CUSP Labs

Through our previous and current Office of Naval Research (ONR) grants, we have developed the following 3 new laboratories for undergraduate and graduate level courses:

- Electric Drives (Basic + Advanced) Lab
- GaN-based Power Electronics Lab
- Emulated Power System Lab

Each of these lab kits costs approximately 2,500 dollars. All these 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, for example, and an entire lab can be established at a low-cost of approximately 2,500 dollars.

ELECTRIC DRIVES LAB

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 this newly developed lab is a factor of five cheaper than that previously developed by UMN and acquired by 109 U.S. universities.

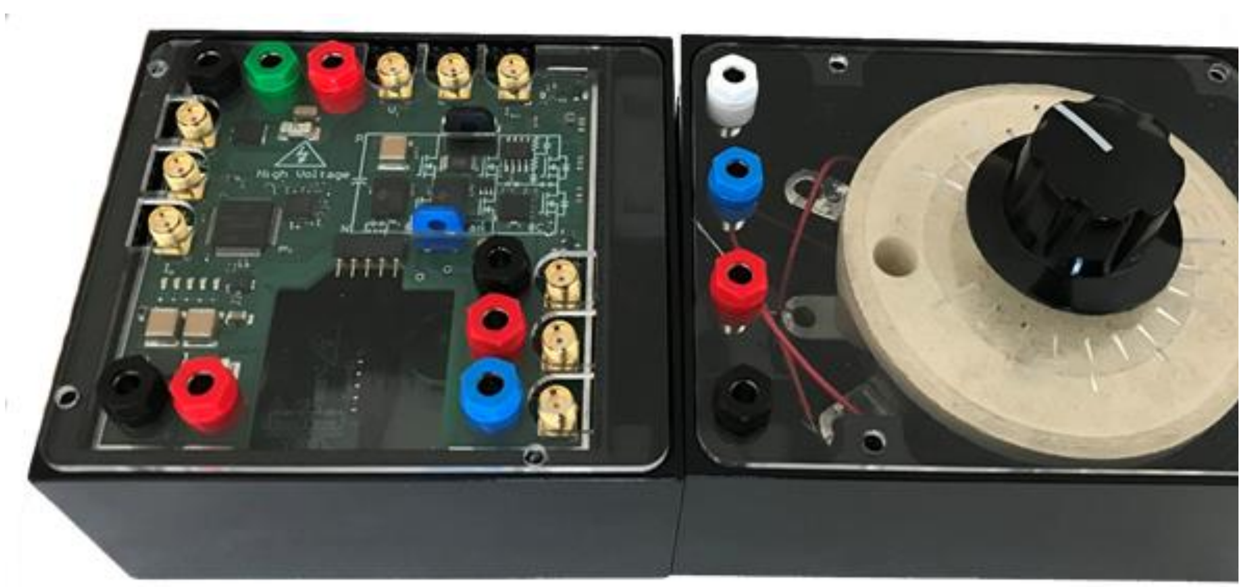
The list of experiments that can be performed using this kit is listed below:

List of Experiments:

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

POWER ELECTRONICS LAB

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.



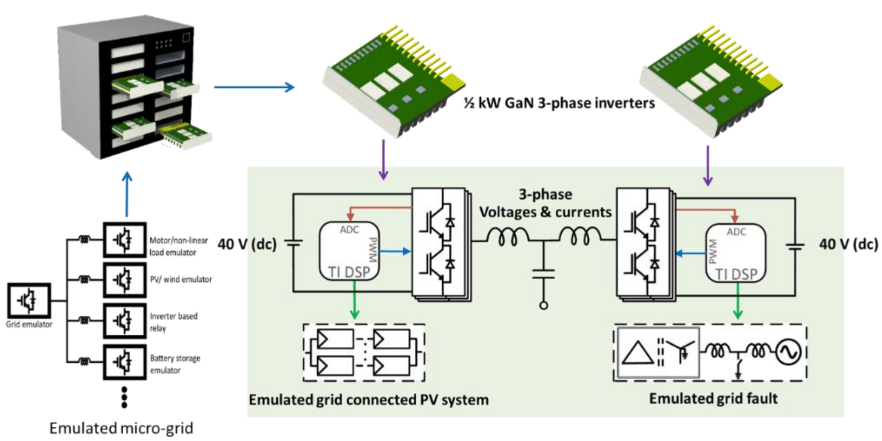
This lab is targeted toward undergraduate students. The list of experiments that can be performed using this kit is listed below:

List of Experiments:

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

EMULATED POWER SYSTEMS LAB

The power systems lab is designed using low-cost digitally reconfigurable GaN-based three-phase inverters. Each of these cards consists an on-board controller that can be controlled by Workbench to emulate a PV panel, Wind-turbine-generator, diesel generator, battery storage, motor and non-linear loads etc. All of these can be interconnected to form an AC or DC micro-grid as shown on the left in the figure below, consisting of five nodes, with the entire tabletop microgrid costing around 2,500 dollars.



Another example of its capability is shown on the right part of the figure by an Inverter-Based Resource (wind or solar), emulated by the card on the left, and feeding power to the grid emulated by the card on the right. This setup can be used to determine the required control of the IBR such that the relays can detect unbalanced faults on the grid. This is work in-progress and in this workshop, we will demonstrate the eventual capability of such a setup by one card emulating the 60-Hz grid and the other emulating an electric machine.