Isolated Bridgeless Power Factor Correction Converter using SiC/GaN Devices

School of Engineering + Technology

Original Objectives

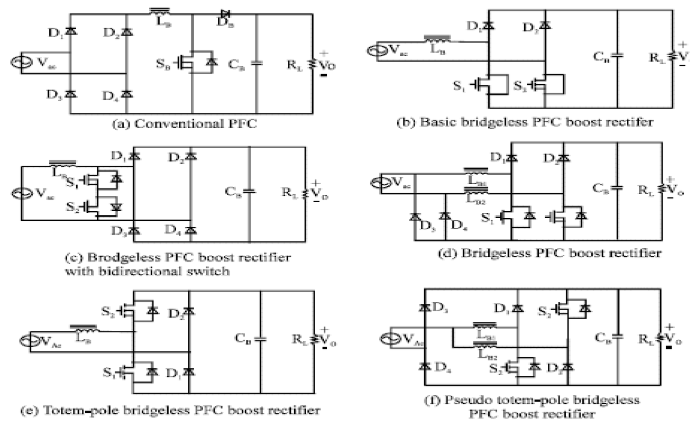
- Select, design, and implement an Isolated Bridgeless Power Factor Correction circuit
- Research the performance and properties of Gallium Nitride components
- Test the developed circuit in accordance with its designed parameters

Requirements

- 60Hz-400Hz Operation
- 1000W Output Power
- 85 to 260VAC Input Voltage
- 320VDC Output Voltage
- Up to 98% Efficiency at 100% Load
- Power Factor Correction > 0.99 at 100% Load
- Total Harmonic Distortion (THD) < 3%
- As Compact as Possible (2”x3”x1/2” goal)

Concepts

- Initial considered topologies were rejected due to their nonisolation, a requirement that had gone overlooked.
- Silicon Carbide transistors were also briefly considered, but Gallium Nitride was unanimously deemed a more nascent technology.

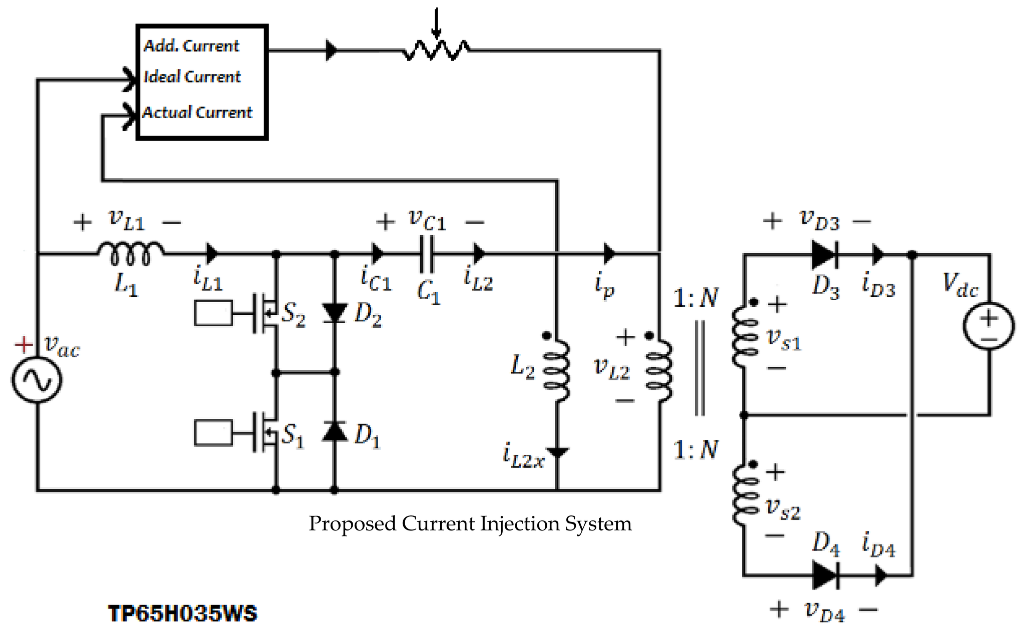


Problem Statement

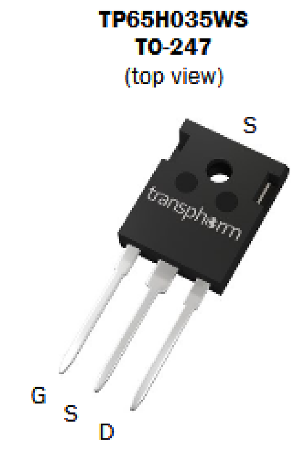
Wide bandgap (SiC & GaN) transistors and diodes have the potential to significantly reduce losses in power converters and therefore increase efficiency. In this project, the capstone team will design and prototype an isolated bridgeless PFC converter from the ground up (topology, device types, etc.) with the specific goal of achieving high efficiency using wide bandgap power devices.The PFC will consist of components necessary to rectify and boost AC voltages from 85VAC-265VAC with up to 98% efficiency. The PFC should have a power factor correction (PFC) capability of at least 0.99, and total harmonic distortion (THD) of less than 3%.

Final Design/Results *

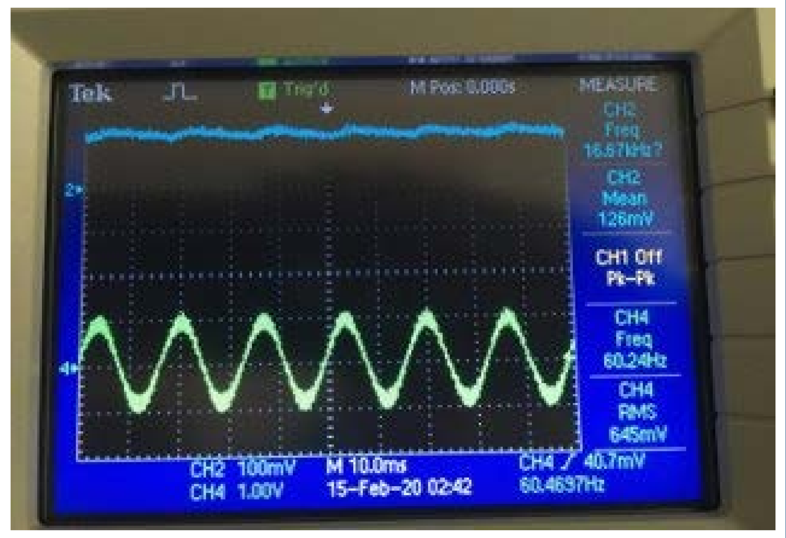
The proposed rectifier design uses a single-ended primary-inductor converter (SEPIC) topology PFC utilizing series transistors and a three-winding transformer for galvanic isolation. This is a common topology with a significant amount of research, but not for GaNFETs. The advantages of the SEPIC converter are reduced conduction losses, low electromagnetic interference, and fewer components than other topologies. Disadvantages include efficiency losses on output diodes and the requirement of two transistors.



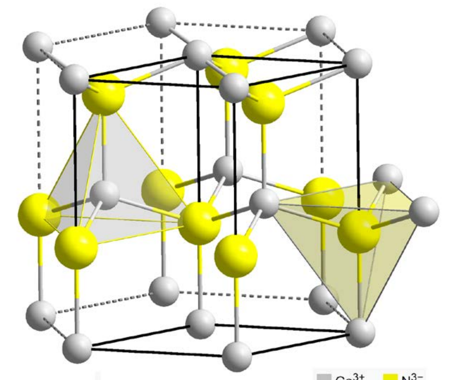
Proposed Current Injection System



Gallium Nitride Transistor


Input & Output Waveforms.

This prototype circuit was initially implemented in the electrical power lab on the campus of Western Carolina University. It was connected to a waveform generator to supply a square wave input to drive the transistors, an oscilloscope to monitor the voltages across the circuit, and another waveform generator to supply an AC voltage input. The group was limiting the input voltage due to the inherent safety requirements of working on labs on campus. All components used in the prototype circuit with the exception of the specialized Gallium Nitride transistors were supplied by way of materials readily available on the university campus.


Gallium Nitride

* On March 16, 2020 classes and labs were closed to students due to the COVID-19 Pandemic. Without access to fabrication and testing equipment, Objectives and Deliverables were modified accordingly.

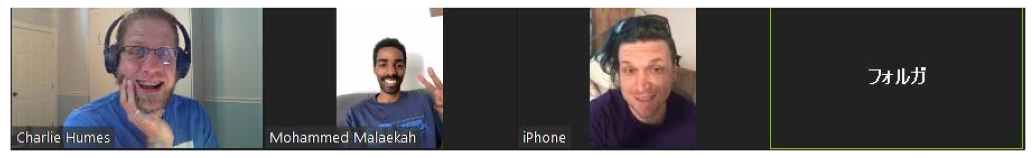
Modified Objectives*

- Printed board assembly was no longer feasible in a remote participation context
- Physical system testing was no longer feasible.
- The team coped as well as one might have hoped, pivoting to a research and simulation focus.

Summary

- Gallium Nitride transistors perform as advertised, practically lossless compared to standard Silicon-based transistor technology. While their always-on behavior was initially a concern, at least one manufacturer has produced a transistor that follows traditional behavior. The Capstone Team was able to confirm this through research and experimentation.

Team & Acknowledgements



Brandon Gibby Clifford Forga


Dr. Peter Tay, Ph. D

- Charles Humes, BSEP
- Mohammed Malaekh, BSEE
- Brandon Gibby, BSEE
- Clifford Forga, BSEE
- Dr. Peter Tay (Mentor)
- Matt Vansteen (Sponsor Contact) BSEET
- Mark Mason (Sponsor)

[1]. *Sliding mode control of the isolated bridgeless SEPIC high power factor rectifier interfacing an AC source with a LVDC distribution bus*, Oswaldo Lopez-Santos et al, MDPI Energies 2019, 12, 3463; doi:10.3390/en12183463 (Primary Reference)