Storage Integrated AC-AC Converters

Jonathan W. Kimball
Department of Electrical and Computer Engineering
Missouri University of Science and Technology

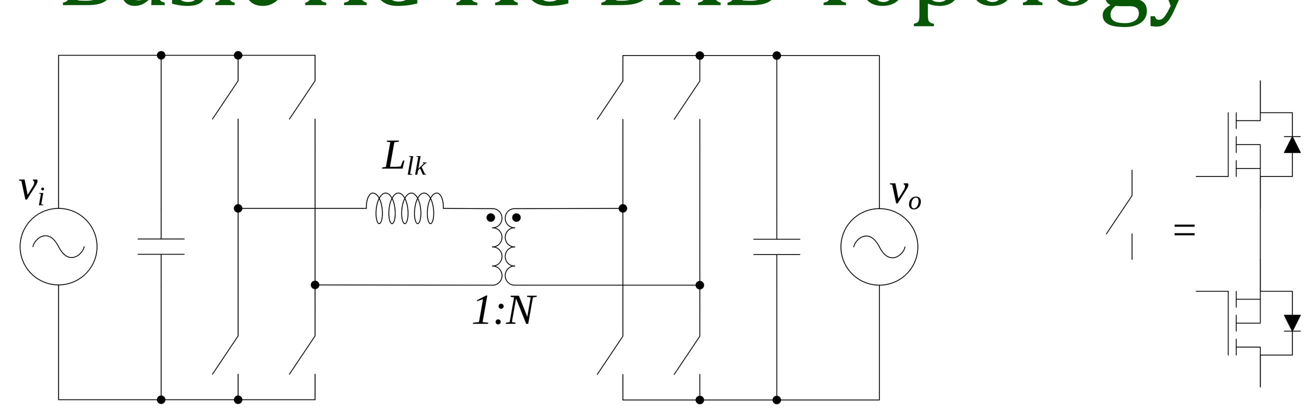
Abstract

This project explores an innovative power converter that enables integration of energy storage with two single-phase ac grids *without* the need for a dc link. Conventional approaches require converting each ac port first into a dc level, which requires large capacitors to buffer the double-frequency power fluctuation. In this converter, the ac port is directly interfaced with a high-frequency transformer.

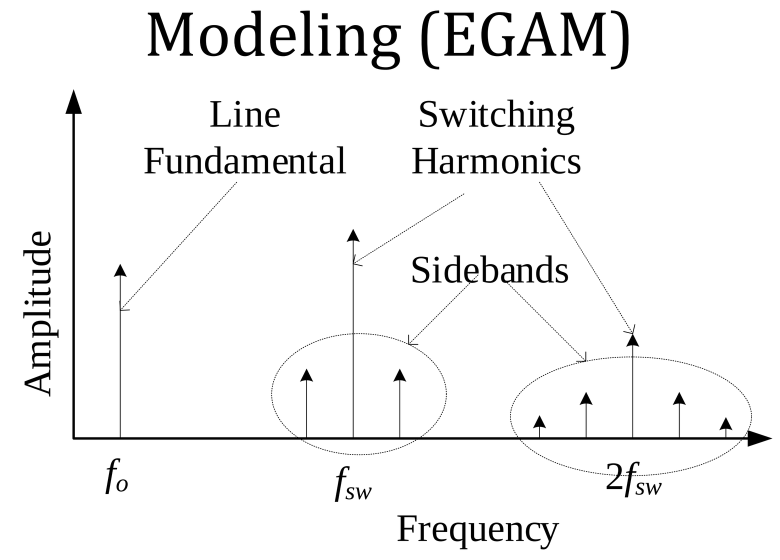
The basic building block of the converter is an active bridge, that is, an H-bridge of transistors, that connects to one winding of a high-frequency transformer. The input terminals of the bridge may connect to a dc port, as is typical and as is needed for the energy storage port, or to an ac port, with bidirectional power flow on every port. The topology is a "one-stop shop" to interface with any combination of ac and dc power systems.

The primary focus of the present work is a triple active bridge (TAB) in which energy storage is connected to the first port to support the power needs of the other two ports, which are connected to ac grids. Some work continues on control of an ac-ac dual active bridge (DAB) as a building block for control of a TAB.

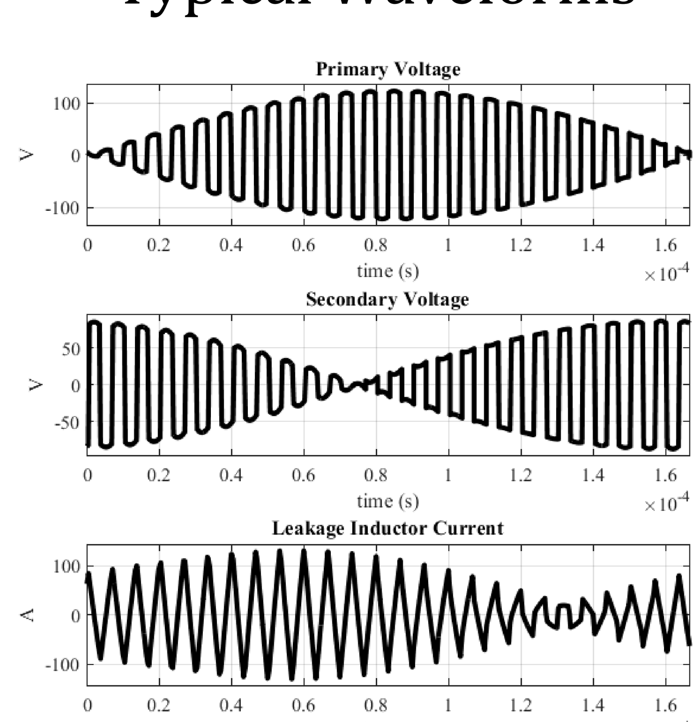
Basic AC-AC DAB Topology



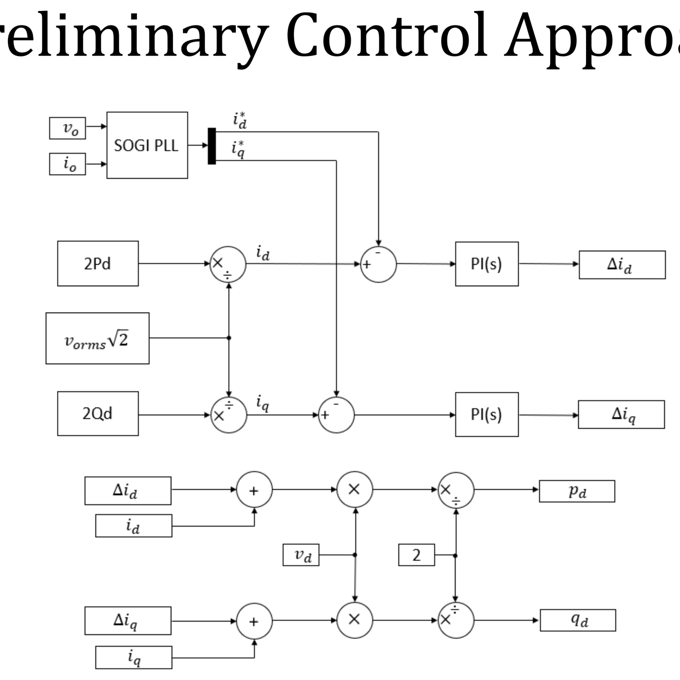
Extended Generalized Average Modeling (EGAM)



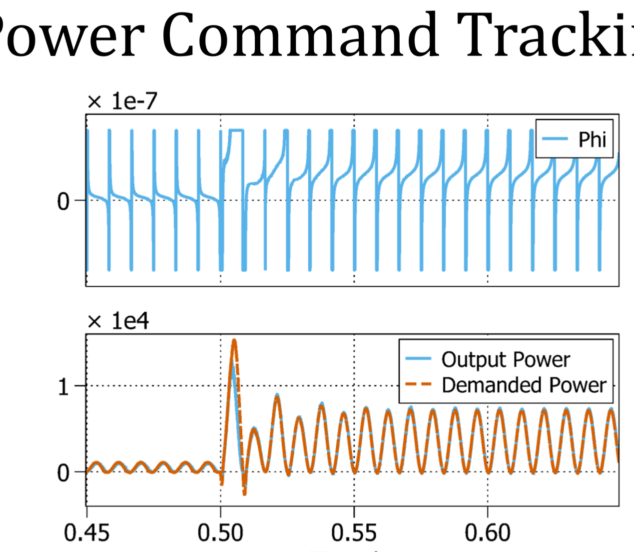
Typical Waveforms



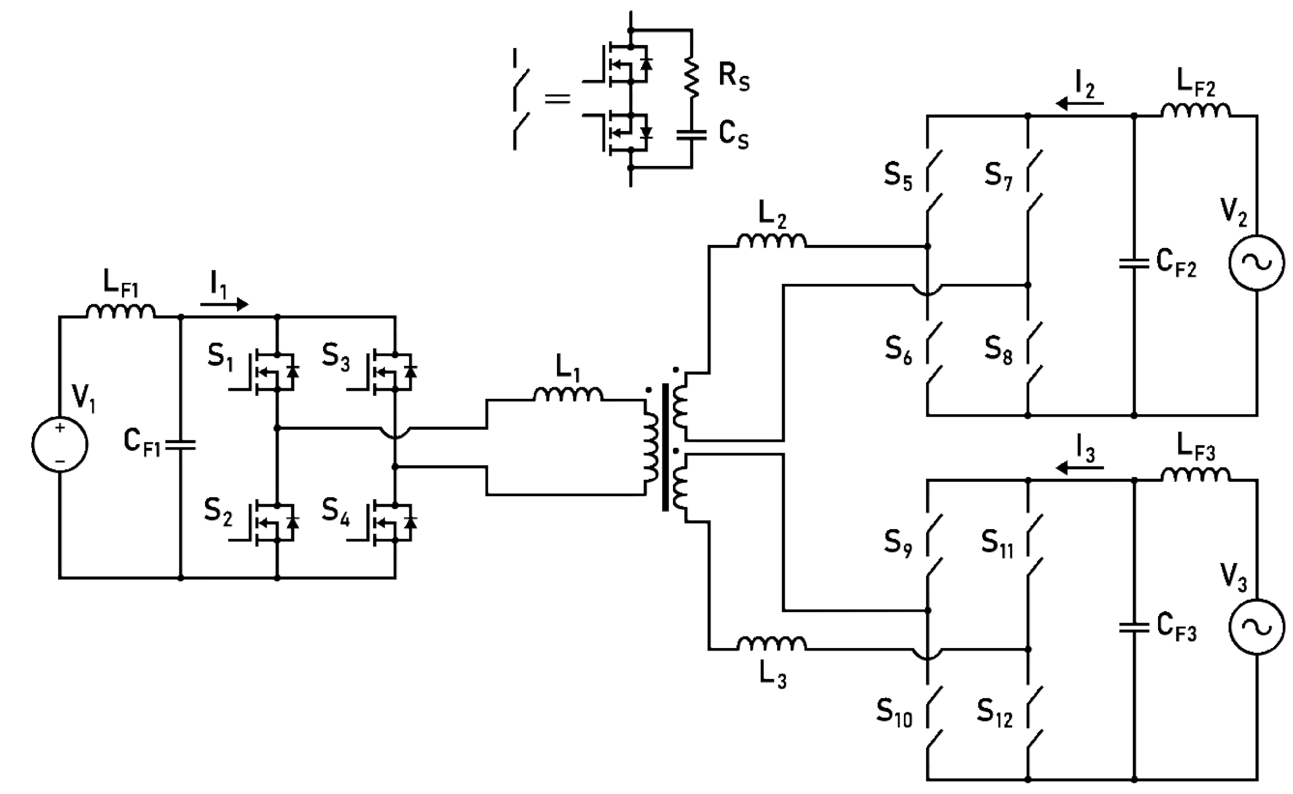
Preliminary Control Approach



Power Command Tracking



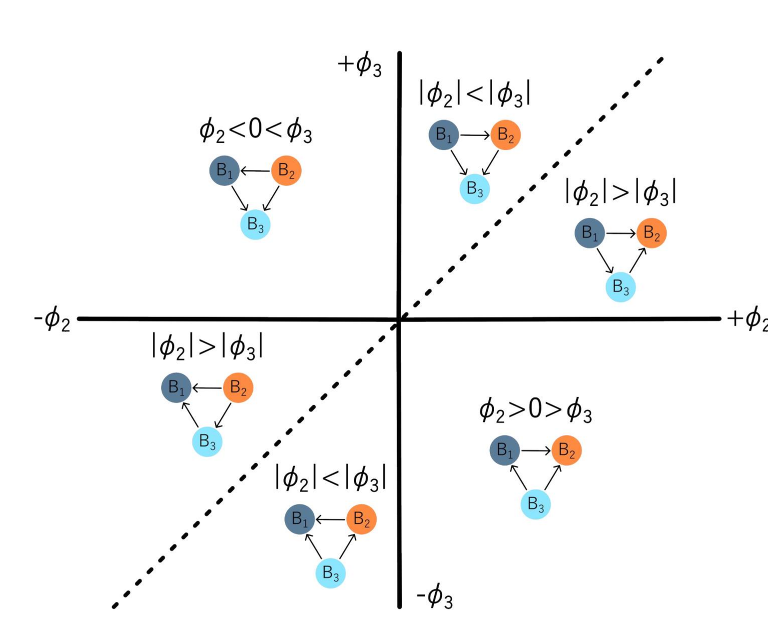
DC-AC-AC TAB Topology for Energy Storage Integration



Advantages of DC-AC-AC TAB Over Conventional Solutions

- Direct ac-ac conversion of main power flow – **higher efficiency**
- No dc link capacitors – **higher reliability**
- High-frequency transformer – **high power density**
- **Integration of energy storage – can be used to support either ac port**
- Particularly useful on power distribution networks to provide voltage regulation, active & reactive power support, low voltage ride-through, and fault isolation

Challenges
- Transformer design for controlled leakage inductance – achieved with newly derived method
- Power flow control – extra flexibility results in extra control complexity
- Modeling – requires EGAM to accurately capture dynamic interactions

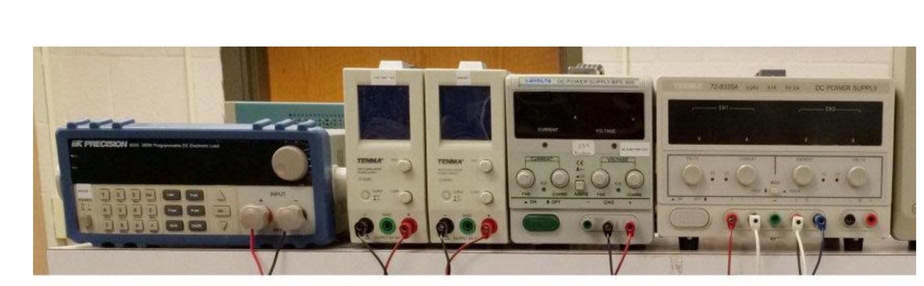


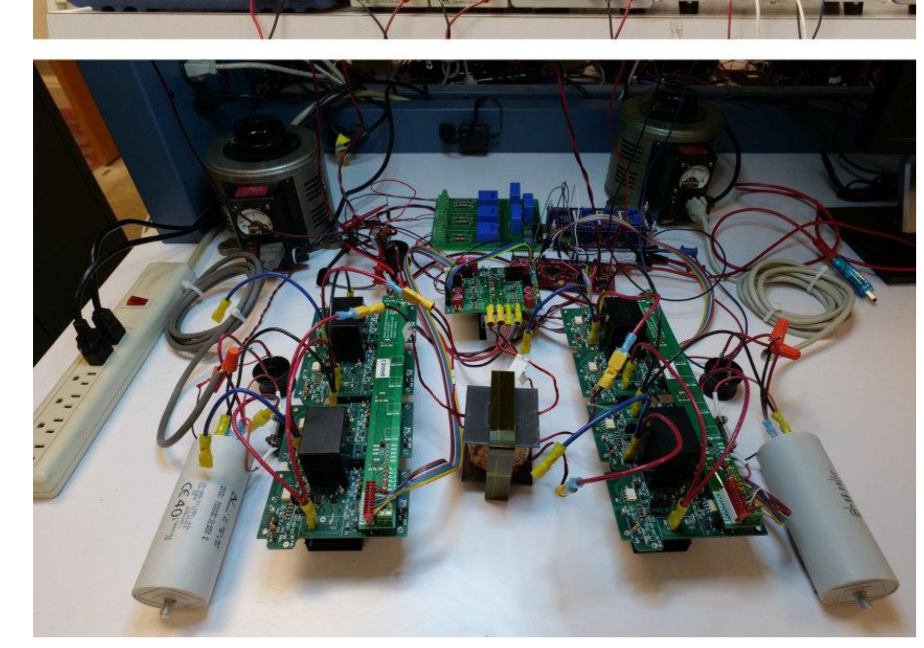
Power Flow Control

Taking the dc port square wave as reference, there are six combinations of relative phase shifts on the other two ports. The controller can choose the two phase shifts to achieve a desired instantaneous power flow dispatch. The nonlinear relationships are easily solved with a Newton-Raphson algorithm.

Hardware Prototype

To develop the switching algorithm, feedforward control, and feedback control, a low-voltage low-power prototype was constructed. The dc port uses SiC MOSFETs and the ac ports use Si MOSFETs paired with SiC Schottky diodes.





We gratefully acknowledge the DOE OE Energy Storage Program and Dr. Imre Gyuk for generous financial support of this project.

Contact: kimballjw@mst.edu.

MISSOURI S&T