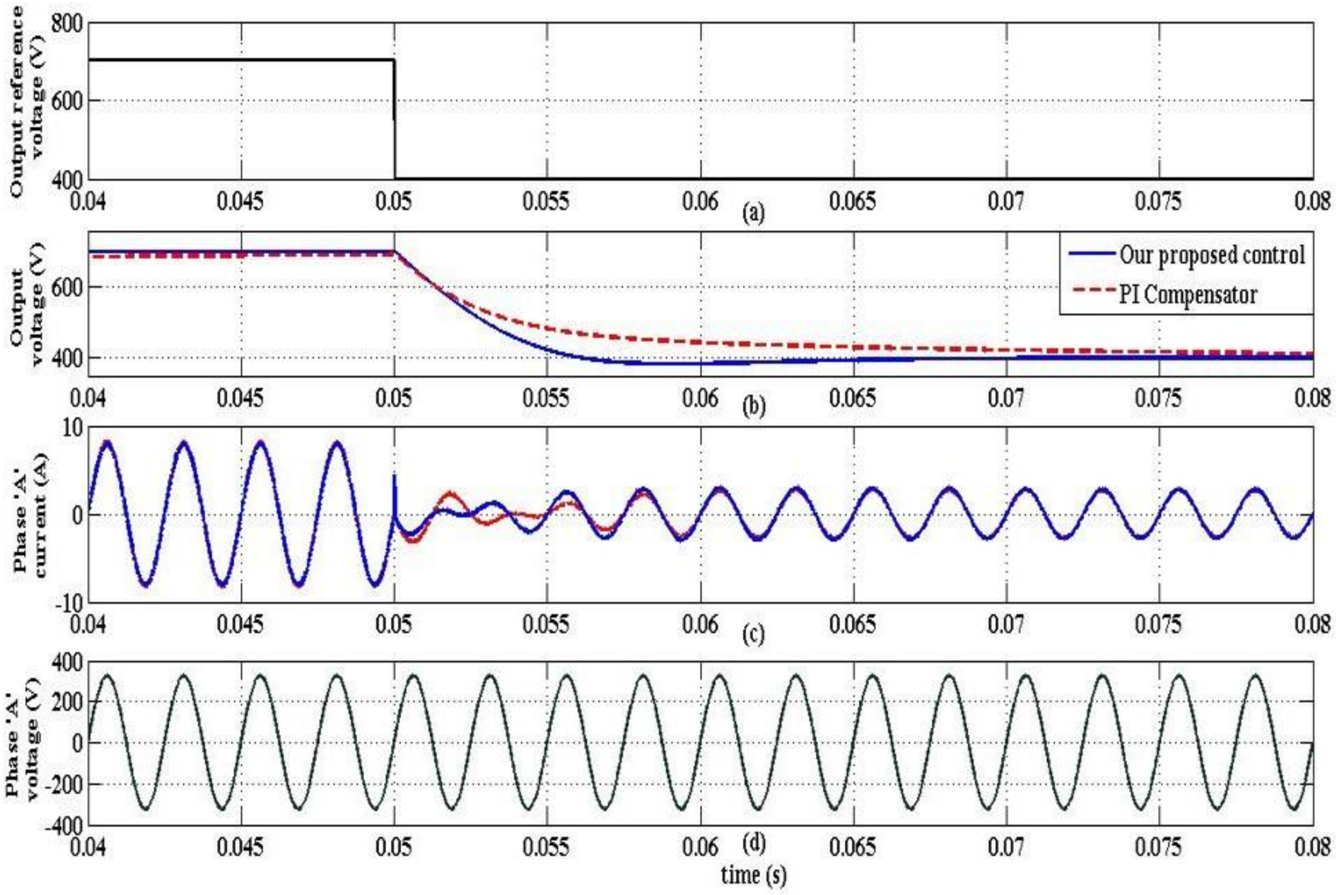
- Control strategy successfully implemented
  - One PI-controller
- State-space averaging methods control rectification process
- SVPWM implemented to generate switching pulses

Simulation Results

- 700V (boost-mode)
- 400V (buck-mode)
- Total Harmonic Distortion (THD) of 2.3%
- Unity Power Factor Achieved

$$THD = \sqrt{\sum_{h=2}^{h=h_{\max}} \left(\frac{I_h}{I_1}\right)^2} \cdot 100\%$$

$$\lambda = \frac{P}{S} = \frac{I_1 \cos(\varphi)}{I_{rms}} = \frac{\cos(\varphi)}{\sqrt{1+THD^2}}$$



(a) DC output reference voltage; **(b)** DC link voltage (V) with our proposed control and PI compensator; **(c)** Phase ‘A’ current (A) with our proposed control and PI compensator **(d)** Phase ‘A’ input voltage.

Future Work & Acknowledgements

Future Work:

- Expand upon modeling and simulation efforts to successfully implement the Buck-Boost control strategy in physical hardware
- Improve upon the dynamic response of the closed loop system by implementing a non-linear control method

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