Power Electronics, Microgrids & Subsea Electrical Systems Center (PEMSEC)

Power **E**lectronics, **M**icrogrids, and **S**ubsea **E**lectrical **S**ystems Center (PEMSEC) at the University of Houston, Texas research and educational efforts are focused on electric power & energy systems, including advanced power electronics, electric drive systems, subsea electrical systems, transportation electrification, and microgrid energy management technologies.

Selected Present Research Projects

Sensorless Control of Permanent Magnet Motor with Long Cable for Subsea Applications

A typical subsea motor drive includes a sinewave filter, transformer, and long cable. The motors are located far from the Variable Speed Drive (VSD) unit and are connected through a long cable. Permanent Magnet (PM) motors are becoming increasingly popular in subsea applications for natural gas and oil extraction. Sensor-based position measurement is not practical as the motors are located several kilometers away from the VSD unit. Hence, the subsea industrial practice is to use V/Hz or I-f control to start the motor, then switch to the sensorless vector control. Accurate estimation of the system parameters and rotor position is necessary to achieve a stable and efficient performance. The current research is focused on achieving high-performance sensorless control of the PM motor across its full-speed range.

GaN FETs – Based High-Density DC-DC Power Conversion and Machine Learning-Based Prediction of System-Level Remaining Useful Life

This project aims to develop compact and robust power electronics systems for limited-space military installations like ships and aircraft. The U.S. Department of Defense is funding the project with a $2.5 million grant for three years starting in April 2020. The project has two parts. The first involves developing power converters using Gallium Nitride (GaN) devices to operate radar systems. The second part uses machine learning to predict the lifespan of GaN devices and circuits, designing a health monitoring system to predict individual component lifetimes. Tagore Technology, an Illinois-based semiconductor company in the USA, supports the project.

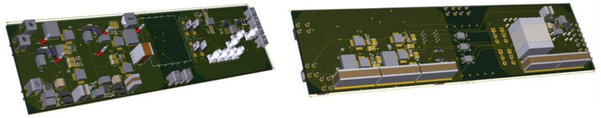
(i) High power density isolated DC-DC converter for pulsed load applications
(ii) Characterization of GaN HEMTs at different load profiles
(iii) Characterization of electrolytic dc-link capacitors

Modeling and Stability Analysis of Grid Following and Grid Forming Converters:

Ensuring system stability and accurate reactive power sharing in the presence of feeder impedance mismatch has become a critical concern with the expanding use of power electronic converters in modern power systems. At PEMSEC, we use impedance-based models to investigate overall system stability from the DC side, and develop mathematical models based on Eigen-value analysis to assess AC microgrid stability. Additionally, we propose control strategies to ensure accurate sharing of active and reactive power in AC microgrids, which we verify using controller hardware in the loop.

Gallium Nitride-Based Miniaturized Pulsed Power System Architecture for Mission-Critical Applications (ARPA-E)

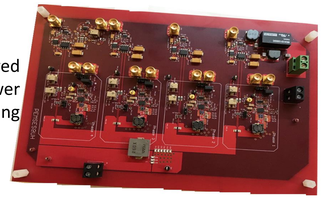
This project aims to enhance the power density, efficiency, and operational life of converter systems in pulsed power applications like healthcare tech and water purification. Miniaturization will reduce the cost of downhole well logging tools in fossil and geothermal energy production. A $1 million grant from the U.S. Department of Energy's Advanced Research Projects Agency will fund the project for three years from April 2022. The project has two main components: designing a high-temperature DC-DC converter capable of producing a few kilowatts for sub-surface characterization and developing power converters for miniaturized MRI applications.



3-D plot of 24 sq. in GaN-Based high power high-temperature PCB design

GaN-based Power Supply Design for 4G/5G Envelope Tracking

This project focuses on developing a power supply that utilizes envelope tracking (E.T.) technique for a 4G/5G power amplifier-based wireless communication system. Traditional RF power amplifiers (RFPAs) use fixed-voltage D.C. power supplies, leading to inefficiency and excess heat generation, resulting in bulky communication base station systems. E.T. power supplies extract the transmitted signal waveform's envelope and modulate the output voltage to track the envelope of the communication signal, leading to increased efficiency and smaller system size. However, for 4G/5G signals, E.T. power supplies must switch at several tens of MHz to avoid signal distortion.



High-frequency four-phase interleaved Buck converter GaN based Power supply for 4G/5G envelope tracking applications

Fault-tolerant architectures for distributed Electric/Hybrid Aircraft Propulsion systems

This research proposes fault-tolerant power distribution architectures to address issues with current electric propulsion systems. In the event of a fault in the main bus or generator failure, all propulsion motors in that channel shut down, placing a greater burden on the remaining motors. As a result, motors have to be oversized, which requires the DC-AC converters, cables, and circuit breakers to be oversized, increasing the aircraft's overall mass. The proposed architectures protect the system from busbar faults without disconnecting all propulsion motors, enhancing aircraft safety, and reducing overall system mass. This decrease in mass has the potential to reduce emissions.

Hydrogen and Battery–Based Energy Storage System (ESS) for Future DC Microgrids

This research proposes a hydrogen-based energy storage system (ESS) for DC microgrids, which can complement battery ESS for future grids with high renewable energy penetration. The system uses an isolated DC-DC converter to activate clean hydrogen production via an electrolyzer and store the hydrogen in a tank. The hydrogen is then converted to electricity by a fuel cell and transferred to the grid using a DC-DC boost converter. A Simulink model is used to simulate the power conversion, electrolyzer, storage tank, and fuel cell aspects of the proposed system. The primary challenge is to seamlessly integrate power electronics with fuel cell technology, with the polymer electrolyte membrane (PEM) being the preferred technology due to its economic feasibility

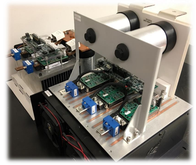
Computer Vision-based Framework for Power Converter Identification and Analysis

Focuses on identifying the individual components in a hand-drawn schematic diagram and performing a simulative analysis of a power converter. YOLOR (You Only Learn One Representation) to detect electronic components like resistors and capacitors in hand-drawn circuit diagrams. A Hough transform algorithm traces the wire connections while KMeans clustering identifies circuit nodes. The circuit information generates a netlist for use in any spice-based simulator (PySpice is used). Future goal is to automate the PCB design of the detected hand-drawn circuit diagram.

Facilities

SiC Converters

Manufacturer: Agile Switch
Three H-bridge configuration
Power rating - 50 kW
voltage rating – 1200 V
current rating – 300 A



Temperature/Humidity Chamber

Temperature range -70°C and 190°C
Wide range of relative humidity operation

Grid Simulator

The Gird simulator emulates the real grid and it is used for testing the 4 quadrant operation of a converter at a variable frequency. The capabilities of the grid simulator at the PEMSES center are:
Power – 30KVA, 0-300V, DC and AC
Frequency range – 30-100Hz
Operation – 4-quadrant | Interface - GPIB, USB, RS232, & Ethernet protocol

B1506A Power Device Analyzer / Curve Tracer

Manufacturer: Keysight
It evaluates FET device parameters under a wide range of operating conditions, including IV parameters and on-resistance, as well as three terminal FET capacitances, gate charge, and power loss.

Typhoon HIL microgrid setup

The Microgrid Testbed includes HIL devices with protection relays and controllers that can be configured independently for each building block. Each HIL604 can simulate either the highly dynamic or less dynamic parts of the circuit with 1µs or 10µs resolution, respectively.

AC Machine Drive

The system features dual opposing 7.5 kW AccuDyne four-quadrant AC motoring dynamometers, variable frequency drives, and a variety of subsystems configured for testing electrical machines.

Microwave & RF Signal Generators

Signal generation for all major digital communications standards incl. 5G NR, LTE, and WLAN

Typhoon HIL 604/602+/402

Typhoon HIL is useful for real-time Hardware-In-Loop testing. The operation of a controller for a converter can be tested in real-time simulation using Typhoon HIL unit before deploying it for an actual converter. The Typhoon HIL unit present in our lab has the following capabilities:

EDUCATION

Master's program with a specialization in Power & Energy

- **ECE 6305 -** Power Electronics Converters and Control
- **ECE 6317 -** Adjustable speed Motor Drive systems
- **ECE 6318 -** Advanced Power Converters and Applications
- **ECE 6319 -** Dynamics of Electric Machines
- **ECE 6343 -** Renewable Energy and Distributed Power Generation
- **ECE 6327 -** Smart Grid Systems
- **ECE 6329 -** Protection and Monitoring of Power System Infrastructure
- **ECE 6377 -** Power System Analysis
- **ECE 6379 -** Power System Operations and Modeling

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