Advanced Electric Drive Vehicle Education Program: Development and Implementation of Degree Programs in Electric Drive Vehicle Technology

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Wayne State University

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Macomb Community College

NEXTENERGY

Economic Security through Energy Diversity

Wayne State University

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Educating the Workforce

Overview

Timeline

- Start – Jan 2010
- Finish - Dec 2012
- 40% Complete

Barriers

- Laboratory Development
- Curriculum Integration
- Funding for Internship

Budget

- Total project funding
  - DOE - $5.0 M
  - WSU/MCC - $1.25 M

Partners

- Macomb Community College (William Stark)
- NextEnergy (Jim Saber)

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Objective/Relevance

To prepare our current and future workforce with the education and skills necessary for the advancement and maintenance of electric-drive vehicles.

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Objective/Relevance

Develop and implement a comprehensive set of advanced educational programs in electric drive vehicles, including:

- a Master's Degree in Electric Drive Vehicle Engineering (EVE),
- a Bachelor's Degree in Electric Transportation Technology (ETT),
- an Associate's Degrees (AAS) in Automotive Technology and Electronic Engineering Technology,
- an undergraduate concentration and a graduate certificate program (GPC) in EVE

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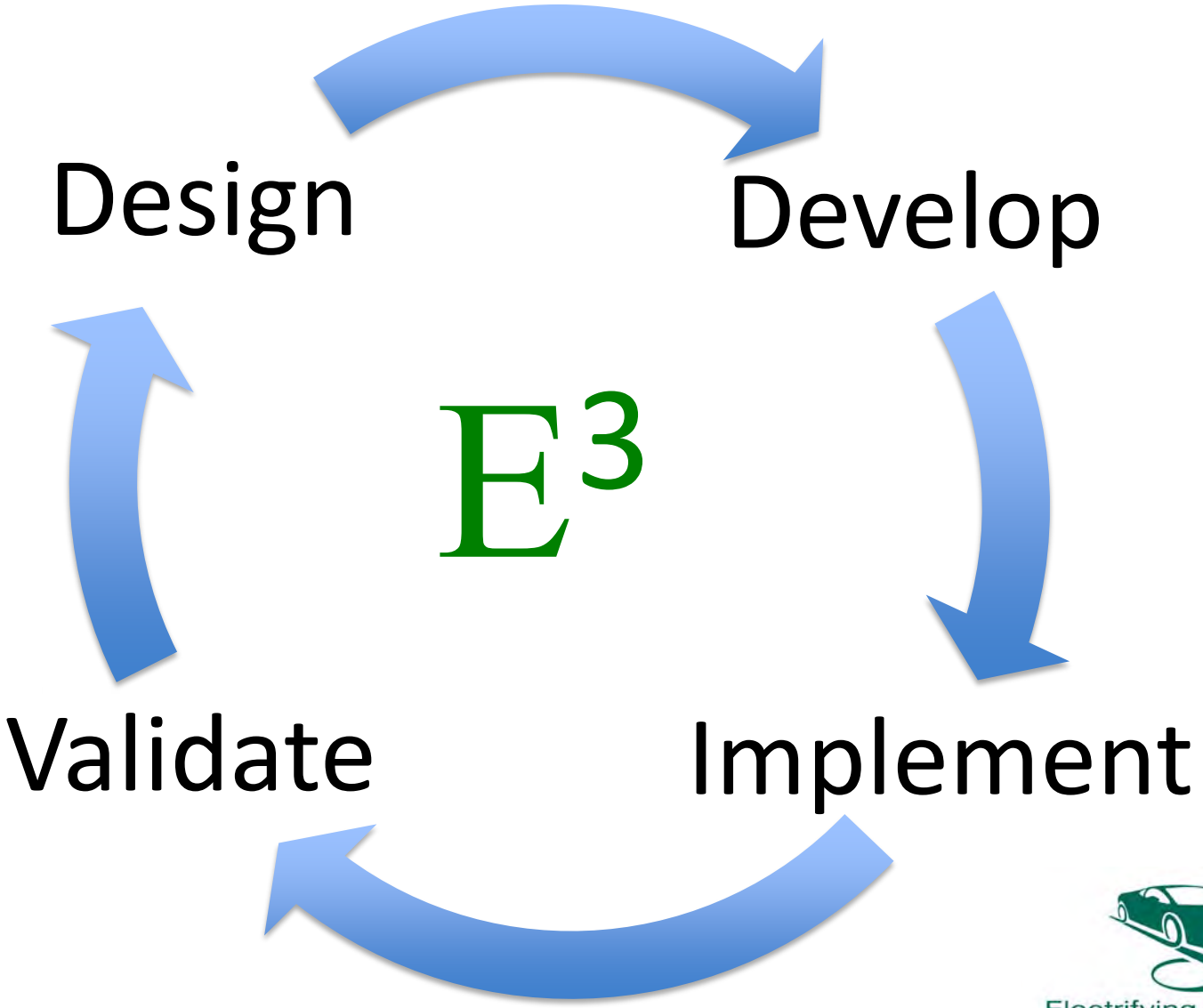
Approach



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Approach

Comprehensive

- Multidisciplinary
- Existing Strength

Industry Oriented

- Input from Industry
- Laboratory Intensive

Broad Impact

- Integrated 2 + 2 + 2 Curriculum
- Distant Learning
- ABET Accredited

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Milestone

Key Milestones	Date	Remarks
EVE Advisory Board Formed	February 15, 2010	14 Board Members
Launch EVE Website	April 1, 2010	8,484 visits (as of March 11, 2011)
E3 Workshop: *Meeting the Educational Needs of the Electric Vehicle Industry*	May 25, 2010	Over 100 participants
A Two-day Short Course for K-12 Science Teachers Offered	June 24 - 25, 2010	30 participants
M.S. Degree Program in EVE Offered	Fall Semester, 2010	11 courses offered with 162 students enrolled
Graduate Certificate Program in EVE Offered	Fall Semester, 2010	
B.S. Degree Program in ETT Offered	Winter Semester, 2011	4 courses offered
Energy Storage Laboratory Completed	Winter Semester, 2011	Laboratory modules developed for 2 courses.
Control and Integration Laboratory Completed	Winter Semester, 2011	Laboratory modules developed for 2 courses.
Electric Propulsion Laboratory Equipment Delivered	Winter Semester, 2011	Laboratory modules being developed
E3 Workshop: *Taking Charge of Electric Vehicle Industry's Educational Needs*	April 19 -20, 2011	Target 200 participants

Accomplishment/Progress (MS EVE)

Tasks	Status
Task 2.0 Development and Implementation of MS Program	Submitted the university-internal MS degree program proposal, and successfully and expeditiously obtained unanimous approvals from the College of Engineering, the Graduate School, and WSU Board of Governors.
Subtask 2.1 Program Objective	Posted the program vision, mission statement, program goals and program outcome, which will regularly be reviewed and revised as necessary based on inputs from the constituents. Policies on admissions requirement, program requirement, and graduation standards have all been established in the proposal submitted.

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Accomplishment/Progress (MS EVE)

Tasks	Status
Subtask 2.2 Curriculum Design	A curriculum development workshop entitled "EV's in Higher Education: Meeting the Educational Needs of the Electric Vehicle Industry" was held on May 25, 2010. An advisory board meeting was held on February 15, to seek inputs and feedback on the curriculum.
Subtask 2.3 Development	Established a total of 15 new graduate level courses, all with responsible faculty and instructors identified. Discussions have been begun and progresses have been made to integrate the 3 centralized labs with all 15 new courses. A proposal for graduate certificate program was submitted and approved by WSU Board of Governors on May 4, 2010.

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Accomplishment/Progress (MS EVE)

Tasks	Status
Subtask 2.4 Implementation	A year-round course offering schedule has been posted on the web, showing 13 of the 15 courses will be offered in Year 1. The remaining 2 courses require backgrounds from other proposed courses.
Subtask 2.5 Validation	Holding next E3 conference "Electrifying the Economy - Educating the Workforce: *Taking Charge of the Electric Vehicle Industry's Educational Needs* April 19-20, 2011 to begin validation process.

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Accomplishment/Progress (BS ETT)

Tasks	Status
Task 3.0 Development and Implementation of BS Program ***Subtask 3.1 Curriculum Design***	Submitted the university-internal BSETT degree program proposal, and successfully and expeditiously obtained unanimous approvals from the College of Engineering, and WSU Board of Governors.
Subtask 3.2 Courses and Laboratory Development	All proposed BSETT technical courses are under the development of program development team. The course syllabus for each proposed course, including course description, learning objectives, and course outlines, have been developed and included in the BSETT program proposal. All necessary laboratory equipments have been identified and ordered.

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Accomplishment/Progress (BS ETT)

Tasks	Status
Subtask 3.3 Implementation and Validation	Four courses were offered during the Fall 2010 semester to begin the program.
Subtask 3.4 Outreach	A two-day short course for K-12 science and technology teachers, community college instructor, or incumbent engineers or displace workers was delivered to 30 participants June 24 – 25, 2010.
Subtask 3.5 Provide Educational Pathway for Community College Graduates	The 2+2 Course Sequence for community college transfer students has been developed.

Accomplishment/Progress (AAS)

Tasks	Status
Task 4.0 Development and Implementation of Associate Degree Program.	Delivery of the 3 originally planned Courses are proceeding as experimental classes this Winter 2011 semester. Delivery of the AES courses are commencing this Winter semester 2011 as non - credit offerings convertible to credit upon request of students in the EET program. The AES courses will become a credit course by Fall 2011. The Capstone Course is being delivered as an experimental course this Winter 2011 semester.
Task 5.0 Expand Automotive and Electronic Engineering Technology Laboratories to provide hands on instruction for new courses.	Lab experiments for the 3 original courses are defined. Equipment selection is 100% complete.

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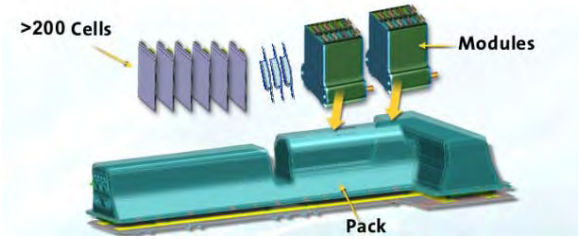
Technical Accomplishments: Energy Storage Laboratory

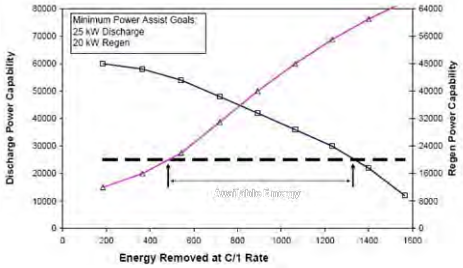
Pack and Module Characterization

ABC150

Bitrode Tester &
Thermal Chamber

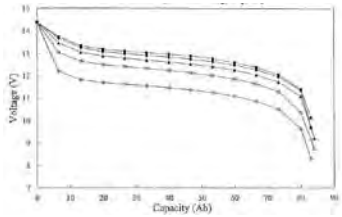


HPPC testing

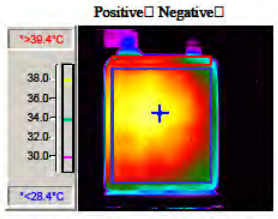


Battery Cell
Characterization

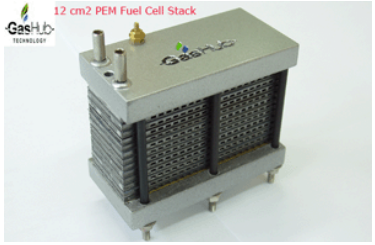
Maccor and Arbin
Cell Testers



Cell performance and
life tests

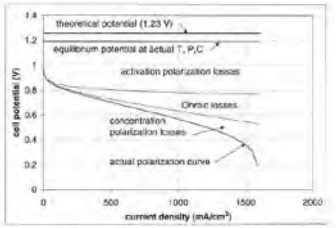


Thermal Imaging



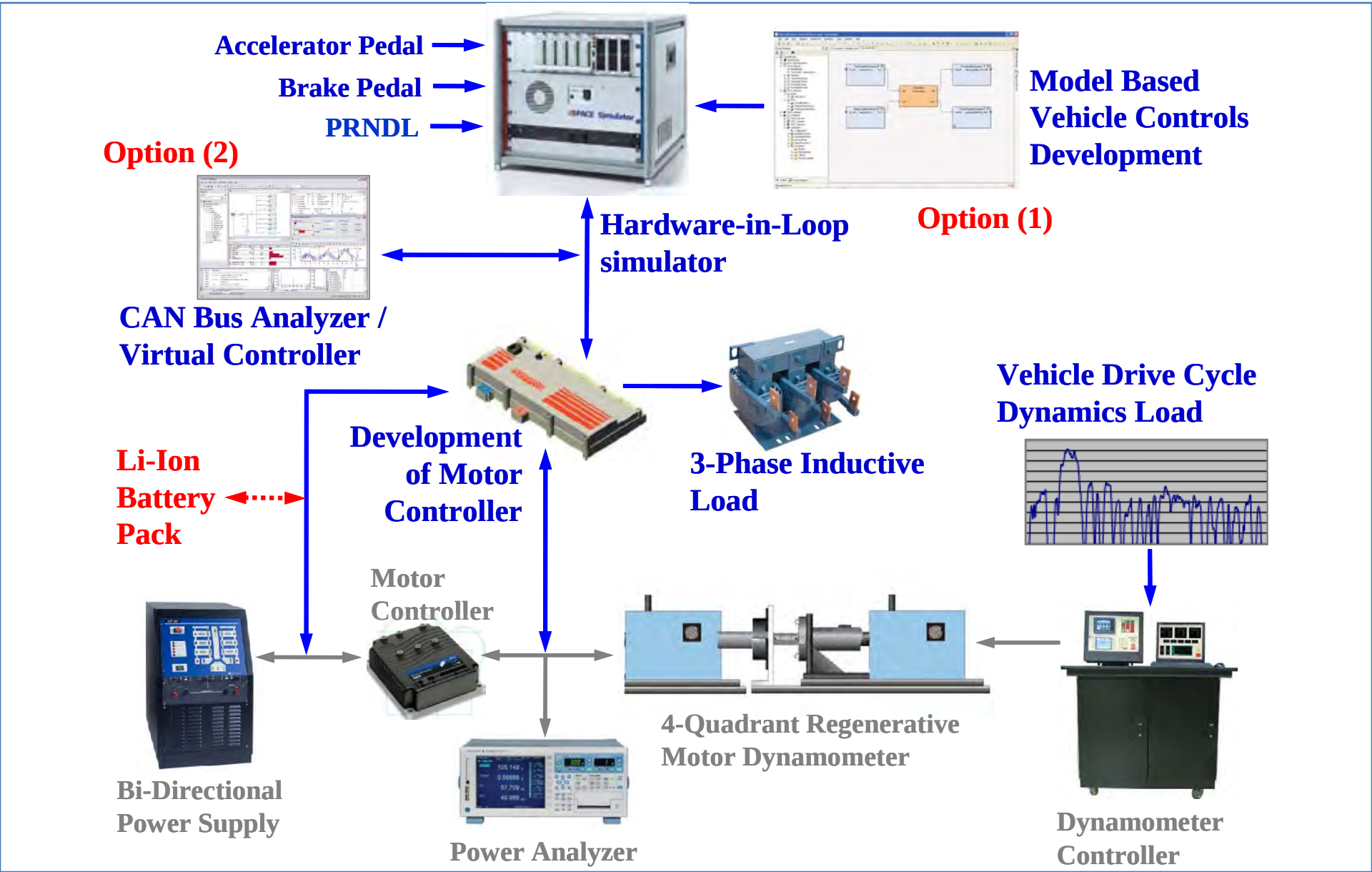
Cell Fabrication and
Materials Characterization

Glove Box for Li-Ion Cell
Fabrication

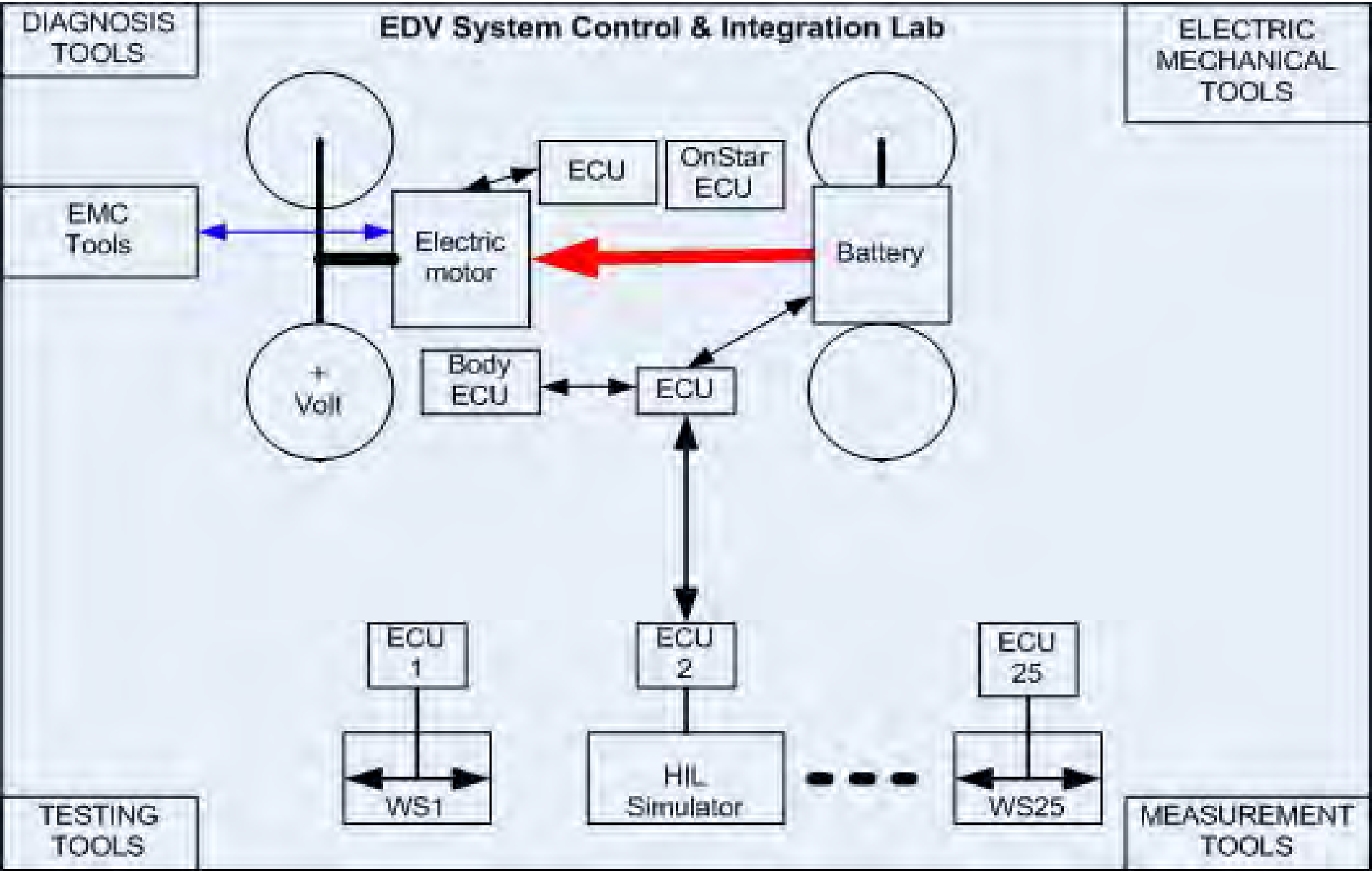


Fuel Cell Polarization
Curves

Technical Accomplishments: Electric Propulsion Laboratory



Technical Accomplishments: Control and Integration Lab



Collaboration

- Macomb Community College
  - AAS program
  - Articulation Agreement
  - Shared Laboratory Resources
- NextEnergy
  - E3 Conference: *Meeting the Educational Needs of the Electric Vehicle Industry*
  - Workshops
- Industrial Advisory Board
  - Internship
  - Guest Lecturers
  - Plant visits (Volt, A123)

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Future Work (Y2Q2 – Y3Q2)

- Complete equipment installation in three engineering labs
- Complete course development
- Implement course and laboratory modules
- E^3 Seminar Series and Workshop
- Summer Workshop (June – August) for K-12 Instructors from the region
- Summer Academy (June – August) for EV/HEV technology
- Short course for K-12 teachers and community college instructors

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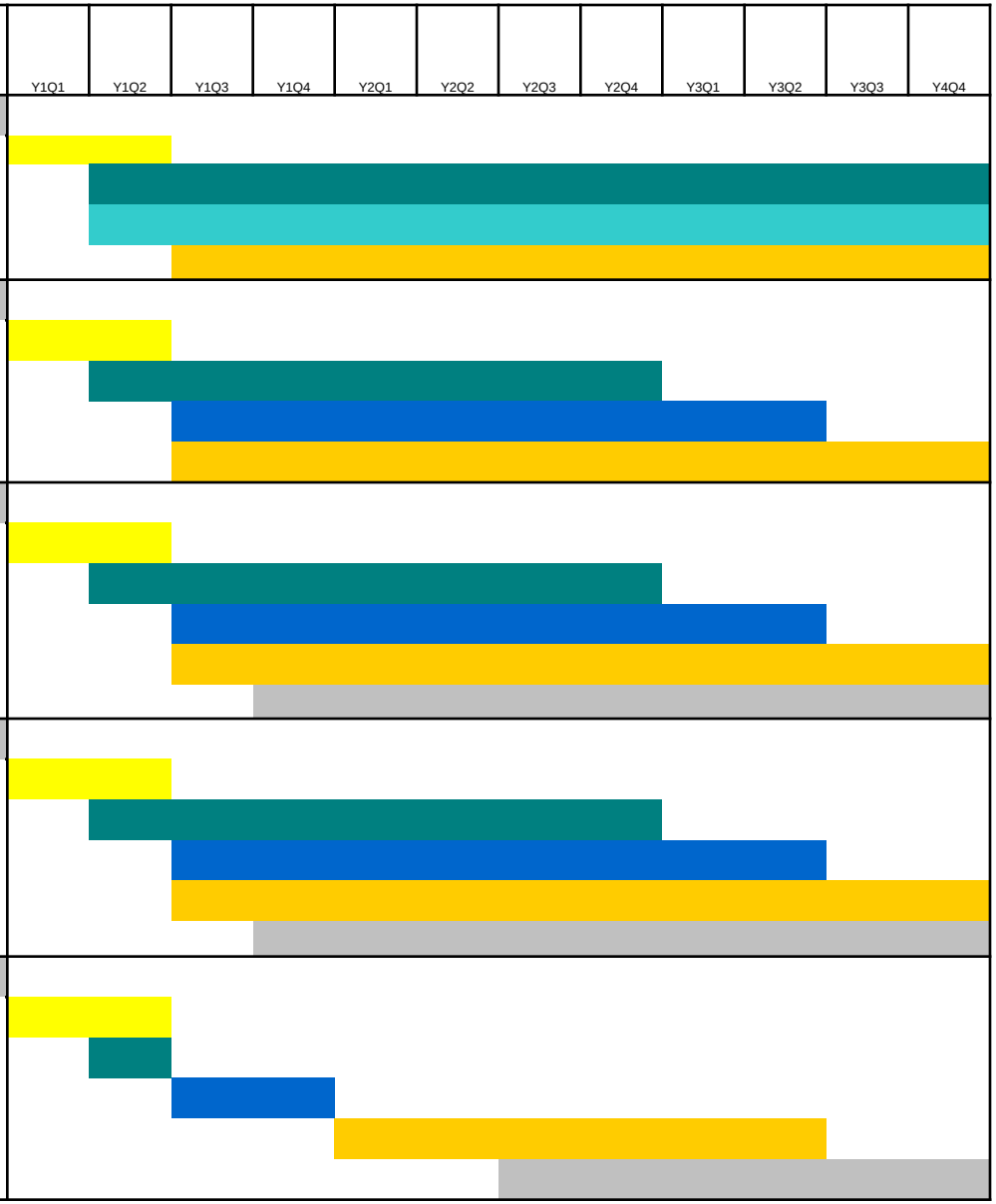
Future Work

SOPO	TASKS	PLANNED START DATE	PLANNED FINISH DATE
1	**1.0 Project Management and Planning**	Y1Q1	Y4Q4
1.1	Management Structures and Communication		
1.2	Curriculum Planning and Implementation		
1.3	Laboratory Planning and Implementation		
1.4	Outreach and Consumer Education Planning and Implementaiton		
2	**2.0 Develop & Implement MS Program**	Y1Q1	Y4Q4
2.1	Program Objective		
2.2	Curriculum Design		
2.3	Development		
2.4	Implementation		
3	**3.0 Develop and Implement BS Program**	Y1Q1	Y4Q4
3.1	Curriculum Design		
3.2	Courses and Laboratory Development		
3.3	Implementation and Validation		
3.4	Outreach		
3.5	Educational Pathway for Community College Graduates		
4	**4.0 Develop and Implement AAS Program**	Y1Q1	Y4Q4
4.1	Curriculum Design		
4.2	Courses and Laboratory Development		
4.3	Implementation and Validation		
4.4	Outreach		
4.5	Educational Pathway for Community College Graduates		
5	**5.0 Development EDVT Laboratories**	Y1Q1	Y4Q4
5.1	Laboratory Objectives		
5.2	Hardware and Equipment Acquisition		
5.3	Hardware and Equipment Installation		
5.4	Initiate Laboratory Sections of Lecture Courses		
5.5	Initiate stand-Alone Laboratory Courses		



Summary

Accomplished all objectives for the Year 1 (Q1-Q5)

- Project Management Structure
- Advisory Board
- Approval of EVE and ETT Degree Programs
- Development of EVE and ETT Courses
- Scheduling for Program Implementation
- Ordered Equipment for Three Integrated Laboratories
- Launched EVE Website
- E^3 Conference
- Developed Summer Academy and Workshop

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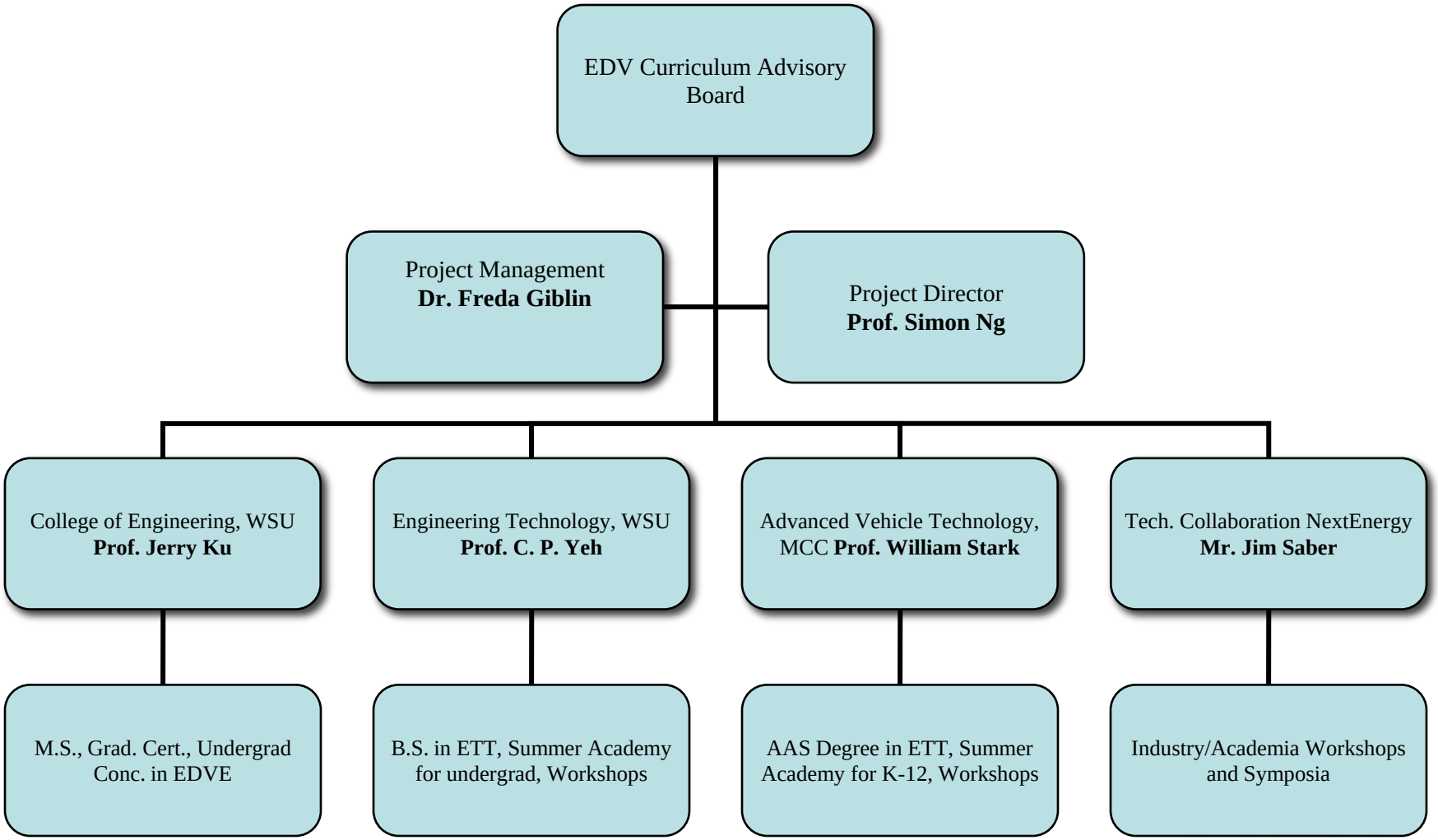
Summary: Organization Chart



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Summary: Advisory Board

- **Ray Boeman**, Director, Advanced Transportation Systems Program and NTRC User Facility, Oakridge National Laboratory
- **Ronald Gardhouse**, CEO of NextEnergy
- **Sen. Hansen Clarke**, State Senator from the First District (Detroit)
- **Michael Fetcenko**, VP of Ovonic Materials (parent company: Energy Conversion Devices, Inc.)
- **Ricardo Espinosa**, Vice President of Engineering, Azure Dynamics, Inc.
- **Nancy Gioia**, Vice President of Global Electrification, Ford Motor Company
- **David Gorsich**, Chief Scientist, U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC)
- **William Wallace**, Director, General Motors
- **James Jacobs**, President, Macomb Community College
- **Steven Kurmas,** President and COO, DTE Energy
- **Michael Finney**, President, Michigan Economic Development Corp (MEDC)
- **Prabhakar Patil,** President and CEO, Compact Power, Inc.
- **Bob Purcell**, Purcell & Associates, LLC
- **Hilary Ratner,** WSU Vice President for Research and Chair of the Advisory Board

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Summary: EVE Courses 1/2

EVE 5110	**ME**	**Fundamentals of Electric-drive Vehicle Engineering**
EVE 5120	**ChE**	**Fundamentals of Battery Systems for Transportation**
EVE 5130	**ChE**	**Fundamentals of Cell-powered Systems for Transportation**
EVE 5310	**ME**	**Electric-drive Vehicle Modeling and Simulation**
EVE 5410	**ECE**	**Power Electronics and Charging Infrastructure for Electric-drive Vehicles**
EVE 5430	**ECE**	**Modeling and Control of Electric-drive Powertrains**
EVE 5450	**ECE**	**Control and Optimization for Integrated Electric-drive Vehicle Systems**
EVE 5600	**IME**	**Electric-drive Vehicle Product and Infrastructure Development**

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Summary: EVE Courses 2/2

EVE 5620		**Energy Economics and Policy**
EVE 5700	**ME**	**Electric-drive Vehicle Capstone Design**
EVE 7310	**ChE**	**Materials Science Aspects of Lithium Ion Batteries**
EVE 7320	**ME**	**Electric-drive Vehicle Thermal Management**
EVE 7410	**ChE**	**Hydrogen Production and Storage for Vehicles**
EVE 7450	**ECE**	**Embedded Systems for Vehicles**
EVE 7990		**Directed Studies**
EVE 7995		**Special Topics**
EVE 7996		**Directed Research**
EVE 8999		**Master's Thesis**

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Optional Slides

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Course List & Scheduling – 1/2

	Fall 2010	Winter 2011
Funda-mentals	**EVE 5110** ***Fndmntls Elect-drive Vehicles*** **EVE 5120** ***Fndmntls Batteries***	**EVE 5130** ***Fndmntls Fuel-cell-powered Sys***
Infr str		**EVE 5410** ***Power Elect & Chrgng Infrstr***
Mode-ling	**EVE 5430** ***Modeling Ctrl of EV Powertrain***	**EVE 5310** ***EV Modeling & Simulation***

Course List & Scheduling – 2/2

	Fall (few Summer) 2010	Winter 2011
Product Design	EVE 5600 *EV Prod & Infrstr Development*	EVE 5620 *Energy Economics & Policy* EVE 5700 *EV Capstone Design*
Advanced Topics	EVE 7110 *Materials Sci of Batteries* EVE 7430 *EV Sys Ctrl & Optimization* EVE 7450 *Embdd Sys*	EVE 7320 *EV Thermal Management* EVE 7410 *Hydrogen Production and Storage*

EVE 5110 Fundamentals of Electric-drive Vehicle Engineering

General backgrounds of electric and hybrid electric vehicle (HEV) related technologies, including technical concepts, design factors, energy analysis, and unified modeling approach. Discussion of hybridization, hybrid powertrain architectures, IC engines for hybrid electric vehicles, associated types of transmissions used, fuel-cell vehicles (FCV), plug-in's, and on-board energy storages. Introduction to beginning-level computer tools. Introduction to control and optimization fundamentals. Key issues in future developments.

(F; 4 cr.)

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EVE 5120 Fundamentals of Battery Systems for Transportation

This course addresses the fundamental electro-chemistry and design aspects for secondary batteries for electric propulsion applications at battery cell, module, and system levels. A descriptive overview of battery technologies including lead acid, nickel metal hydride, and lithium ion batteries will be provided together with their application to hybrid and electric vehicle applications. (W; 4 cr.)

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EVE 5130 Fundamentals of Fuel-cell Powered Systems for Transportation

This course addresses the fundamental process and materials aspect of fuel cell technology, the reforming of hydrocarbon fuels to hydrogen, and the application of fuel cell for transportation. The course includes a review and discussion of various types of fuel cells, materials properties of electrodes and polymeric membranes, and electrochemical mechanisms. Reforming of various types of hydrocarbon fuel to hydrogen and the application of reforming technology to stationary and vehicle fuel cells will be discussed. (F; 4 cr.)

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EVE 5310 Electric-drive Vehicle Modeling and Simulation

Fundamentals in modeling of energy conversion, storage, utilization and optimization of complete ground vehicle systems for conventional, electric and hybrid vehicles. Modeling and simulation for a system consisting of components such as IC engine, electric machine, energy storage, and/or fuel cells, with the necessary controllers for specific power flow processes in hybrid and electric vehicles using Matlab/Simulink, Modelica/Dymola, dSPACE, GT-Drive, and/or AVL-Cruise. (W; 4 cr.)

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EVE 5410 Power Electronics for Electric-drive Vehicles

Control of electric energy using solid-state devices, diodes, thyristors, triacs; mathematical analysis of circuits containing these devices; power converters and control; solid-state drives for motor control. (S; 4 cr.)

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EVE 5430 Modeling and Control of Electric-drive Powertrains

Understand how power electronic circuits and motors are combined with battery systems, internal combustion engines to form an EDV (electric drive vehicle) power train. The course will cover dynamic modeling and control of power electronics, motors, battery systems, and power regeneration. Powertrain system components, such as motors, DC/AC converters, DC/AC inverters, battery systems, and engines, will be discussed and their basic models and component integration will be derived. Control methods will be discussed. The powertrain systems test bench in the EDV Integrated Control Laboratory will be utilized to gain hands-on knowledge in applying basic understanding and simulation experience to a real system. Models and control strategies will be evaluated by simulating an EDV powertrain in Matlab/Simulink and dSpace Hardware-in-the-Loop (HIL) Simulator. (F; 4 cr.)

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EVE 5450 Power Electronics and Charging Infrastructure for Electric-drive Vehicles

Prereq: EVE 5430. To understand how to control a system using modern control theory, how to optimize the performance of a system using various optimization technologies, and how to apply the control and optimization technologies to EDV (electric drive vehicle) systems. The course will start with system models using state equations and their connections with transfer functions. Key properties of systems, such as stability, controllability, and observability will be discussed. Controller design using pole placement will be presented. Optimal control techniques will be derived. These materials will be taught in the framework of EDV systems. Applications to EDV systems will be illustrated. Optimal controller for EDV systems will be designed and simulated using Matlab/Simulink. Performance of controlled systems will be evaluated. (W; 4 cr.)

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EVE 5600 Electric-drive Vehicle Product and Infrastructure Development

This course will provide students the design and development experience of electric vehicle products. It will demonstrate process framework related to electric vehicle product design and concept validation methodology. Also, this course will provide an in-depth understanding of the product realization life cycle, business and process issues necessary for making appropriate business and technical decisions. The students in this class are expected to conduct team-based system realization projects to develop innovative and competitive electric vehicle product design and/or infrastructure concepts. The goal of this exercise is to learn product development principles and methods in electric vehicle product realization. (F; 4 cr.)

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EVE 5620 Energy Economics and Policy

This course explores the theoretical and empirical perspectives on individual and industrial demand for energy, energy supply, energy markets, and public policies affecting energy markets. It discusses aspects of coal, oil, natural gas, electricity, and nuclear power sectors and examines energy tax, price regulation, deregulation, energy efficiency and policies for controlling emissions. (W; 4 cr.)

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EVE 5700 Electric-drive Vehicle Capstone Design

Prereq: EVE 5110, and EVE 5310 or EVE 5430. To simulate a realistic competitive environment similar to the workplace, the class is divided into teams competing on same or similar Electric Drive Vehicle (EDV) system design project. Team score consists of half of student's final grade. Individual efforts are earned through homework, individual design exercise/project, quizzes, and peer review. The team design projects usually are on contemporary EDV issues with relevant vehicle powertrain and energy system contents. The design analyses usually include energy (thermal-fluid, electric), environmental, safety, economic and public impact/educational analyses. Each team should identify a mentor from the EDV faculty or industry expert; or the instructor will act as the mentor. The class format includes: lectures, computer lab, individual and team presentations, and weekly group discussion and interactions. (W; 4 cr.)

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EVE 7110 Materials Science Aspects of Lithium Ion Batteries

The development of advance battery materials has led to the high energy batteries now in widespread use in portable electronics applications such as laptop computers and cellular telephones. Lithium-ion batteries have improved in energy density to the point where the introduction of electric vehicles is now underway. This course provides a fundamental understanding of the role of advances in materials science and engineering to the development of these high energy batteries. Details on the novel synthesis of these new materials together with their physical and electrochemical characterization will be included. The relationship between materials structure-composition and performance will be emphasized. Promising new concepts and future trends for next generation of energy storage systems will be discussed. (S; 4 cr.)

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EVE 7320 Electric-drive Vehicle Thermal Management

Prereq: EVE 5110 and EVE 5310. To understand, model and numerically simulate thermal management scenarios for electric drive battery to ensure optimum electrochemical performance of cell charge acceptance, power and energy capability, reliability, cycle life, safety and cost. A secondary purpose of the course is to expand such thermal management analyses in an integrated approach to include other components such as electric machine, inverter, fuel cell (in FCV's) and internal combustion engines (in HEV's). Simulations are based on 2 major approaches – computational fluid dynamics (CFD) for detailed analyses at the component level, and phenomenological equivalent circuit-based modeling (ECM) for system level. (F; 4 cr.)

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EVE 7410 Hydrogen Production and Storage for Vehicles

The hydrogen economy depends on not only fuel cells but the production and storage of hydrogen fuel. This course focuses on the engineering of hydrogen production technologies including reformation of hydrocarbons, electrolysis, photoelectrochemistry, and the thermal decomposition of water. It also provides a background in hydrogen storage technologies including high pressure compressed gas, liquid hydrogen, metal hydrides, and chemical hydrides. The gravimetric and volumetric energy density are compared to goals for fuel cell hybrid vehicles. Energy efficiency and thermal issues related to hydrogen storage are also addressed. (W; 4 cr.)

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EVE 7410 Embedded Systems for Vehicles

Prereq: EVE 5430. Introduction to advanced embedded processors. Advanced processor core, power modules, auxiliary execution engine, display interface, memory controller, USB controller, DMA, I/O, initialization and configuration, programmable serial controller, serial audio interface, and video input. Embedded operating systems. Algorithm implementation on advanced embedded processors. (F; 4 cr.)

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