CUSP Curriculum Developed at the University of Minnesota with ONR Funding

NSF Workshop
University of Minnesota Team (Ned Mohan, Siddharth Raju, David Maiden Mueller)
Minneapolis, October 21-22, 2022

Acknowledgment

ONR Grants -

1. Center for Reforming Undergraduate Education in Electrical Engineering Energy Systems – A Critical Infrastructure for National Security Jun1, 2006 – Sept 30, 2012
2. Center for Developing and Disseminating a Graduate/Undergraduate Curriculum 6/1/2011- 02/29/2016
3. Increasing Electric Power and Energy Engineering Pipeline Nationwide 3/15/2014- 4/30/2016
4. Offering of Web-Enabled, Instructor-Taught Online Courses based on ONR-Funded Graduate Power Curriculum 6/2015 – 05/31/2020
5. National Dissemination of the CUSP™ Electric Power Curriculum 8/10/2018-5/31/2021, UMN: Co-Institution
6. Developing WBG-Based, Extremely Low- Cost Laboratories for Power Electronics, Motor Drives, and Power System Protection and Relays for National Dissemination 01/01/2019 – 12/31/2022
7. A Low-Cost Scalable Tabletop Emulator for Shipboard Power System, 6/1/2022 – 12/31/2026

History of Electric Energy Curriculum and Interest Nationwide

- EE curriculum started with power engineering in the 1880's
- Interest in power engineering declined after mid-1900's
  - Courses did not change
  - Students were not excited
  - Instructional capacity declined
- Power engineering is now seen as critical to growth and sustainability
  - Requires rethinking the curriculum

Objective:

Develop A Comprehensive Electric Energy Education Curriculum

- **Enable *all* universities to**
  - Provide a first-rate education **and**
  - Graduate students in large numbers

S&T Objectives: Develop Courses and Labs for Power &Electric Energy Education

- A better-trained supply of U.S. graduates in STEM to tackle various research challenges in the Navy
- Adding flexibility and safety to ensure that they will be useable in a variety of future Navy courses and learning needs
  - Do so by enabling all universities to provide a first-rate education and educate students in large numbers

A Holistic View – wherever Electric Power is used

Electricity Generation, Transmission and End-Use:

- Renewables/storage
- Conservation

Transportation

- Trains
- Planes
- Hybrids/EVs

Defense

- Navy
- Air Force
- Army

Industrial Competitiveness

- Automation/Robotics/Advanced Manufacturing

Electric Power Engineering

- Power Systems
- Power Electronics
- Electric Machines and Drives
- Controls

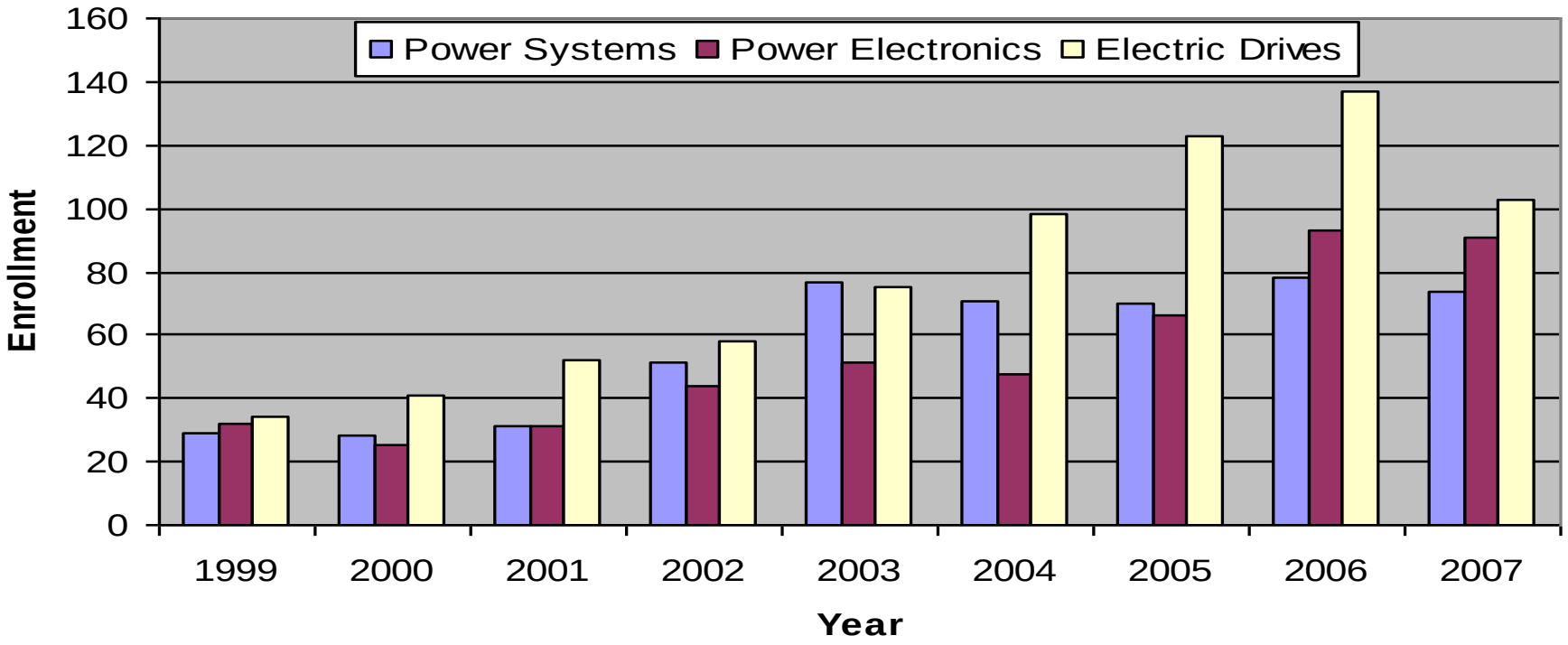
Approach Implemented

- A pipeline course
- Fewer, carefully designed, undergraduate Courses
- Graduate courses shared with colleagues across the country - online

Increasing Student Enrollments –

Fall 2007 Enrollments at the University of Minnesota

Power Systems: 78 (limit), Power Electronics: 81, Electric Drives: 103



Fundamentals-based Education Leads to Graduate Education and PhD Research

2008-2009:

Power Systems – 90

Power Electronics – 118

Electric Drives - 124

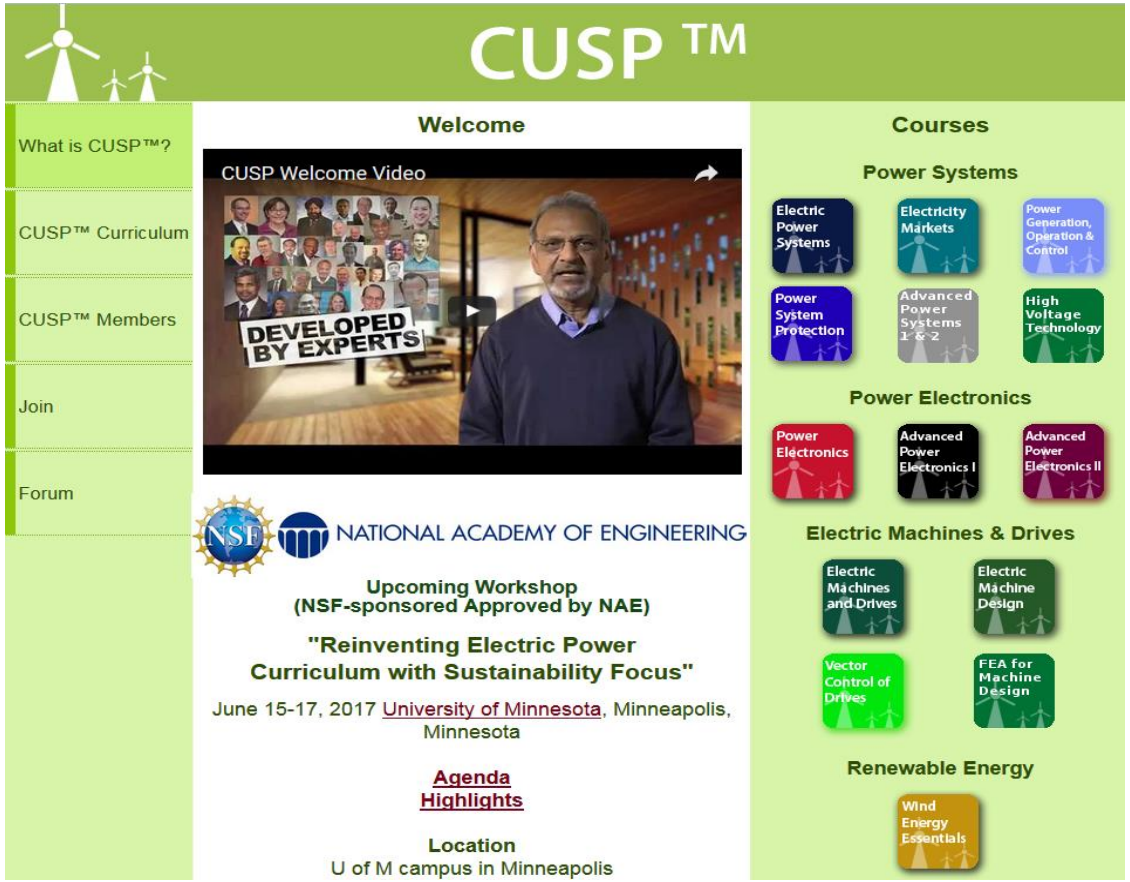
19 Senior/Graduate-Level Courses

Power Systems (22 Credits)
1. Power Systems + Lab (3 + 1 Credits)
2. Advanced Power Systems I (3 Credits)
3. Advanced Power Systems II (3 Credits)
4. Power Gen, Op and Control (3 Credits)
5. High Voltage Technology (3 credits)
6. Protection and Relaying (3 Credits)
7. Electricity Markets (3 Credits)

Power Electronics (16 Credits)
1. Power Electronics + Lab (3 + 1 Credits)
2. Advanced Power Electronics I (3 Credits)
3. Advanced Power Electronics II (3 Credits)
4. Digital Control of Power Electronics (3 Credits)
5. WBG Course developed by Prof. Agarwal (3 Credits)

Electric Machines/Drives (14 Credits)
1. Electric Machines/Drives + Lab (3 + 1 Credits)
2. Vector Control of Drives + Lab (3 + 1 Credits)
3. Electric Machine Design (3 Credits)
4. FEA-based Machine Design (3 Credits)

Renewable Energy (2 Credits)
1. Wind Energy Essentials (2 Credits)



235 U.S. Universities as members (over 450 faculty)

https://cusp.umn.edu

Structure of Each Course

- Learning Objectives
- Textbook
- Slides
- Videos
- Hardware/Software Lab
  - List of Experiments

Example of an online course

Course Number:

Course Title: Power Electronics

Credits:

Instructor:

Pre-requisites: Contents of the Optional Course: Math/Physics/Circuits.

Course Description: Power Electronics is an enabling technology, and the focus of this class is such that students learn its various applications, basic converter structures and how these converters are used and controlled in these applications. By exploiting the commonality of various converters, students get a much deeper and broader understanding.

Purpose of Course: To have students obtain a thorough understanding of the basic principles behind power-electronic converters, and the applications where they are used, to analyze and build these in industry, and to use as a springboard for further research in this field.

Textbook: Power Electronics: A First Course ISBN: 1118074807; Wiley

Course Objectives/Competencies/Weekly Coverage (some topics over 2-3 weeks):

Week 1: Material to be covered [Chapter 1]; Assigned video clips – 1, 2; Homework Questions: 1-2, 1-4, 1-15, 1-16, 1-17

Week 2: Material to be covered [Chapter 2]; Assigned video clips – 3, 4; Homework Questions: 2-3, 2-4, 2-5, 2-7, 2-8

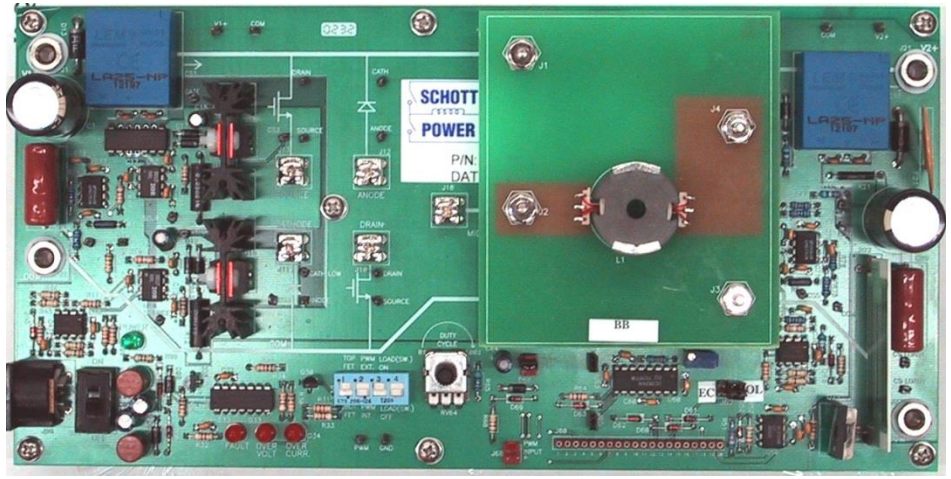
- **Online only**
- **111 students**
  - **85% from other colleges**
  - **60% female**

http://z.umn.edu/ee1701

Another Pipeline Course

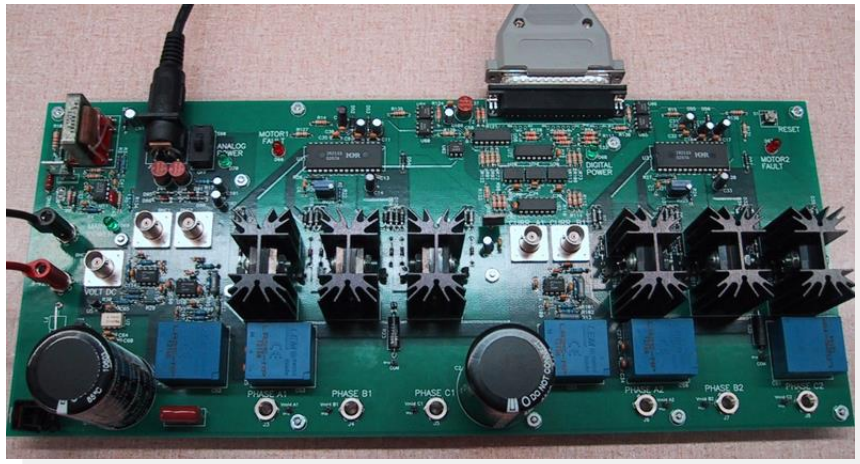
EE2701 “Sustainable Electricity Supply: Renewables and Conservation

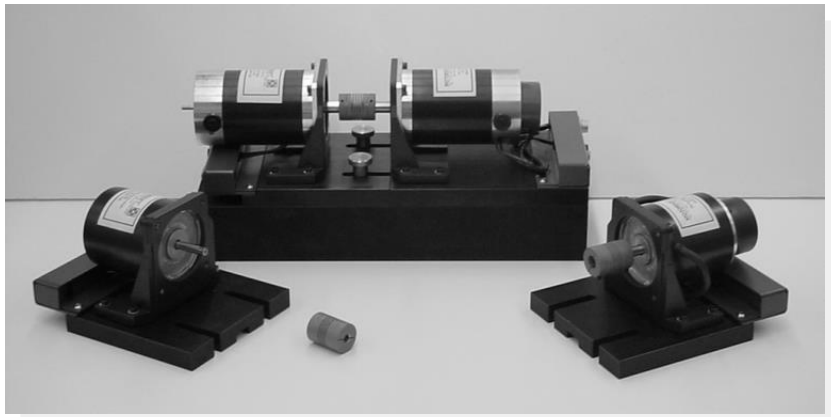
Legacy Hardware Laboratories – Funded by NSF



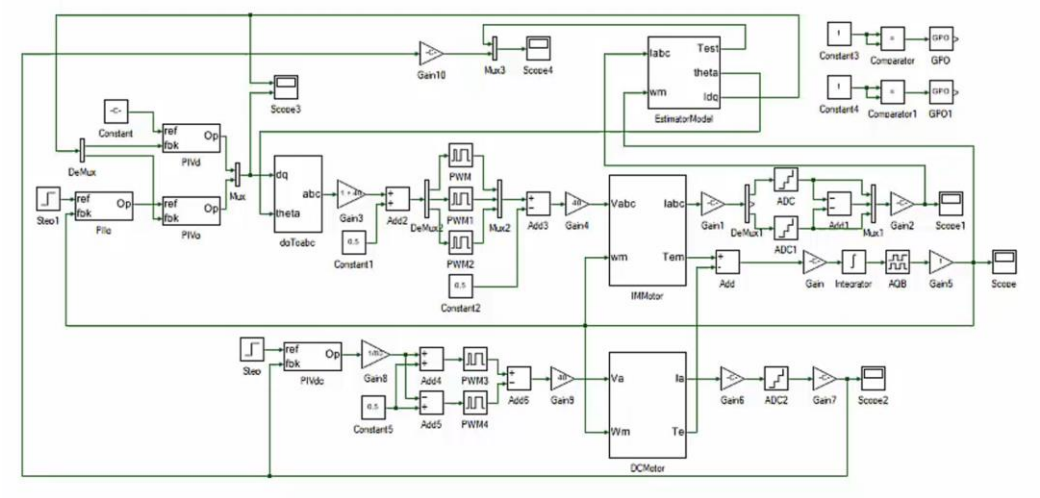
NSF - CCLI

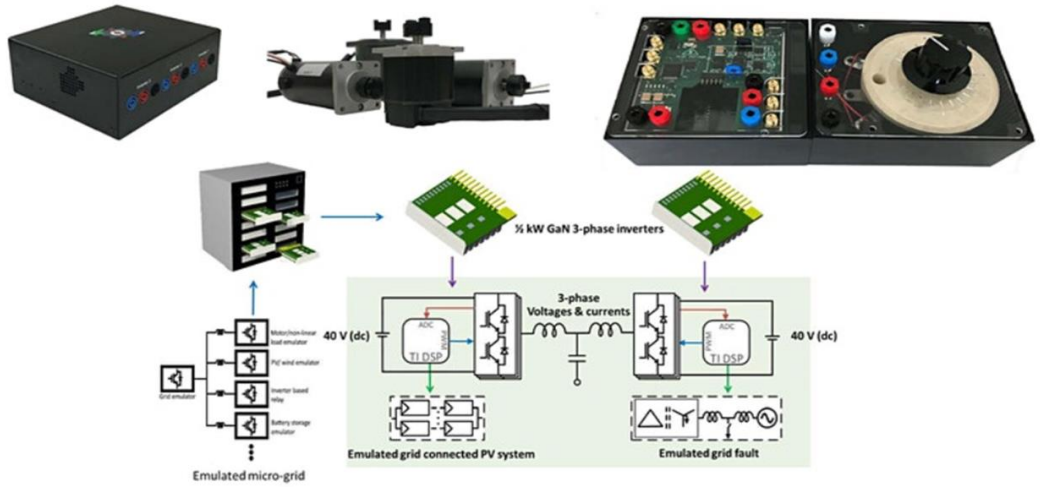
Acquired by 109 US Universities





CUSP™ Laboratories – Funded by ONR





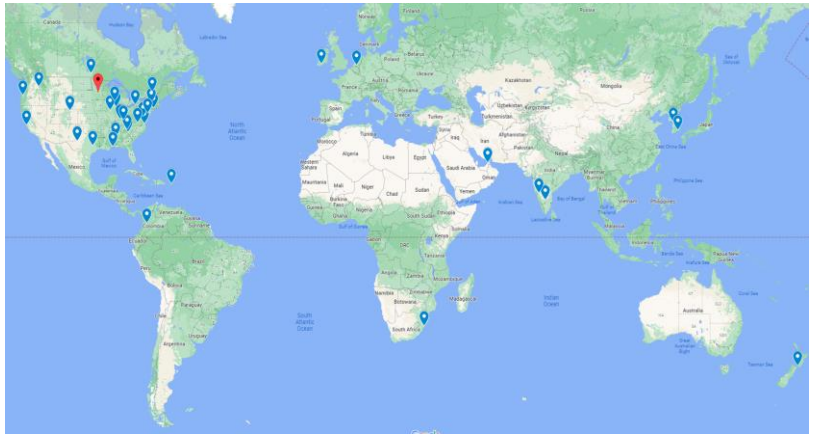
Power Systems Lab using PSS®E and Python

Main Characteristics:

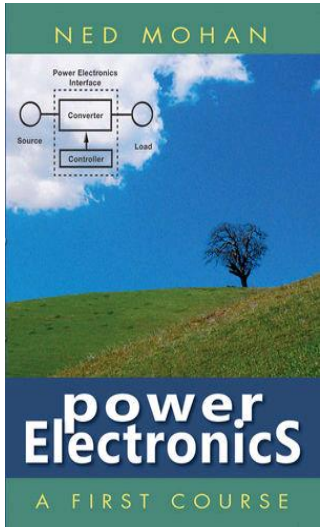
- Extremely Low-Cost
- **Remotely Accessible**

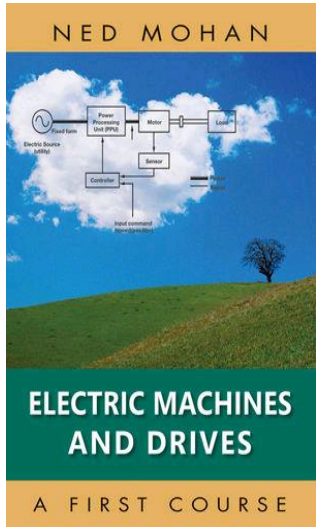
UMN Labs: EE1703, EE2703, EE4703, EE4722, EE4743, EE5707, EE8741

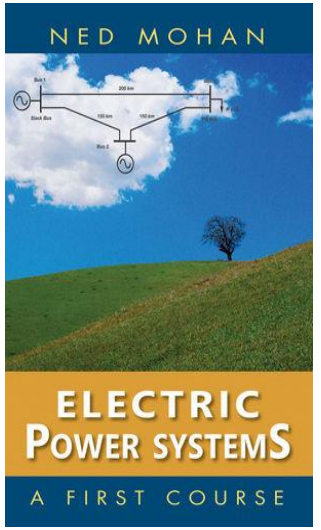
Available From: Sciamble – A UMN Startup
https://Sciamble.com

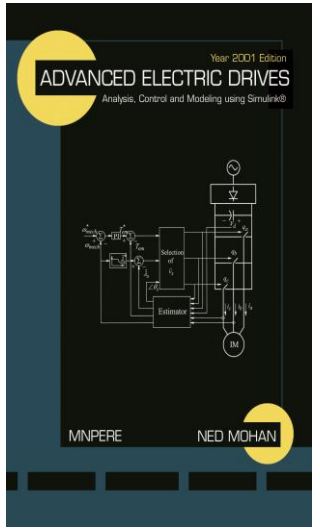


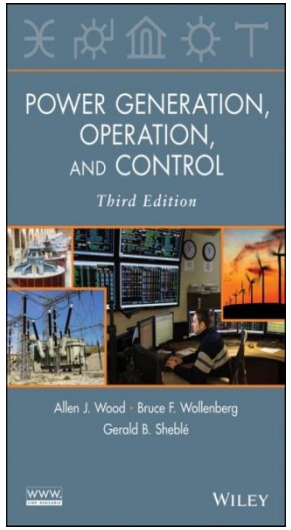
Textbooks underlying these courses:

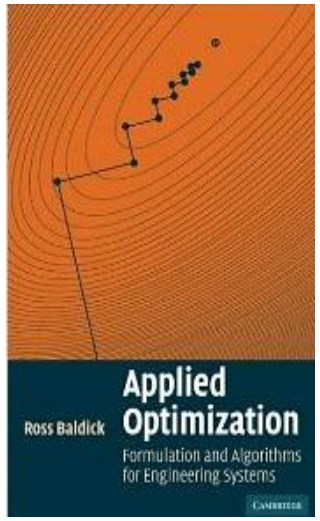


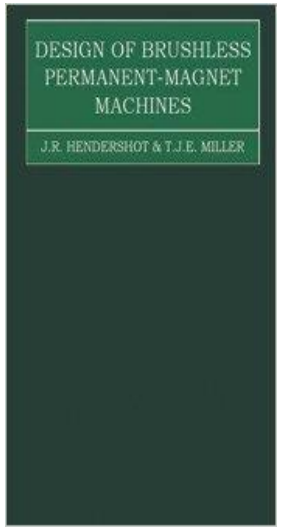


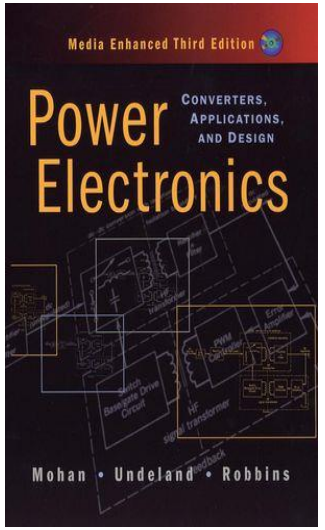






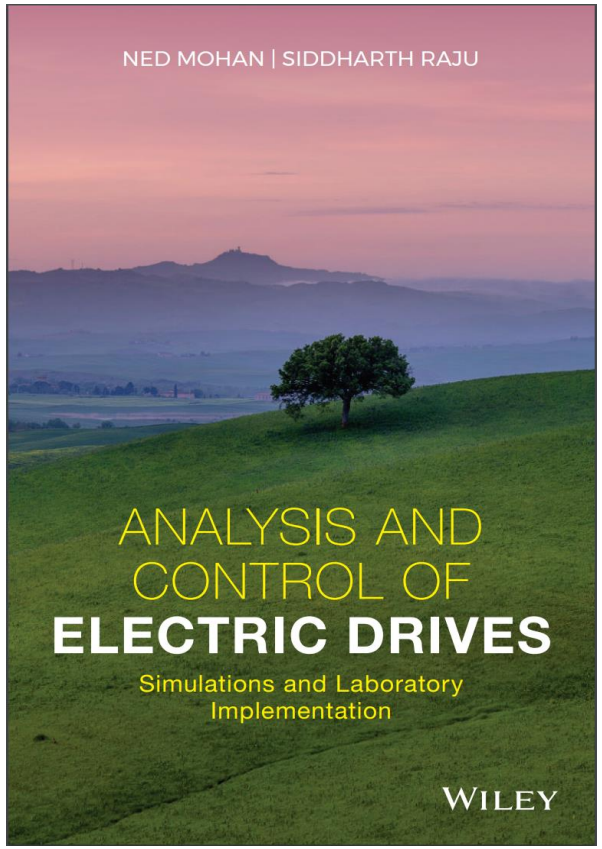




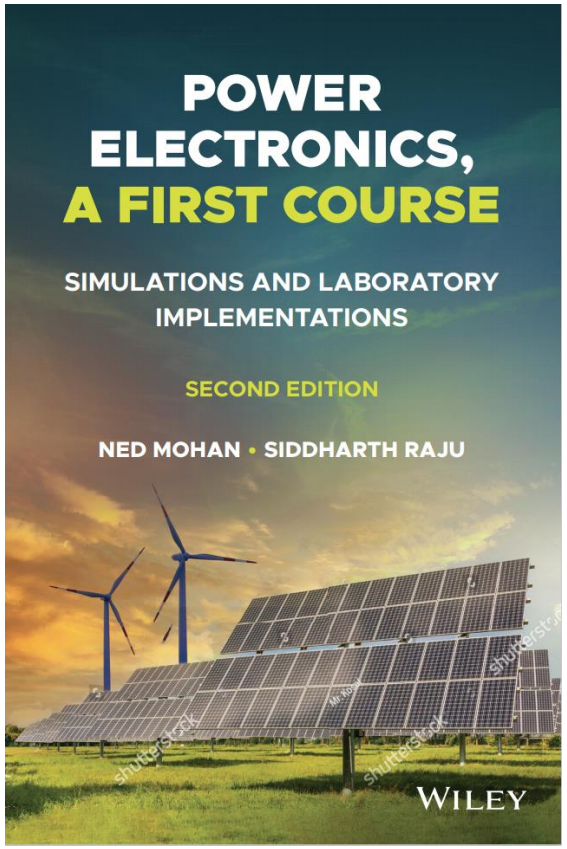


- **Translated into 9 Languages**

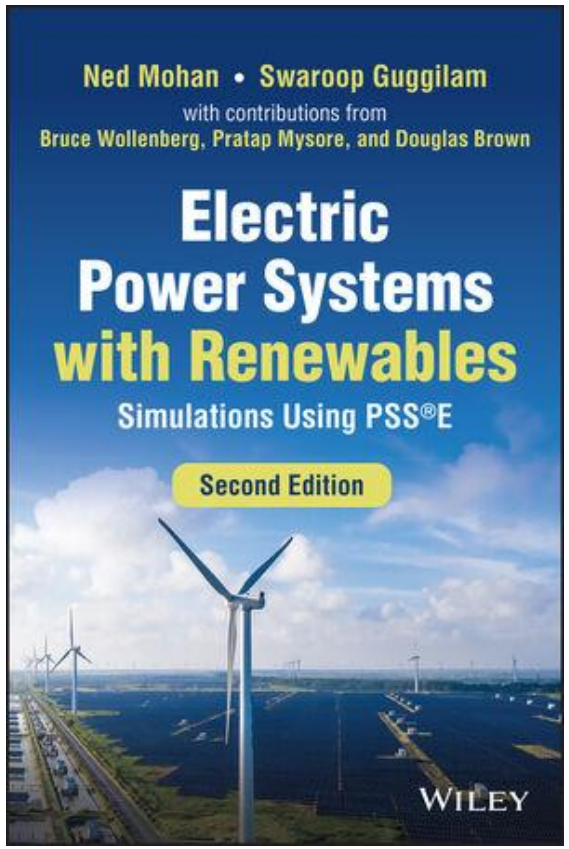
Recent Textbooks



Published by Wiley, August 2020



To be Published by Wiley, Feb 2023



To be Published by Wiley, March 2023

Another Two textbooks to be published by Wiley by Summer 2023

1. Power Electronics for Grid-Integration of Renewables: Analysis, Simulations and Hardware Lab
2. Electricity Supply: From Renewables to Manufacturing -Simulations and Laboratory Implementation

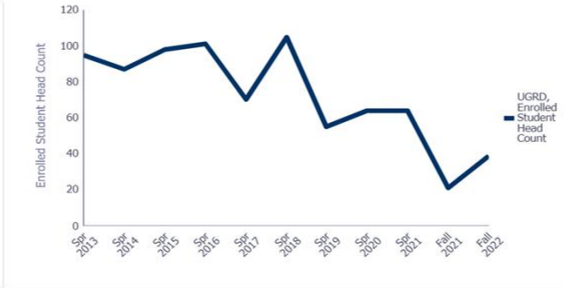
NSF/NAE Workshop:

Crisis in Power Engineering Education: A National Security Concern

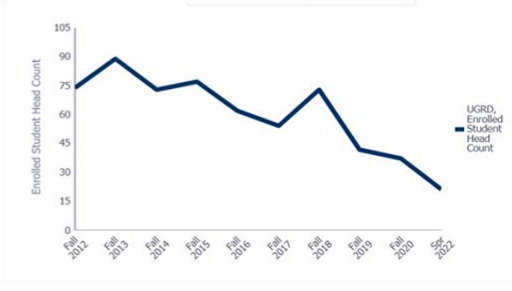
Minneapolis, MN October 21-22, 2022

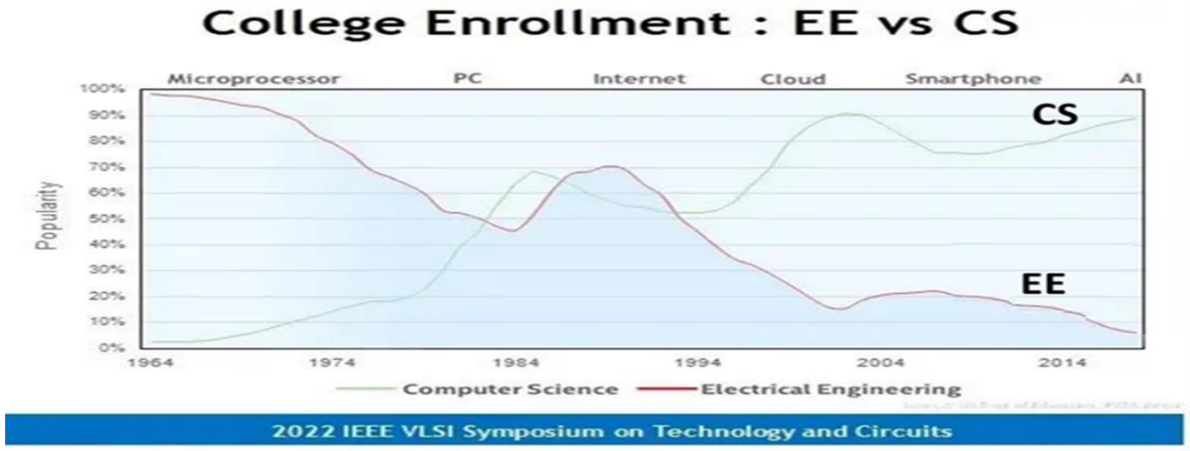
EE 4721 – Basic Power Systems

EE 4701 – Electric Machines/Drives



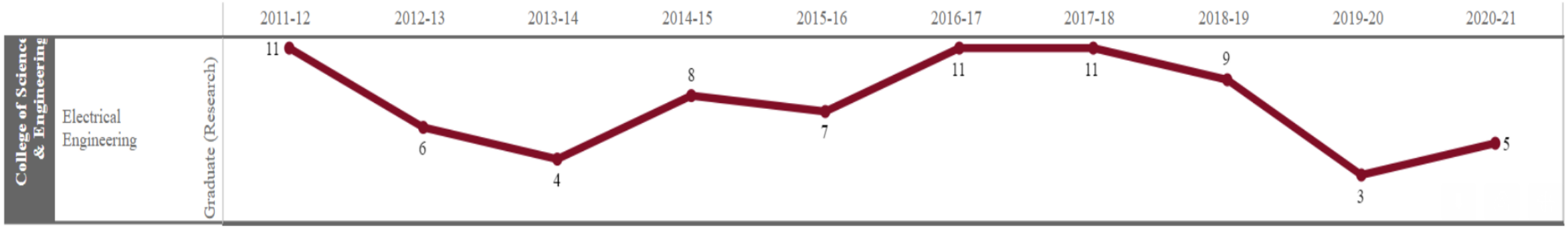
EE 4741 – Basic Power Electronics



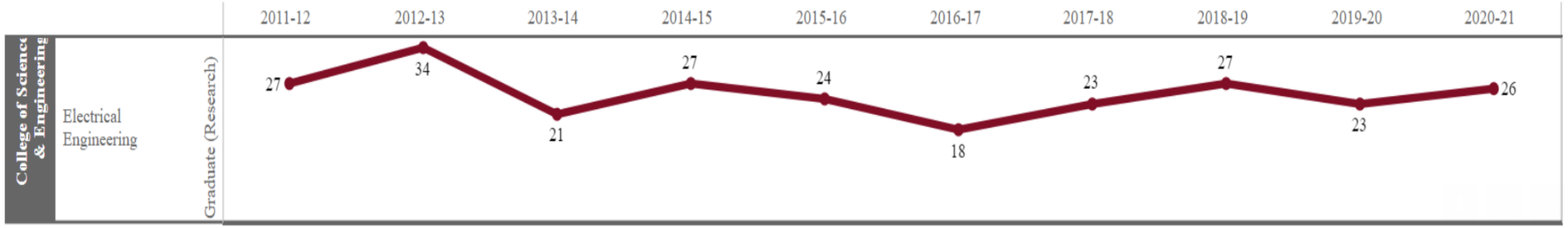


Number of PhDs Graduating in EE at UMN

College(s): College of Science & Engineering | **Graduate/Professional Program(s):** Electrical Engineering | **Degree Type:** Graduate (Research) | **Degree Level:** Doctoral | **Race/Ethnicity:** All | **Sex:** All | **Citizenship Status:** Domestic | **Degree Year:** All



College(s): College of Science & Engineering | **Graduate/Professional Program(s):** Electrical Engineering | **Degree Type:** Graduate (Research) | **Degree Level:** Doctoral | **Race/Ethnicity:** All | **Sex:** All | **Citizenship Status:** International & unknown | **Degree Year:** All



Workshop Agenda: at-a-glance – first day

Presentations:

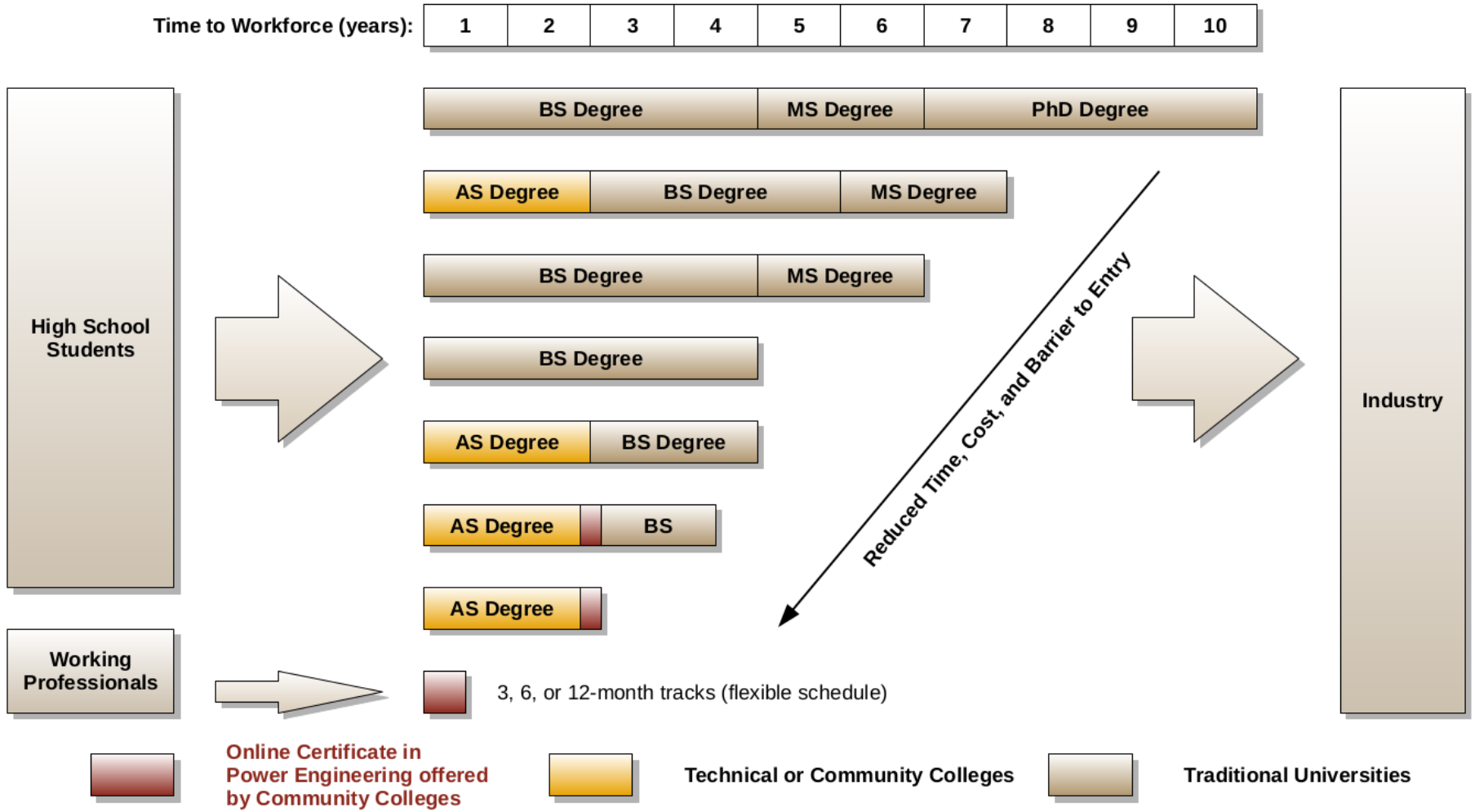
- Aranya Chakrabortty - Program Director, National Science Foundation
- Lynn J. Petersen, CAPT USN(Ret) – Program Officer, Office of Naval Research (ONR)
- Guru Madhavan –Senior Director of programs and Senior Scholar, National Academy of Engineering
- Mingyan Liu – Chair of ECE, UMichigan- Ann Arbor, and Treasurer, ECEDHA
- Isik Kizilyalli, Associate Director, ARPA-E
- Joe Gothard, Superintendent, Saint Paul Public Schools
- Larry Lundblad, Executive Director of Workforce and Economic Development, Minnesota State Colleges, and Universities
- Ahmed Rubaai, Professor and Chair, Department of ECE, Howard University
- David McMillan, Chancellor, University of Minnesota, Duluth

Lightening Presentations:

- Electric Utilities – Great River Energy; ACES Delta; Form Energy
- Electric Vehicles - Future of EVs; Tesla
- Industrial Manufacturing – Cummins Power Generation, John Deere, Siemens USA
- Microchip-related manufacturing – Intel
- Defense – Lockheed Martin

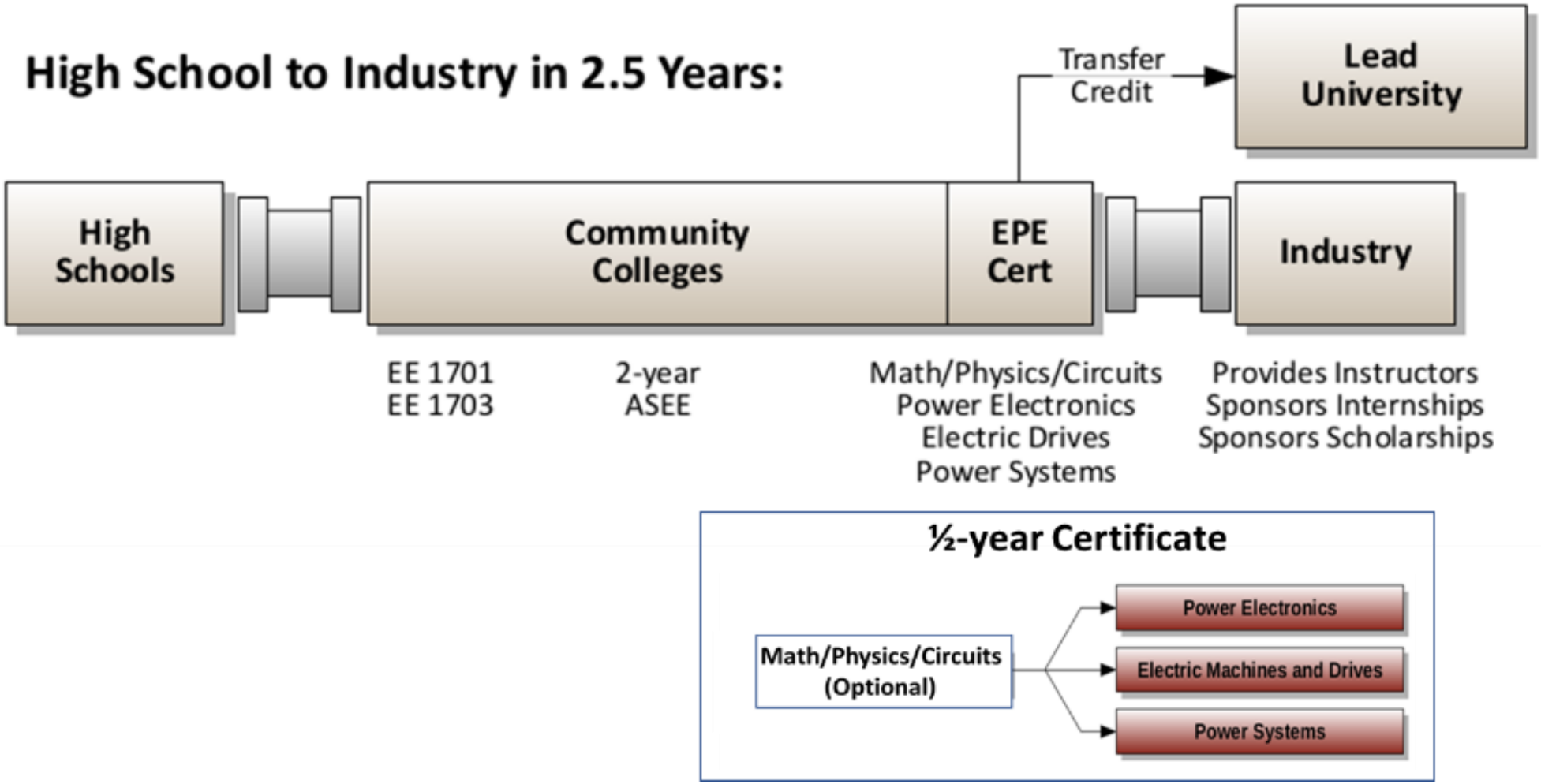
Poster Presentations

Multiple Pathways to a Robust Power Engineering Workforce



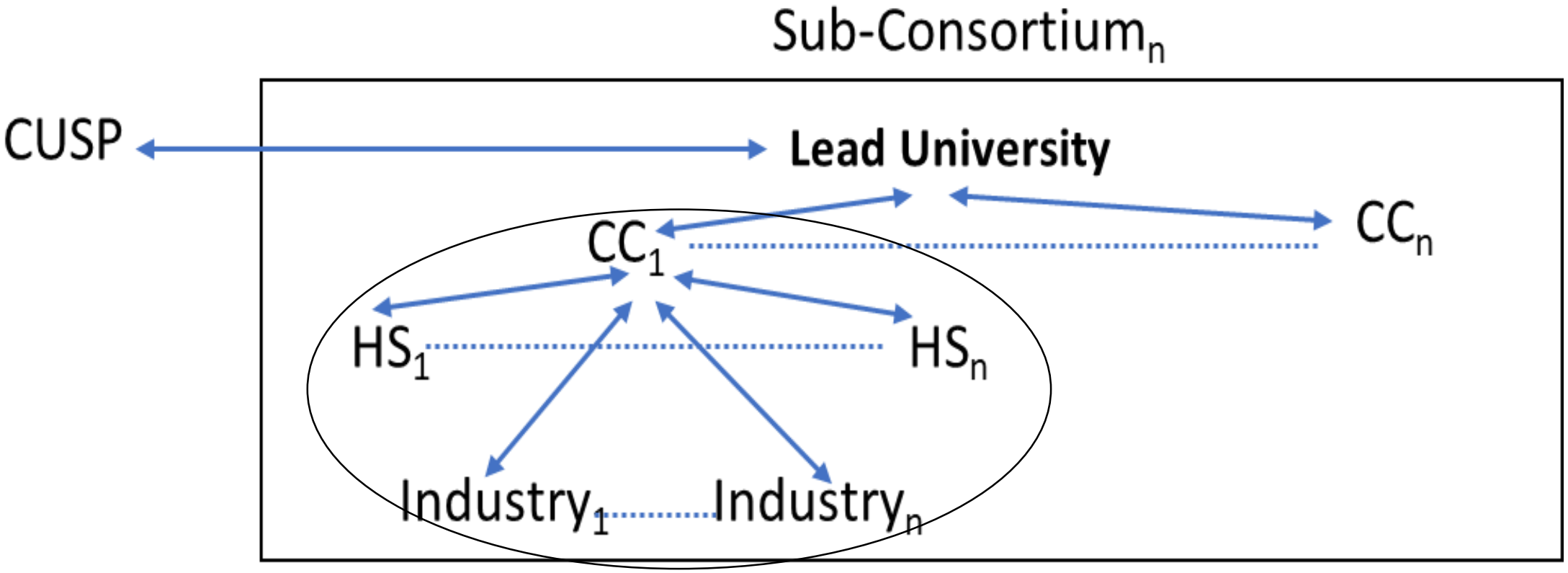
Certificate includes three **online** courses in Power Systems, Power Electronics, and Electric Machines and Drives, with an optional Electrical Fundamentals course covering the math, physics, and circuit concepts needed for the other three courses. Courses based on the CUSP™ curriculum, each 10 weeks long, with the option to be taken in parallel.

High School to Industry in just 2-1/2 Years



Highly Decentralized Certification Effort

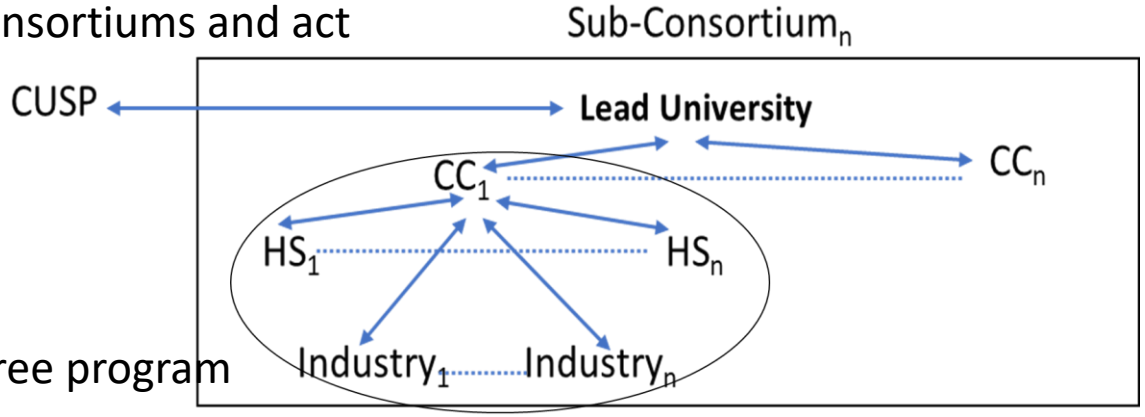
Proposed Make-up of a Sub-Consortium



Role of Various Participants in this Decentralized Certificate Effort

CUSP

- Develop the Certificate-related Courses and Labs including the pipeline course
- Promote the Certificate Effort to various universities to form sub-consortiums and act as lead universities
- Identify industry instructors nationwide to each these courses



Within Each Sub-Consortium

- **Lead University**
  - Reach out to community colleges and high schools
  - Offer courses and labs developed by CUSP within their BS Degree program
  - Have labs that can be used online by community colleges
  - Identify industry instructors who can teach Certificate courses in Community Colleges
  - Accept credits from the Certificate program in their own upper division
- **Each Community College**
  - Reach out to high schools and promote them to teach the pipeline course
  - Offer Certificate in Electric Power Engineering through industry instructors
  - Get funding from industry for scholarships and arrange internships for their students
- **Each High School**
  - Teach the pipeline course
  - Promote this pathway in many ways including through student counselors
- **Each Industry**
  - Provide instructors to teach Certificate courses in community colleges
  - Provide funding to community colleges and high schools; provide internship opportunities to their students

Offering Online Master's Degree: CUSP Academy(?)

1. Educated Workforce to meet increasing demands related to electric energy
2. Make a large selection of courses available to students and industry nationwide
3. Keep certain power-related courses, critical to national infrastructure, from disappearing
4. Keep evolving these courses
5. Offering Graduate Certificates after 9 or 15 credits(?)

Thank you.

Questions and Comments