2011 DOE Vehicle Technologies Program Review Presentation

Recovery Act—Transportation Electrification Education Partnership for Green Jobs and Sustainable Mobility

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ARRAVT038

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Kettering University

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Overview

Timeline

- Start date: **2009/10/01**
- End date: **2012/09/30**
- Percent complete: 60%

Barriers

- Lab renovation and development
- Development of lab content
- Outreach to K-12 students

Budget

- Total project funding
  - DOE share: $2.5M
  - Contractor share: $735,975
- Funding received in FY10: 884k
- Funding for FY11: 467K

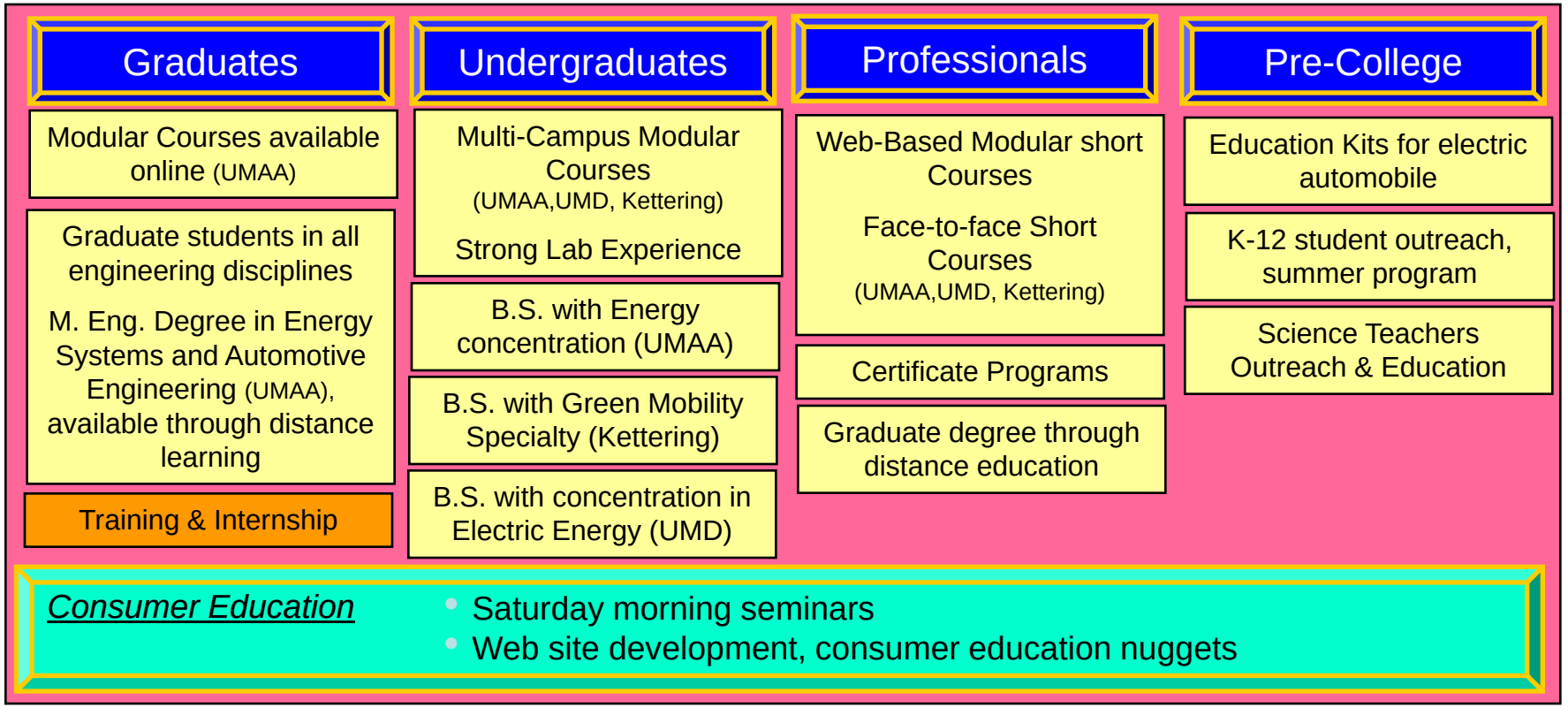
Partners

- A&D in equipment
- GM/Ford/DTE in course development and teaching
- GM in short courses

Project Scope-Relevance

Objective:

To develop graduate, undergraduate and short courses and outreach activities in the field of Electrified Transportation



Overview of Project -Approach/Strategy

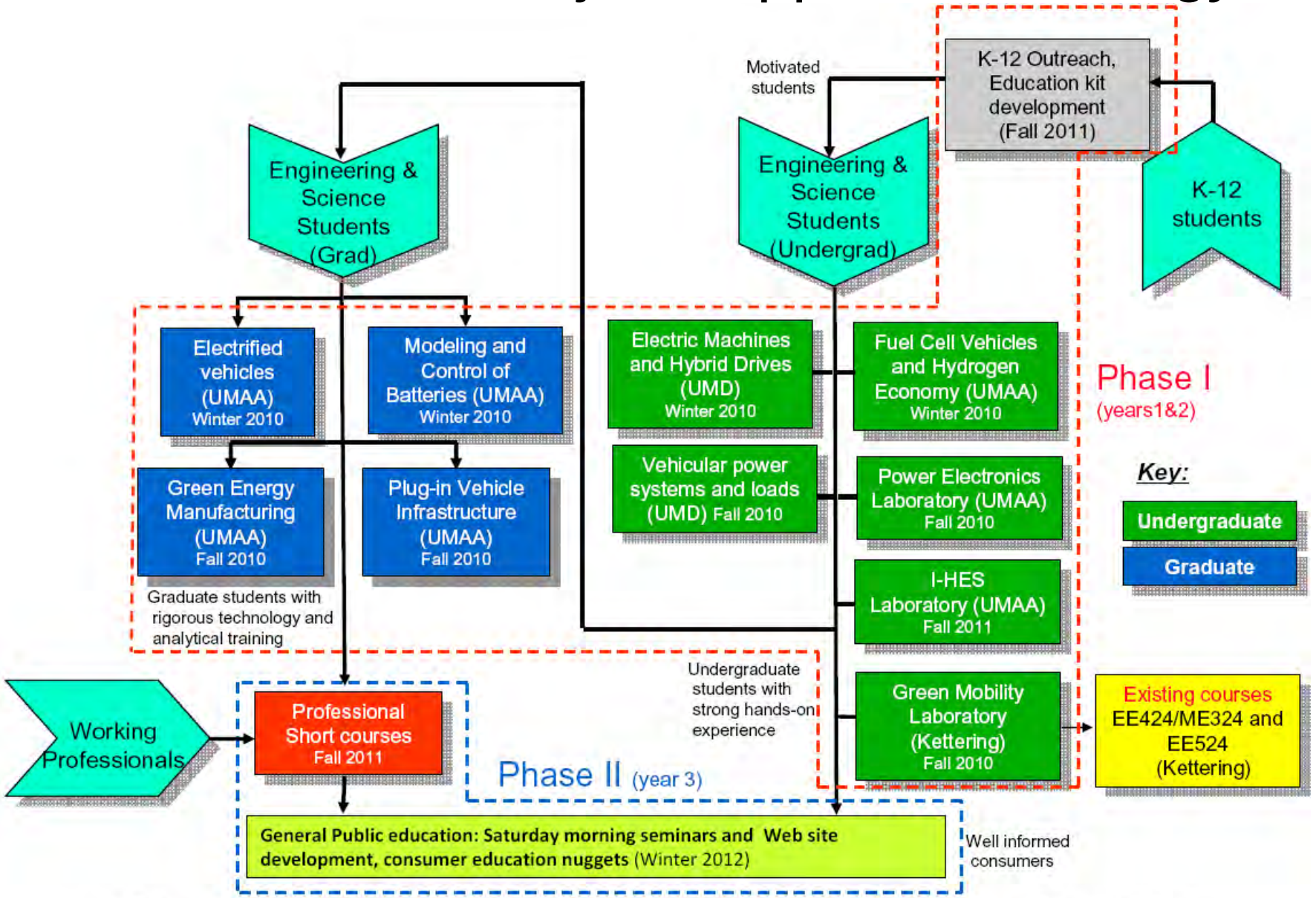


Figure 4 Flow chart and timing of the proposed educational activities

Project Timeline- Approach/Strategy

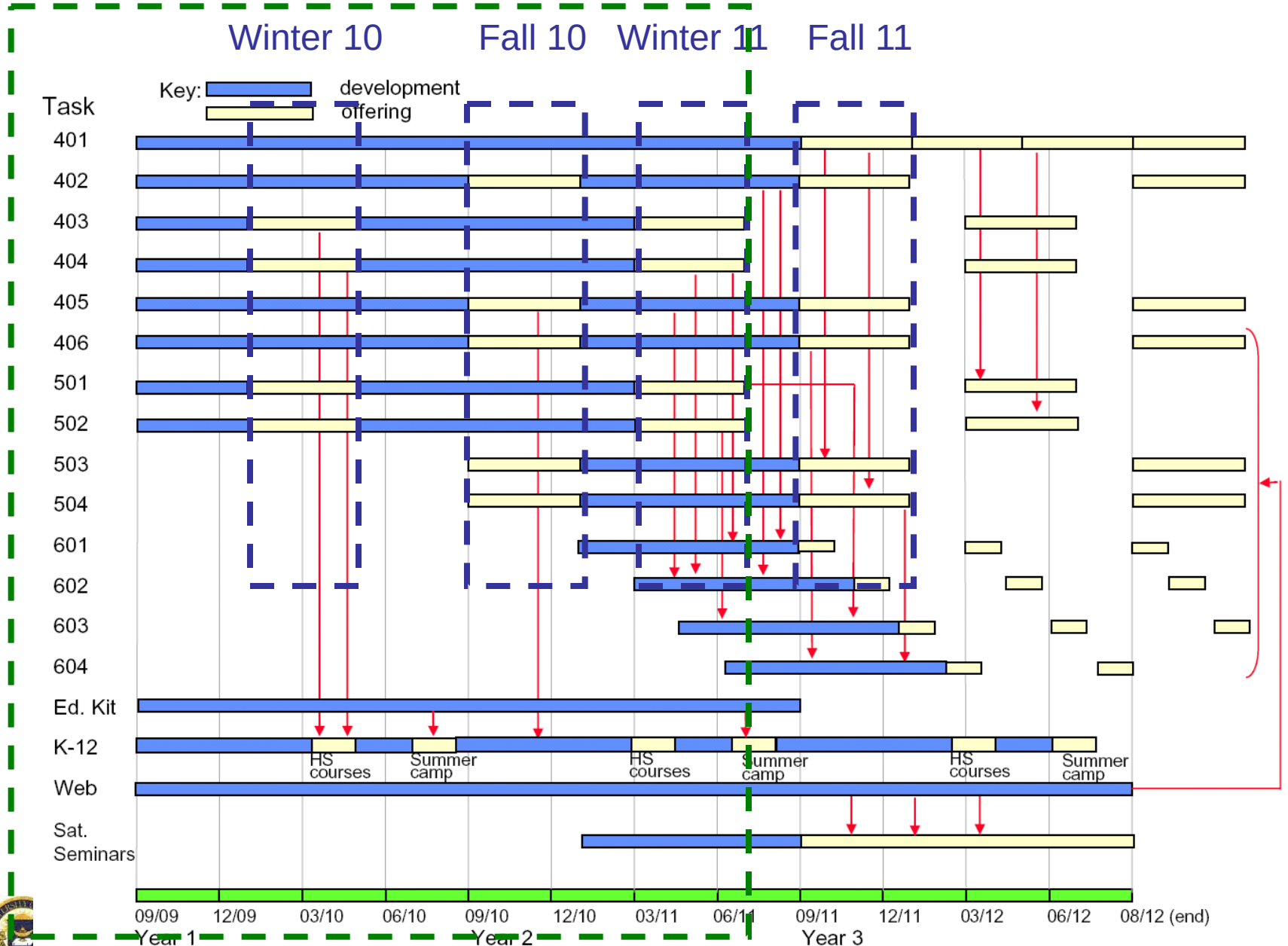


Figure 9 Proposed timeline

Tasks (years 1-2)-- Approach/Strategy

Task 1 – Development of 4 graduate courses

Campus	Course	Faculty	Title
UMAA	501	Peng & Filipi	Electrified Vehicles
UMAA	502	Stefanopoulou & Fathy	Modeling and Control of Batteries
UMAA	503	Hu	Green Energy Manufacturing
UMAA	504	Hiskens	Plug-in Vehicle Infrastructure

Task 2 – Development of 6 undergraduate courses and laboratories

Campus	Course	Faculty	Title
UMAA	401	Filipi & Peng	Integrated Hybrid Electric System (I-HES) Laboratory
UMAA	402	Hiskens	Automotive Power Electronics Laboratory
UMAA	403	Siegel & Stefanopoulou	Fuel Cell Vehicles and Hydrogen Infrastructure
UMD	404	Mi	Electric Machines and Hybrid Drives
UMD	405	Mi	Power Systems (vehicular power systems and loads)
Kettering	406	Gover, Thompson & Hoff	Green Mobility Laboratory

Task 3 – Development of K-12 outreach activities

Campus	Course	Faculty	Title
UMAA	"101"	Hiskens & others	K-12 Outreach
UMAA	"102"	Fathy	Development of an Education kit for Electric Automobiles

Tasks (year 3)-- Approach/Strategy

PHASE II (year 3)

Campus	Course	Faculty	Title
UMAA	"103"	Peng & Borbely	Saturday morning Seminars and Web site development
UMD	"601"	Mi	Power Electronics System Integration
	"602"	Gover	Electrified Vehicle Semiconductor Power Devices and Heat Transfer
UMAA	"603"	Stefanopoulou	Modeling and Control of Batteries
UMAA	"604"	Peng & Filipi	HEV and PHEV System Integration and design

Accomplishments and Progress

- Winter 10 Courses (4)
- Fall 10 courses (4)
- Winter 11 Courses
- Summer camp for high school students
- Automotive education kit
- Laboratory development

Winter 2010 Courses

- Electrified vehicles (AA)
  - Enrollment: 33, plus 60 in SP/SU 2010
- Modeling and control of batteries (AA)
  - Enrollment: 59
- Fuel Cell Vehicles and Hydrogen Infrastructure (AA)
  - Enrollment: 47
- Electric Machines and Hybrid Drives (Dearborn)
  - Enrollment: 47

Fall 2010 Courses

- Infrastructure for Vehicle Electrification (AA)
  - Enrollment: 20
- Power Electronics Lab (AA)
  - Enrollment: 24
- Vehicular Power Systems and Loads (Dearborn)
  - Enrollment: 19
- Green Mobility Laboratory (Kettering)
  - Enrollment: ~50

Winter 2011 Courses

- Electrified vehicles (AA)
  - Enrollment: 23, plus 55 through distance learning
- Modeling and control of batteries (AA)
  - Enrollment: 41
- Electric Machines and Hybrid Drives (Dearborn)
  - Enrollment: 25
- Green Manufacturing (AA)
  - Enrollment: 20

Courses in red are repeat from Winter 2010

Infrastructure for Vehicle Electrification

Topics:

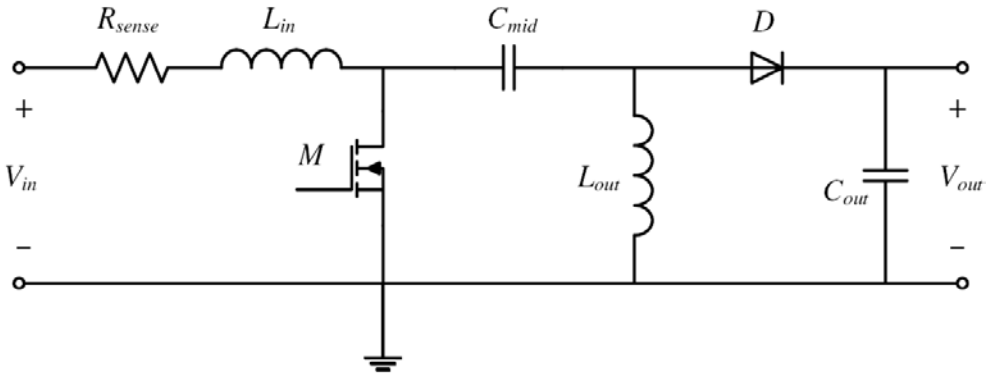
1. Overview of power systems
2. Local power system infrastructure
   - Distribution system topology; Supply connections; Transformers: tapping, heating/cooling; Protection; Voltage regulation; Reliability; Vehicle-to-grid integration.
3. Vehicle-grid interface
   - Grid-to-vehicle and vehicle-to-grid converter technologies; Standards; Safety systems; Quality-of-supply; Information transfer.
4. Global power system infrastructure
   - Daily load variation; Generation scheduling; Large-scale integration of PEVs.
5. Communications infrastructure
   - Information requirements for smart/dumb charging; Advanced metering infrastructure; Smart meters; In-home networks; Data management.
6. Control
   - Time-based and price-based load shifting strategies; Direct control; Hierarchical control structures; Valley filling control; Tracking control: smoothing renewable generation variability.
7. Business models for ubiquitous charging.

Power Electronics

- **Objectives:** Upon completion of this course, the student should:
- Understand how fundamental power electronic circuit topologies operate.
- Quantitatively determine the power quality impact of AC-connected power electronic circuits.
- Be able to design control algorithms for DC-DC converter circuits.
- Be familiar with the properties of power semiconductor devices (i.e., diodes, transistors, …) as they are used in power electronic circuits.
- Understand how to calculate the efficiency of power electronic circuits.
- Be able to analyze and design magnetic inductors and transformers for power electronic circuits.
- Possess a basic understanding of the cooling of power electronic circuits
- Have hands-on experience with many power electronic circuit topologies in the laboratory.
- Have designed a power electronic circuit as part of a course project.

Power Electronics Contents

- AC-DC Conversion
- DC-DC Conversion
  - Fundamental converter topologies
  - Isolated converter topologies
- Control of DC-DC Converters
- Power Semiconductor Devices
  - Diodes
  - Thyristors
  - BJTs
  - MOSFETs
  - IGBTs
- Power Electronic Components
- Capacitors
- Inductors, Transformers
- Auxiliary Circuitry
- Gate and Base Drive Circuits
- “Snubber” Circuits
- Thermal Analysis



Vehicular Power Systems and Loads

Catalog Description

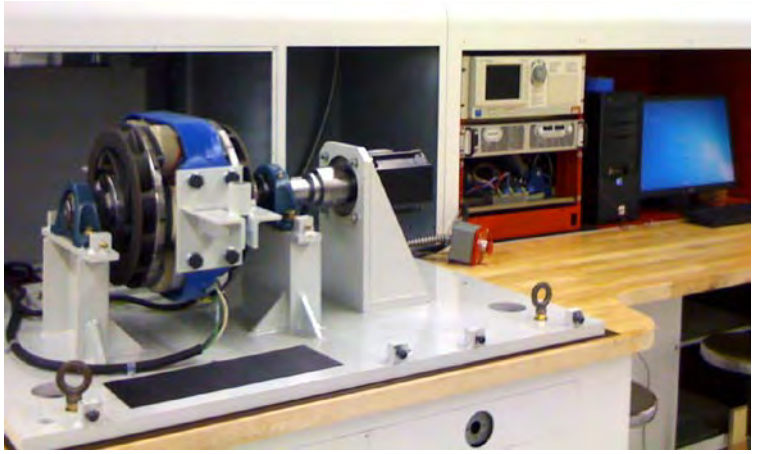
This is an introductory course on power systems and load analysis with focus on automotive applications. The objectives are to familiarize the students with the basic principles and concepts of vehicular power systems and loads. Students are expected to be able to analyze and design basic vehicular power systems. The topics covered in this course include an overview of power systems, vehicular power system architecture, DC and AC power grid in vehicular systems, power system stability, reliability, reactive power control, load flow analysis, short circuit analysis, and vehicular power system protection. Four lecture hours per week.

Prerequisite material

- Circuit analysis
- Physics: Electricity and Magnetism
- Calculus and differential equations
- Complex numbers

Green Mobility Lab

- Three laboratory stations have been built for the Green Mobility Laboratory.
- The lab is currently used by two courses
  - EE524, Fuel Cell System Integration and Packaging did use the Green Mobility Laboratory (Winter)
  - EE424, Power Electronics for EEs (both winter and spring terms)
  - Planned to be used by another course, EE324, Power Electronics for MEs



Green Mobility Lab—EE424

- Technical content
  - State variable modeling of classical DC-DC converters: buck, boost, buck-boost and Cuk. Models are amenable to PI or PID controls.
  - State variable modeling of advanced DC-DC converter topologies: floating interleaved dual boost converter, floating double-interleaved dual boost converter, floating double boost double stage boost converter, and isolated full H-bridge converter.
  - Single phase inverter design
  - Three phase, six-step inverter design
  - Sinusoidal pulse width modulation of inverters
  - Harmonic elimination pulse width modulation of inverters
  - Space vector modulation of inverters
  - Space vector modeling of motor drives for permanent magnet motors and induction motors.
  - A module on electromagnetic radiation generated in power electronics was developed and taught as a short course at the 2010 IEEE Vehicular Power and Propulsion Conference.
  - Future development will include linking the state variable and state space models to control systems.

Green Energy Manufacturing

Part I: PV manufacturing
Introduction: motivation, PV principles, and materials
PV system, performance metrics
Thin film cell production: TCO sputtering process
Thin film cell production: CIGS deposition process
Module assembly process: gridline printing process
Efficiency testing and accelerated life testing
Part II: Lithium batteries
Introduction: Battery types and structure
Cell manufacturing
Assembly and packaging
Quality assurance
Testing and performance
Part III: Others
Guest lecture: Electrification vehicle and fuel cell (Prof. Huei Peng in ME)
Guest lecture: Wind turbine system (Joseph Abbud, VP, Danotek Motion Technologies)

High School Summer Camp-2010

- 11th and 12th graders
- August 11-13

Electrified Transportation Summer Camp Day 1 Schedule
Wednesday August 11th 2010

8:30	**Report to Camp (1303 EECS)**
9:00	**Welcome & Introductions (1303 EECS)** Professor Huei Peng
9:10	**Lecture 1 Overview and Introduction to Electrified Vehicles (1303 EECS)** Professor Huei Peng
10:00	**Break**
10:10	**Lecture 2 Hybrid Vehicles (1303 EECS)** Professor Zoran Filipi
11:00	**Break**
11:10	**Lecture 3 Electric Grid (1303 EECS)** Professor Ian Hiskens
12:00	**Lunch at Commons**
13:30	**Lecture 4 Batteries (1303 EECS)** Professor Anna Stefanopoulou **Levi's Battery lab tour and hands-on experience**
15:00	**Break**
15:20	**Lecture 5 Electric Motors (2052 AL)** Professor Chris Mi
16:10	**Break**
16:20	**Lab 1 Electric Motors (2052 AL)** Professor Huei Peng, Jean Chu, Sei Jin Park, Daniel Yang
17:30	**End of day 1**

Electrified Transportation Summer Camp Day 2 Schedule
Thursday August 12th 2010

8:30	**Board Bus (in front of GGB)**
8:45	**Arrive at site 1 (UM Solar Car team,** 574 S. Mansfield, Ypsilanti**)** Rachel Kramer, Project Manager, 248.231.1234
9:30	**Leave site 1**
10:30	**Arrive at site 2 (Volt, Milford Proving Ground)** Tim Grewe, Chief Engineer and Director, GM (248) 840-2423
12:00	**Leave site 2 and lunch**
13:30	**Arrive at site 3 (ITC Transco,** 27175 Energy Way, Novi, MI 48377**)** Archisman (Archie) Gupta (734) 660-1402
14:30	**Leave site 3**
15:00	**Arrive at site 4 (Ford,** Research Innovation Center (RIC) at 2101 Village Road, Dearborn**)** Tony Phillips, 313-594-4717
16:30	**Leave site 4**
17:30	**Return to campus**

Electrified Transportation Summer Camp Day 3 Schedule
Friday August 13th 2010

8:30	**Lecture 6 Fuel Cells (1303 EECS)** Professor Anna Stefanopoulou
9:20	**Break**
9:30	**Lecture 7 Hydrogen (1303 EECS)** Professor Don Siegel
10:20	**Break**
10:30	**Tour of COE labs** in two small groups Group 1: **10:50-11:10 Anna's fuel cell lab**; **11:15-11:35 Zoran's HEV lab**; **11:40-12:00 Ian's electric lab** Group 2: **Ian's electric lab**; **Anna's fuel cell lab**; **Zoran's HEV lab**
12:00	**Lunch at Commons**
13:30	**Lecture 8 Wind power (1303 EECS)** Professor Ian Hiskens
14:15	**Break**
14:30-17:00	**Lab 2 and Electric car kit competition (2052 AL)** Professor Huei Peng, Jean Chu, Sei Jin Park, Daniel Yang
17:00 - 17:30	**Awards and close of camp** Professor Huei Peng

They have a lot of fun!










Summer Camp-2011

ACCELERATE YOUR SUMMER

UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING

LEARN ABOUT SUSTAINABLE ENERGY, ELECTRIFIED VEHICLES, AND GREEN TRANSPORTATION IN A THREE-DAY IMMERSION AT THE UNIVERSITY OF MICHIGAN!

Advances in vehicle electrification, batteries, wind, and solar power are rapidly changing the future for everyone. Hear lectures from U-M faculty and industrial experts, participate in hands-on experiences, and take related field trips.

SEE WHAT IS HAPPENING IN A NEW FIELD AND BE READY TO BE PART OF IT

AUGUST 3–5
Wednesday & Friday: 8:30 am–4:30 pm
Thursday: 8:30 am–5:00 pm
College of Engineering
U-M North Campus, Ann Arbor

COST FOR 3-DAY CAMP
$100 includes registration, lunch and snacks, field trip transportation, project materials, and T-shirt.

REQUIREMENTS
- Students must have completed their junior year in high school before participating in the camp. The camp is also open to high school seniors who graduated in spring or summer 2011.
- A grade point average of 3.4 or higher
- 300-word essay

This U-M Summer Camp is supported by a grant from the U.S. Department of Energy

HOW TO APPLY Visit EnergySummerCamp.engin.umich.edu
Your application must include a transcript and a 300-word essay that presents a statement of purpose for attending the camp.

APPLY BY JULY 1, 2011

Automotive Educational Kit

- Off-the-shelf toy race cars employing combustion engines powered by “nitro fuel” (a mix of methanol, oil, and nitro methane), broken down and modified to incorporate brushless DC motors controlled by National Instruments NXT boards to become “toy hybrids”.
- The students have connected with the child development and education community at Penn State,
- Target 8-11 year-old kids in close cooperation with Penn State’s Women in Science and Engineering (WISE) society.

Laboratory Development

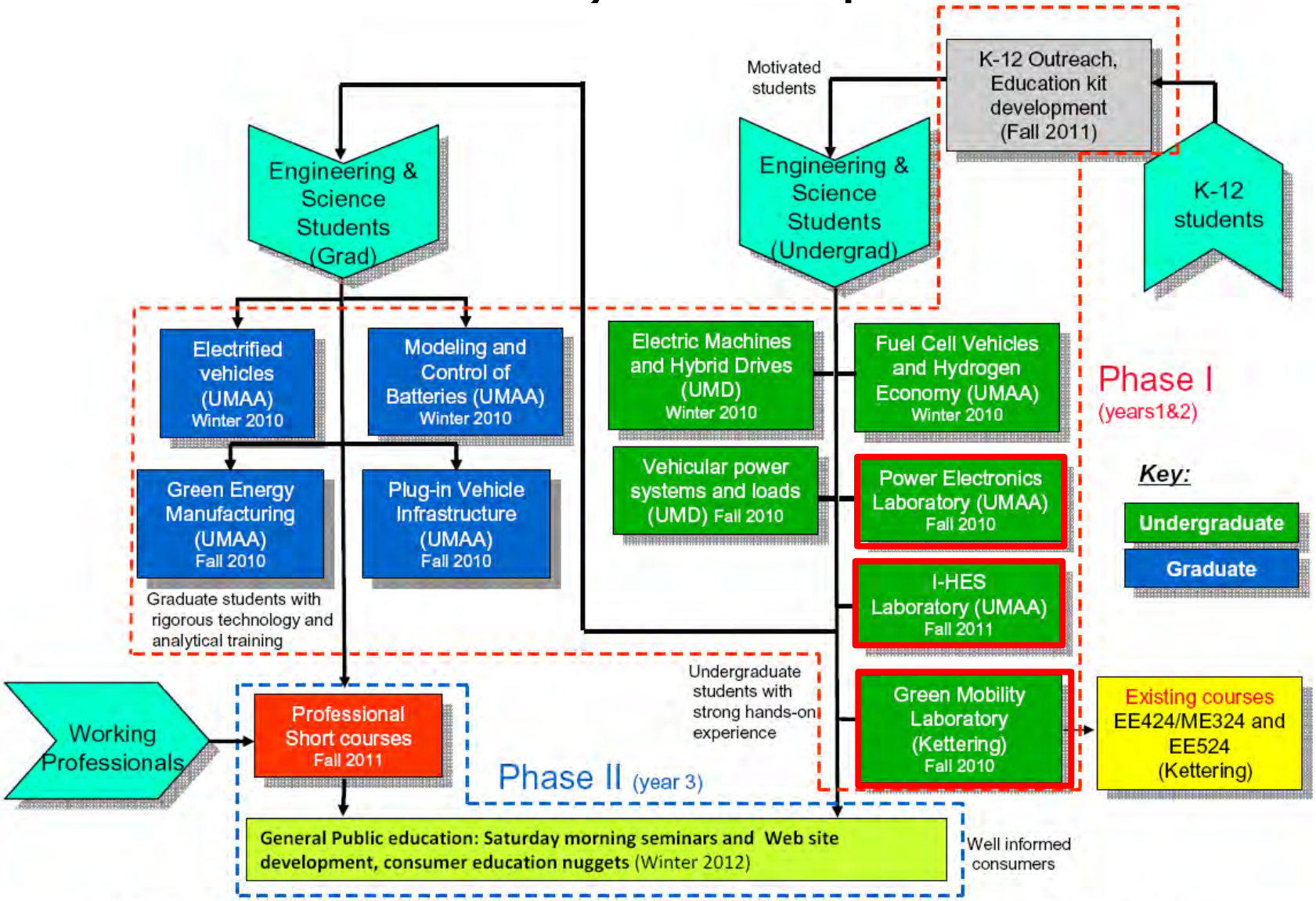
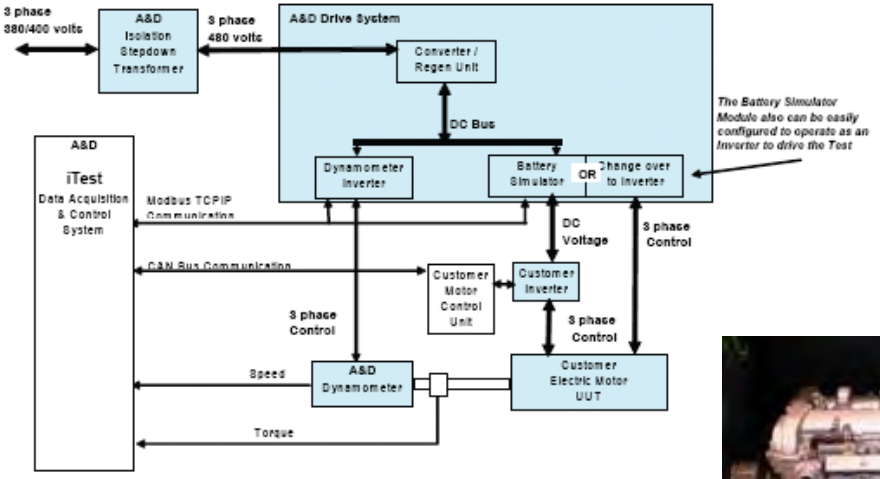
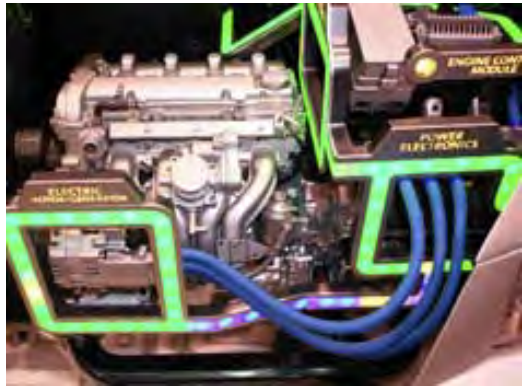


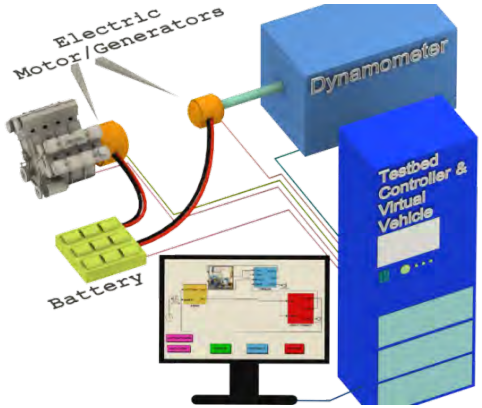
Figure 4 Flow chart and timing of the proposed educational activities

Laboratory Development

- In addition to the Power Electronics lab (AA) and Green Mobility Lab (Kettering), an Integrated Hybrid Electric System Laboratory is under construction.
- AND was selected to provide the equipment
- Equipment: 1M. Lab renovation: 1M (UM matching)







Kettering Green Mobility Lab

- Four experimental stations, 4 kW power at each station to study:
  - Batteries
  - DC-DC converters
  - Inverters
  - Motors
- One system-level station for vehicle level modeling.
- Courses utilizing DOE Lab:
  - Power Electronics for ME/EE
  - 2 Hybrid Vehicle System Courses
  - 2 DOE Sponsored Hybrid Vehicle Technology Courses (EE5XX/EE5YY)

Ann Arbor Power Electronics Lab

- 9 stations, each with
  - DC Electronic Load, 600W
  - Power Supply ±25V, 1A
  - Function Generator
  - Digital Multi-Meter
  - Oscilloscope 100 MHz
  - Power measurement and analysis
  - 50 MHz, AC/DC Current Probe
  - 100 MHz Differential Voltage Probe
  - 2MHz LCR meter
  - IR and Thermometer
  - Control Board

Collaboration

- This project involves three partner schools: UM Ann Arbor, UM Dearborn and Kettering University.
- Industrial collaborators that have been involved in our course and lab development include
  - GM, Ford, DTE, A&D
  - They serve the roles of equipment providers, invited lecturers, course material provider, and support our K-12 outreach activities.

Proposed Future Work

- Develop and offer
  - 504 Plug-in Vehicle Infrastructure (Fall, UMAA)
  - 402 Automotive Power Electronics Laboratory (Fall, UMAA)
  - 405 Vehicular Power Systems and Loads (Fall, UMD)
  - 406 Green Mobility Laboratory and associated courses (Fall, Kettering)
  - 503 Green Energy Manufacturing (Winter, UMAA)
  - 401 Integrated Hybrid Electric System Laboratory (Winter 12, UMAA, the last of 10 courses to be developed)
  - 102 Development of an Education Kit for Electric Automobiles (Winter 12)
  - 103 Saturday morning seminar series on Green Mobility and Web site development (Winter 12)

Summary

- 9 of the 10 proposed courses have been developed and taught annually.
- All three planned laboratories will be ready by Winter 2012.
- The 10 credit courses are expected to impact 300-500 students annually.
- The short courses will impact 100-200 professional engineers annually.
- K-12 and other consumer education and outreach activities should impact > 1,000 annually.
- Final goal: job creation through training and education