CUSP Labs

Through our previous and current Office of Naval Research (ONR) grants, we have developed the following five hardware labs and one software lab for undergraduate and graduate level courses:

1. Electric Drives (Basic + Advanced) Lab
2. GaN-based Power Electronics Lab
3. Climate Crisis Implementing Solutions Lab
4. Sustainable Electricity Supply Lab
5. Advanced Power Electronics Lab
6. Power Systems Lab using PSSE

All hardware labs operate at a safe voltage of 42V, are extremely compact, and use the in-house developed, freely available, simulation and real-time control software - Workbench.

These labs can be operated remotely as well, so that practicing engineers as well as students taking courses online/off-campus can perform these labs online and obtain results from a physical laboratory setup running remotely in a campus laboratory. In such a case, only one setup is required for a lab consisting of thirty students.

ELECTRIC DRIVES LAB (Available)

Understanding of electric machines/drives is even more crucial than ever given the rapid developments in the transportation sector to reduce its carbon footprint that now exceeds that of the electric power sector. Recently, General Motors announced that starting in 2035, their cars will be electrically driven. This translates to extra generation of electricity from renewables such as wind where electric drives are used. In addition, a rapid pace of automation is needed for industrial competitiveness.

The basic drives lab (senior undergraduate level) and the advanced drives lab (graduate level) enable students to understand the workings of commonly used DC and AC motors and a provides a hands-on experience in designing control systems for these motors. The cost of using this newly developed lab is a factor of five cheaper than that previously developed by UMN and acquired by 109 U.S. universities.

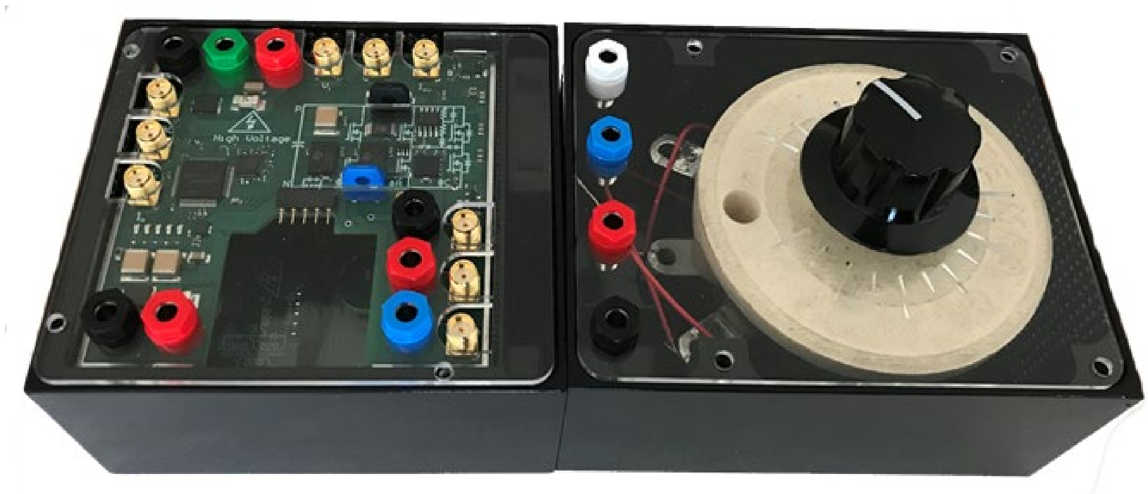
The list of experiments that can be performed using this kit is listed below:

List of Experiments:

Basic Drives Lab (Undergraduate level)	Advanced Drives Lab (Graduate level)
1. Switched-mode DC-DC converter	1. Characterization of Induction motor
2. Characterization of DC motor	2. Induction motor V/f control
3. DC motor closed-loop speed control	3. Vector control of induction motor
4. Four-quadrant operation of DC motor	4. Encoder-less vector control of induction motor
5. Torque-load angle characteristics and speed control of PMAC motor	5. Direct torque control of induction motor
6. Determination of Induction motor parameters	6. Space vector Pulse width modulation of two level three-phase inverter
7. Torque-speed characteristics and speed control of Induction motor	7. Vector control of surface PMAC motor

POWER ELECTRONICS LAB (Available August 2023)

With a constant drive toward electronics miniaturization and improving power conversion efficiency, a better understanding of power electronics has become critical. This newly revised lab demonstrates the operation of commonly used DC-DC converters (buck, boost, buck-boost, flyback, forward, push-pull) and their digital control (voltage and peak-current mode), as well as, DC-AC inverters. The lab demonstrates the operation of each of these converters using both GaN as well as Si-based devices.



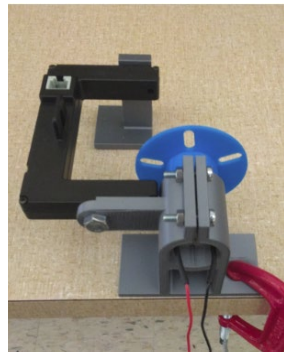
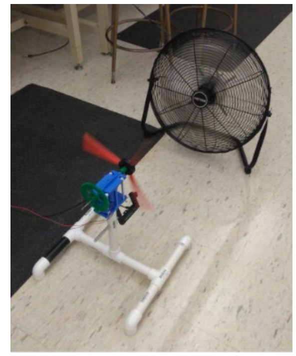
This lab is targeted toward undergraduate students. The list of experiments that can be performed using this kit is listed below:

<u>List of Experiments:</u>

1. Si and GaN power-device characteristics
2. Buck converter
3. Boost converter
4. Buck-boost converter
5. Digital voltage mode control
6. Digital current mode control
7. Flyback converter
8. Forward converter
9. Full-bridge converter
10. Single-phase DC-AC inverter
11. Three-phase DC-AC inverter

<u>CLIMATE CRISIS IMPLEMENTING SOLUTIONS LAB (Available January 2024)</u>

This is an introductory course providing an overview of electrical generation, storage, distribution, and applications. The accompanying lab provides hands-on experience with the fundamentals of DC electricity, exploring solar and wind generation, battery storage, and applications of electrical energy through LEDs and motors.

List of Experiments:

1. Indoor Hydroponic Farming (with LEDs)
2. Greenhouse Effect due to CO2
3. Simulating Electrical Fundamentals
4. Internal Resistance of a Battery
5. Photovoltaic Cells: iV Curve and MPP
6. Photovoltaic Panels in Series and Parallel
7. Economics of Rooftop Solar
8. Economics of Community Solar Gardens
9. Resistive and Electronic Dimming
10. DC Motors
11. Wind Turbines: iV Curve and MPP

SUSTAINABLE ELECTRICITY SUPPLY: RENEWABLES AND CONSERVATION LAB (Available 2024)

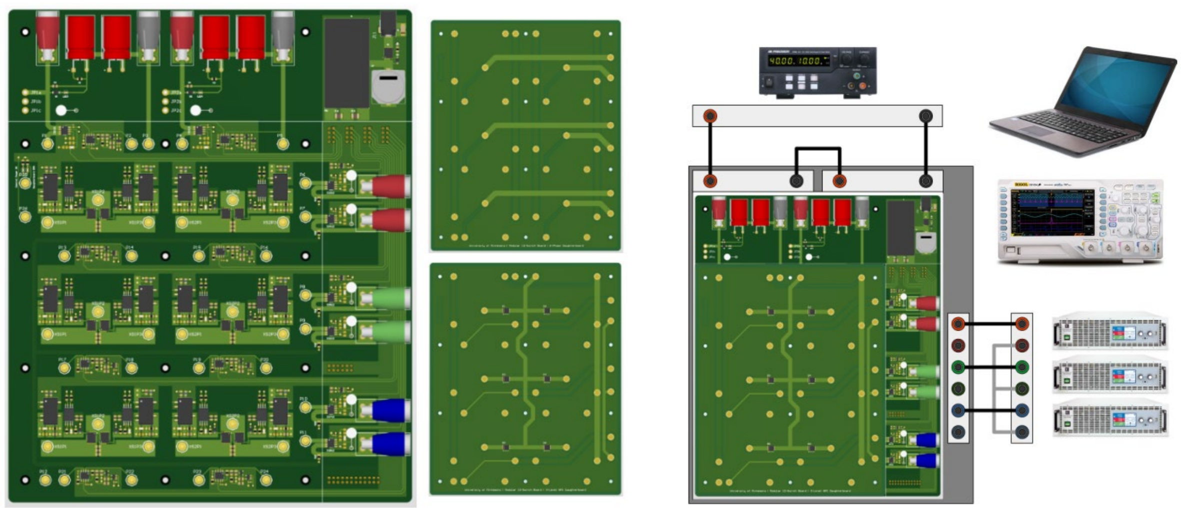
This is an introductory course providing an overview of electrical generation, storage, distribution, and applications. The accompanying lab provides hands-on experience with the fundamentals of AC electricity, exploring impedance, transformers, rectifiers, inverters, and AC motors and generators.

List of Experiments:

1. Introduction to AC Electricity
2. Impedance of a Capacitor
3. Impedance of an Inductor
4. Resonant Circuits
5. Transformers
6. 3-Phase Circuits
7. Diode Rectifiers
8. Mosfet Switches
9. Half-Bridge Inverter
10. AC Motors and Generators
11. Power Flow on the Grid
12. Generation and Grid Energy Storage

ADVANCED POWER ELECTRONICS LAB (Available March 2024)

This is a graduate-level lab course presently under development. It centers around a modular power electronics breadboard that can be used to implement a range of multi-phase and multi-level converter topologies.



List of Experiments:

1. Half-Bridge Inverter
2. H-Bridge Inverter
3. 3-Phase Inverter
4. Active Rectifier
5. Phase-Shifted Full-Bridge
6. Resonant Converter
7. Dual Active Bridge Converter
8. Cascaded H-Bridge Inverter
9. Neutral-Point-Clamped Inverter
10. Flying Capacitor Inverter
11. Multilevel Modular Converter (MMC)

ELECTRIC POWER SYSTEMS LAB USING PSSE (Expected January 2024)

We are developing an exciting lab course for undergraduate and graduate students. Through the accompanying lab, participants will gain hands-on experience in developing electrical power grid networks using the PSSE Simulation tool. Although primary simulation software will be PSSE, some experiments will be explored using MATLAB. They will perform simulation analysis for various power system concepts and learn the modeling of different power system components.

Additionally, they will learn using the python programming language to automate various tasks learned throughout the lab for routine activities. Join us to explore the world of power grids and enhance your skills in simulation, coding, and modeling.

List of Experiments:

1. Visit a local substation or a generating plant.
2. Familiarizing yourself with PSSE Software (Installation and the Graphical User Interface Usage).
3. Designing the transmission line parameters using PSSE-Lineprop Tool.
4. Power Flow analysis using MATLAB and PSSE.
5. Modeling and analysis of Transformers.
6. HVDC transmission line modeling and performing various control actions on voltage source converters.
7. Synchronous generator model and analysis.
8. Voltage regulation using generators, shunts, static compensators, capacitor banks, etc.
9. Inverter based resources modeling for steady state analysis in PSSE.
10. Performing optimal power flow using PSSE.
11. Transient Stability using MATLAB.
12. Setting up PSSE Python Environment and Basics.
13. Performing power flow and analysis using python automated script.