AC 2007-307: IMPLEMENTING AN INTEGRATED LEARNING ENVIRONMENT FOR HYBRID ELECTRIC VEHICLE TECHNOLOGY

Gene Liao, Wayne State University

Dr. Liao received the B.S.M.E. from National Central University, Taiwan; M.S.M.E. from the University of Texas; Mechanical Engineer from Columbia University; and the Doctor of Engineering degree from the University of Michigan, Ann Arbor. He is currently an associate professor at the Wayne State University. He has over 15 years of industrial practices in the automotive sector prior to becoming a faculty member.

Chih-Ping Yeh, Wayne State University

James Sawyer, Macomb Community College

Implementing an Integrated Learning Environment for Hybrid Electric Vehicle Technology

Abstract

Given heightened concerns over the environmental and limited fossil fuels, a clear trend toward hybrid electric vehicles (HEV) is emerging. Hybrid electric vehicles are different from traditional automobiles in that an HEV utilizes two propulsion systems in its powertrain and involves high electrical voltage. Automotive engineers and technicians must possess HEV-specialized knowledge acquired through additional training in order to develop and maintain these vehicles. This training includes propulsion systems, control systems, regulations and safety. Currently automobile manufacturers are training their HEV engineers and technicians entirely "in-house," which limits the number of engineers and technicians available for the growing hybrid market. There is a clear need for a systematic training program on HEV. This paper describes a funded project whose goal is to fill this need by developing an integrated learning environment for HEV technology. This project targets engineering/engineering technology students in 4-year universities, automotive technology students in community colleges, automotive engineers and technicians in industries, and K-12 technology teachers.

1. Introduction

The U.S. spends about $2 billion a week on oil imports, mostly for transportation fuel [1]. This need for oil affects our national security. Also, vehicle emissions are the leading source of U.S. air pollution, which jeopardizes the health of citizens. In the era of rising environmental sensibility and limited, even depleting supplies of fossil fuel, the development of a new environmentally friendly generation of vehicle becomes a necessity. Hybrid electric vehicles (HEV), which combine an electric drive-train with an internal combustion engine (ICE) or fuel cell, are one means of increasing propulsion system efficiency and decreasing pollutant emissions [2 – 5]. The expected marginal return of each additional mile per gallon in terms of fuel efficiency will significantly reduce the level of greenhouse gasses emitted via automobiles, thus slowing the rate of global warming and reducing the rate of world pollution.

The hybrid vehicle first reached the market in 1999 and has become increasingly popular, with more than 200,000 sold in the United States in 2005. At present eleven hybrid vehicle models are on the road in the U.S. and sales are projected to increase as the range of choices grows: 44 hybrids are expected to be on sale by 2012, according to J.D. Power Automotive Forecasting [6]. The development of power sources for hybrid vehicles has rapidly increased in recent years, the configuration of which is distinctly different from traditional vehicles. According to the J. D. Power and Associates 2003 Hybrid Vehicle Outlook, HEV sales are expected to exceed 500,000 units annually by 2008, and 872,000 units by 2013 [7]. The steadily increasing production of HEVs by the automotive industry coupled with the specialized set of skills required to accommodate the vehicles' hybrid power configuration, has created a demand for more knowledgeable hybrid powertrain engineers and technicians.

In response to the emerging area of HEV, several research collaborations between universities, automotive manufacturers, and government agencies have been formed [8 - 15]. However, neither systematic courses nor degree programs have been developed to train automotive technicians in the emerging technology of HEV. To date, no automotive technician program in HEV has been developed for the community college level. The required education includes safety, regulations, control systems and propulsion systems. Currently automobile manufacturers are training their HEV engineers and technicians entirely "in-house," which raises the cost of producing HEVs for automotive manufacturers, and ultimately limits the number of automotive engineers and technicians available for the growing hybrid vehicle market. There is a clear need for a systematic training program on hybrid vehicle technology.

This paper describes a funded project that address the critical need for HEV trained automotive engineers and technicians that currently exists, and will continue to grow, by creating a curricular program to train automotive engineers and technicians for work specific to HEVs. This project targets engineering/engineering technology students in 4-year universities, automotive technology students in community colleges, automotive engineers and technicians in industries, and K-12 technology teachers.

2. Objectives of HEV Learning Environment

In order to develop an integrated HEV learning environment, a partnership has been formed between faculty of the engineering technology program at Wayne State University (WSU) and Macomb Community College (MCC) automotive technology program. The partnership also includes industrial partners from major automobile manufacturers and suppliers. The intent of this project is to develop collective effort, among educators, industry, and government agency, to make positive, continual, and lasting contribution for education on the emerging technology for green transportation.

This project aims to develop an industry-based learning environment for HEV automotive engineering technologists, service technicians and K-12 technology teachers. The main objective stemming from this goal is to address the critical need for training automotive engineers and technicians and educating students in this new and emergent technology of HEV. To enable us to make a positive, continual, and lasting contribution to the HEV education, we specifically set the following objectives for the project:

- Prepare students and returning engineers/technicians to be skilled HEV professionals
- Enable students to acquire industry-based experience in HEV technology through a hands-on-laboratory environment
- Expose HEV technology to K-12 teachers, corporate partners, and automotive professionals
- Initiate a pilot program for Automotive Service Excellence (ASE) certification in hybrid vehicles
- Prepare community college students in Associate of Applied Science (AAS) programs to successfully transfer to the WSU's Engineering Technology program to earn a Bachelor of Science and Engineering Technology degree.

3. Implementation

Leveraging the strengths of each institution – the WSU's experience in engineering research and producing talented Bachelor and Master level graduates and the MCC's reputation for innovation and educating highly-qualified automotive technicians – and pooling their respective resources (i.e., their programs, faculty, facilities, location, and industry ties), a series of activities were held to realize the stated objectives. They were as follows:

- Created an advisory committee to oversee the program
- Integrated HEV curriculum with existing AAS program in Automotive Technology
- Revised existing courses, developed HEV specific courses, and delivered these courses
- Developed and delivered a two-day short course
- Developed and delivered seminars and workshops
- Created an HEV specialized laboratory
- Created internship and co-op opportunities, plant visits, and an expert lecturer series
- Developed framework that will be used for ASE certification
- Provided transfer student advising by university faculty at community college

3.1 Advisory Committee

Initiating the development and implementation of all activities requires a system of coordination for exchange of information and resources and effective utilization of institutional strengths. Collaboration among faculty and administrators from both institutions and their industry partners was formalized through the creation of an advisory committee, which meets regularly to develop and implement the planned activities and monitor progress of the project. To create this advisory committee, both institutions extend their existing collaborative partnership between their faculties to incorporate industry partners.

3.2 Curriculum Integration

The current automotive service program at the community college has 500 students. The existing program is traditional and teaches students the eight bodies of knowledge required for ASE Master Certification. The primary objective is to prepare students and working technicians to be skilled HEV technicians. To achieve this objective, the MCC in collaboration with WSU and its industry partners integrate HEV education courses into the Associate of Applied Science curriculum in Automotive Technology.

The HEV curriculum is shown in Table 1. The structured curriculum is divided into three sequential sections: Automotive Fundamentals, Hybrid Vehicle Fundamentals, and Automotive Intermediate. Section I, Automotive Fundamentals, consists of basic courses of critical importance to automotive systems in areas matching the HEV focus area. A student completes this section by completing the four required courses for 11 credit hours. All courses are offered by the community college and are currently enrolling students.

Section II, Hybrid Vehicle Technology, requires two new courses that are developed as part of this project. Together there are total six credit hours, covering fundamental knowledge in hybrid vehicle technology. Students must take both Section I and II (for a total of seventeen credit hours) to complete the HEV training program.

Table 1. Curriculum for HEV technology

Section I: Automotive Fundamentals		
Course No.	Course Title	Credit Hours
AUTO 1000	Automotive Systems	3
AUTO 1030	Automotives Electronics	3
AUTO1200	Automotive Engines	3
AUTO 2410	Advanced Automotive Electronics	2
Section II: Hybrid Vehicle Technology		
Course No.	Course Title	Credit Hours
new	Hybrid Vehicle Fundamentals	3
new	Hybrid Powertrain and Control	3
Section III: Automotive Intermediate (Additional Optional Courses)		
Course No.	Course Title	Credit Hours
AUTO1100	Automotive Brake Systems	3
AUTO 1320	Automotive Transmission Theory and Diagnosis	2
AUTO1400	Automotive Starting and Charging Systems	2
PHED 2070	Wellness – Focus prevention, intervention, treatment of disease, illness, injury	3

Section III, Automotive Intermediate, consists of four optional courses that students may select to strengthen their knowledge in specific areas. Since HEVs contain both an internal combustion engine and an electrical motor using high-voltage (300 Volts), safety has been a primary concern for all who work on hybrid vehicles. A work place safety course was included as an optional course for all HEV students.

3.3 Course Development and Revision

To integrate the HEV curriculum into the Automotive Technology Program, one existing course is revised and two new courses in HEV Technology are developed. For Section I of the curriculum, AUTO-1000 *Automotive Systems* is revised to include HEV technology in the automotive system overview. The revised *Automotive Systems* course is required for all AAS students in the Automotive Technology program at community college. The two new courses that form the requirements for Section II of the curriculum are *Hybrid Vehicles Fundamentals* and *Hybrid Powertrain and Control.* These two courses target current students as well as returning or lifelong students already working in the automotive technician field.

Table 2 lists the contents of the two HEV courses. The development of these courses is based on an existing HEV course (MCT6150 - *Hybrid Vehicle Technology*) currently offered at WSU, input from industrial partners, and manuals and training materials provided by HEV manufacturers. The course development activities include the initial development of the course materials, delivery of the course, and modification of the course contents and materials based on student feedback. The finalized course materials will be posted on WSU and MCC web sites for dissemination.

Table 2. Course contents for the two HEV technology courses

Hybrid Vehicle Fundamentals	Hybrid Powertrain and Control
HEV facts: • Brief background • Operational advantages • Operational disadvantages	Energy and power considerations: • Energy capacity and energy density • Power and power density • Overview of electro-mechanical energy converters • Recharge power levels • Limits on regenerative braking systems
Legislative and regulatory considerations: • Relevant regulatory agencies • Existing regulations	Characteristics of internal combustion engines: • Torque and power curves • Comparison to electric motors • Efficiency maps
Introduction to HEV strategies: • Vehicle performance requirements • Vehicle power usage patterns • Series and parallel hybrids • Other Hybrid classifications	Characteristics of electric motors: • Available types of electric motors • Torque curves • Power ratings • Controller strategies
Important additional considerations: • Structural integrity • Safety (i.e., crash, explosion, Shacks) • Manufacturability (Production & Prototyping) • Availability & cost of various components • Occupant amenities	Characteristics of battery and battery packs: • Discharge curves • Reconciling the inconsistency of available data • Percent and near-term battery technology
Likely directions of future technology: • Advanced battery technology • Flywheels • Ultra-capacitors • Turbines and fuel cells	HEV transmission and torque converter: • Electrical transmission system • Types of transmission used in HEV
	HEV control strategy: • Vehicle lunched by battery and motor • Engine start and stop at city driving cycle • Fuel cut-off during vehicle deceleration

3.4 Two-Day Short Course Development

In addition to the two fundamental HEV courses, a two-day short course is developed for automotive engineers who wish to gain an in-depth understanding of hybrid powertrain configurations and their energy management schemes. The course consists of three modules as listed in Table 3.

Table 3. Course contents for the two-day program

Modules	Contents	Lecture hours
Hybrid Vehicle Fundamentals – Overview	• Concepts and impacts • Hybrid power units • Hybrid power system configurations	4
Electric Machines and Power Systems	• Electric motor characteristics and types of hybrid power units • Electric energy storage systems • Battery packs with charging/discharging and regenerating systems • Power electrics (inverter and dc-to-dc converters)	4
Modeling and Analysis of Hybrid Vehicles	• Vehicle control systems simulation • Vehicle data (mass, tire rolling resistance, road load) and driving cycles (city, highway and US06) • Types of hybrid powertrain architectures and drive train simulation • Vehicle energy management simulation: fuel economy and vehicle performance predictions	6

3.5 Seminars and Workshops Development

The participated community college has offered a variety of workshops and seminars to various groups with a stake in learning more about HEV technology. These workshops and seminars are tailored to meet the specific needs of each group. More specifically, we created:

1. *Workshop for K-12 Technology Teachers*: 40 secondary schools and approximately 120 teachers provides a forum for this project to educate technology teachers.

2. *Workshop for emergency first responders*: First responders to traffic accidents (i.e., police, fire, and ambulatory personnel) need to be educated on the safety practices with respect to HEVs. Police and fire academies are located on the community college campus and are instrumental in the design, instruction, and marketing of these workshops.

3. *Informational seminars for corporate partners*: These seminars are made available in conjunction with the local automobile dealers association.

4. *Informational seminars for automotive repair facilities*: There are approximately 4,845 regional repair facilities. These seminars intend to introduce the technology and safety of hybrid electric vehicles.

5. *Informational seminars for the general public:* These seminars focus on safety, which may be offered for credit and non-credit.

3.6 Framework for Automotive Service Excellence Certification

The participated community college plans to initiate a pilot program for Automotive Service Excellence (ASE) certification in hybrid vehicle technology. The current automotive technician program is ASE certified in all eight areas in which ASE offers certification. Currently ASE does not offer a certification program in HEV technology – a gap that may be filled with this HEV program for automotive technicians. The program's potential to become the pilot program for ASE certification in hybrid electric vehicles extend the program's impact on the auto industry nationally and shape HEV automotive programs across the country in community colleges seeking ASE certification.

3.7 Student Transfer Credit Evaluation and Advising

Faculty from each institution collaborate, along with their industry partners, to create corresponding courses that will benefit their students collectively, and provide for a smooth track within the existing Associate and Baccalaureate programs in automotive technology and engineering technology, respectively. Particularly, the WSU faculty holds a bi-weekly student advising section at the community college campus for student transfer credit evaluation. The advising sections aim to provide community college students the guidelines for pursuing the Bachelor of Science Degree in Engineering Technology (BSET) at WSU, and the plans for maximizing their transfer credits.

4. Summary

Given heightened concerns over the environmental and limited fossil fuels, a clear trend toward hybrid electric vehicles is emerging. Currently automobile manufacturers are training their HEV engineers and technicians entirely "in-house," which limits the number of automotive engineers and technicians available for the growing hybrid vehicle market. There is a clear need for a systematic training program on HEV. This paper describes a funded project whose goal is to fill this need by developing an integrated learning environment for HEV technology. This project targets engineering/engineering technology students in 4-year universities, automotive technology students in community colleges, automotive engineers and technicians in industries, and K-12 technology teachers. It is our intent in this project to develop collective effort, among educators, industry, and government agency, to make positive, continual, and lasting contribution for education on the emerging technology for green transportation. The work is still ongoing but initial student reaction has been quite enthusiastic.

Acknowledgment
This work was supported in part by the National Science Foundation under grant number DUE-0501546.

References

1. U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www.eere.energy.gov.

2. Burke, A.F., “Hybrid/electric vehicle design options and evaluations,” *Society of Automotive Engineers (SAE) paper* 920447, 1992.
3. Ronning, J.J. and Grant, G.L., “Global hybrid electric vehicle markets and missions,” *SAE paper* 1999-01-2946, 1999.
4. Walters, J., Husted, H. and Rajashekara, K.,“Comparative study of hybrid powertrain strategies,” *SAE paper* 2001-01-2501, 2001.
5. Hirose, K., Abe, S. and Killmann, G., “Overview of current and future hybrid technology,” *SAE paper* 2002-33-0016, 2002.
6. “Hybrid and diesel vehicles expected to represent 11 percent of market share in next seven years,” *JD Power and associates*, www.jdpower.com, June 28, 2005.
7. *JD Power and associates*, www.jdpower.com, June 2003.
8. Denton, K., Goldman, J., Hays, B. and Haytt, C., “2000 University of Maryland FutureTruck design description,” *SAE paper* 2001-01-0681, 2001.
9. Conley, J., Caly, B., Waters, R., Toth-Nagy, Cs., Taylor, S., Smith, J. and Atkinson, C., “The development of a fourth generation hybrid electric vehicle at West Virginia University,” *SAE paper* 2001-01-0682, 2001.
10. Adcock, J., Allen, B., Cleary, R., Dobbins, C. and etc., “Design and construction of the University of Tennessee, Knoxville FutureTruck 2000/2001 parallel hybrid vehicle,” *SAE paper* 2002-01-1213, 2002.
11. Parten, M., Maxwell, T. and Jones, J., “Advanced vehicle research in a multidisciplinary project laboratory,” *Proceedings of American Society for Engineering Education (ASEE) Annual Conference and exposition Section 3626*, 1999.
12. Talbert, J., Wicks, F. and Wilk, R., “Evalusting the benefits of Hybrid Electric Vehicles concepts,” *Proceedings of ASEE Section 2633*, 2001.
13. Rizkalla, M., Yokomoto, C., Pfile, R., Sinha, A., El-Sharkaway, M., Lyshevski, S. and Al-Antably, A., “Application of computer-based power electronics to electric vehicle technology, an interdisciplinary senior course,” *Proceedings of ASEE Section 3432*, 2000.
14. Chau, T. and Chan, C., “Electric vehicle technology – a timely course for electric engineering students,” *International Journal of Electrical Engineering Education*, Vol. 35, pp. 212-220, 1998.
15. Guezennec, Y., Rizzoni, G., Washington, G. and Yurkovich, S., “The OSU-GATE program: development of a graduate program in hybrid vehicle drivetrains and control systems at the Ohio state University,” *Proceedings of ASEE Section 2255*, 2001.