AC 2011-197: ESTABLISHMENT OF AN INTEGRATED LEARNING ENVIRONMENT FOR ADVANCED ENERGY STORAGE SYSTEMS: SUPPORTING THE SUSTAINABLE ENERGY DEVELOPMENT

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Establishment of an Integrated Learning Environment for Advanced Energy Storage Systems: Supporting the Sustainable Energy Development

Abstract

There is a great need of electrical energy storage for the effective commercialization of renewable energy resources, load-leveling, and transportation electrification. The steadily increasing capacity of generating power from renewables and production of electric drive vehicles by the industry coupled with the specialized set of skills required to accommodate the energy storage systems in both the stationary and transportation sectors, have created an urgent and continuous demand for more knowledgeable energy storage engineers and technicians. This paper presents the collaboration between university and community colleges to create an advanced energy storage curriculum; setup an industrial-based energy storage laboratory; develop and deliver a short course for on-site training of engineers, technologists, and college instructors working in the alternative energy and advanced automotive propulsion fields; develop and deliver a series of workshops and seminars for K-12 science teachers, corporate partners, energy and automotive professionals; and provide transfer student advising by university faculty.

1. Introduction

The growing demand for energy and the increasing concerns about man-made climate changes have called for clean and sustainable energy development. Generating electricity from renewable, clean energy sources such as wind and solar as well as driving ultra fuel-efficient vehicles are promising solutions to the energy development strategies. A central feature here is maintaining a secure and constant supply of electrical energy, derived from a widely distributed supply infrastructure of generators subject to unexpected variation in their output. These variable output energy sources require energy storage facilities to maintain customer requested output and guard against overcapacity investments. Another important factor related to the need for electric energy storage is the transportation electrification. The steadily increasing capacity of generating power from renewables and production of electric drive vehicles by the industry coupled with the specialized set of skills required to accommodate the energy storage systems in both the stationary and transportation sectors, have created an urgent and continuous demand for more knowledgeable energy storage engineers and technicians. The required education includes safety, regulations, maintenance, control systems, and system integration for energy storage devices.

Intensive research work has been done on different types of energy storage systems from a variety of perspectives. However, the educational effort on energy storage is inefficient for the current and future needs. Many universities/colleges have offered curricula in renewable and sustainable energy [1-8], but only a few universities in the nation and around the world have specific educational program on energy storage technologies [9-10]. In a statement by the U.S. Secretary of Energy before the Budget Committee in the United States Senate, Smart Electricity Infrastructure was one of the priorities. The goals of the Smart Electricity Infrastructure program include improved energy storage, security, smart grid technology, and system reliability [11]. The state of Michigan has created several incentives and programs to assist companies working in energy storages and batteries through the 21st Century Jobs Fund and as stated by James C. Epolito, president and CEO of the Michigan Economic Development Corporation, “It’s estimated that we can create more than 60,000 new jobs by investing in alternative energy, including advanced battery storage, biofuels, and wind and solar energy” [12]. There is a clear need for a systematic training program on energy storage technology, particularly in regions where the sustainable energy development in electricity generation and automotive manufacturers and their advanced battery suppliers are highly concentrated. The goal of this collaborated curricula development is to fill this need by developing an industry-based learning environment to prepare students and returning engineers or technicians to be skilled energy storage engineers or technicians in both the stationary and vehicular sectors.

A majority of states in the USA have passed their Renewable Portfolio Standards, which set aggressive goals to achieve a certain percentage of electricity generated from renewables by a certain deadline [13]. President Obama has also stated in his first address to a joint session of congress that the nation’s supply of renewable energy will be doubled in the next three years [14]. The changing nature of these resources will increase the need for energy storage in both supply and demand. Energy storage facilities hold a key position in energy supply systems; the benefits of electric energy storage include increasing grid reliability, reducing system transmission congestion, helping manage load, and making renewable electricity sources more suitable as base load providers [15-18]. They facilitate the task of matching a varying energy supply with a consistently varying energy demand and permit an interruption-free electricity supply. New electric energy storage technologies coupled with energy efficiency measures are keys to a better utilization of existing and future power system assets.

Another important factor related to the need for storage is the increasing cost of fossil fuels that has made their efficient use more vital than ever before. This is particularly true with the use of oil in the transportation industry. The new Corporate Average Fuel Economy (CAFE) standards were passed to decrease our dependence on fossil fuels by increasing a standard on new vehicles to 34.1 miles per gallon by model year 2016 [19]. One important method of actualizing this required efficiency is electrification with technologies such as the Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), and Plug-in Hybrid Electric Vehicle (PHEV). The in-vehicle, high-power energy storage of these vehicles is distinctly different from traditional vehicles [20-24]. The energy storage units in EVs and PHEVs serve primarily to support the mobile provision of electrical energy. Energy storage technologies, especially batteries, are critical enabling technologies for the development of these advanced, fuel-efficient, light- and heavy-duty vehicles. Energy storage technologies developed for electric transportation applications, and made available via the smart electric distribution grid of the future, can provide grid support in the electric distribution system.

The evolving situation on the energy market requires a new look at the options for energy storage. In overall energy concepts to be expected in the future with high proportions of variable energy sources, the demands on storage of energy will increase. Energy storage facilities thus deserve increasing attention from the technological, societal, economic and political viewpoints. In response to the emerging area of energy storage technology, several research collaborations between universities, automotive manufacturers, and government agencies have been formed. Intensive research work has been carried out on different types of energy storage systems from a variety of perspectives [25]. Supported by the Department of Energy Vehicle Technologies program (DOE-VT) and administrated through the Lawrence Berkeley National Laboratory, the Batteries for Advanced Transportation Technologies (BATT) program is targeted to research and analyze new materials for high-performance, next generation, rechargeable batteries for use in HEVs, PHEVs, and EVs [26]. Moreover, the intensive research work has been carried out on large-scale energy storage systems for power grid applications [27]. The infrastructure development and energy storage management technologies have also been investigated to facilitate the electric power delivery system transformation that will accommodate high penetration of renewable energy sources and support new types of loads such as charging PHEVs or EVs [28-29].

In spite of these research activities, the educational effort on energy storage technology is inefficient for the current and future needs. Several universities/colleges have implemented curricula or degree programs in energy and renewable energy [30-32]. Only a few universities in the nation and around the world have a specific educational program on energy storage. Pennsylvania State University and Ohio State University, two of the few on the list, have an energy storage curriculum embedded within their Graduate Automotive Technology Education (GATE) programs [33-35]. However, neither systematic courses nor laboratory have been developed to train engineer and technicians in the emerging technology of advanced energy storages in both the stationary and vehicular applications. To date, neither an undergraduate engineering curriculum nor service technician program in energy storage technology has been developed. This learning environment establishment responds to this critical need through the creation of laboratory-based undergraduate courses in advanced energy storage systems, tailored with an emphasis on the alternative energy industry in both the stationary and vehicular sectors. We particularly look into four types of advanced energy storages: electro-chemical battery, ultracapacitor (also called supercapacitor), electro-mechanical flywheel, and regenerative/reversible fuel cells or fuel cell/electrolyzer combination.

An energy storage curricula development team has been formed by the faculty of the Division of Engineering Technology at Wayne State University (WSU-DET), Macomb Community College (MCC), and Henry Ford Community College (HFCC). The team also includes industrial partners from major battery manufacturers, solar energy developer, automobile manufacturers and suppliers. The main activities include: creating an advanced energy storage curriculum and setting up an industrial-based energy storage laboratory; developing and delivering a short course for on-site training of engineers, technologists, and community college instructors working in the alternative energy and alternative automotive propulsion fields; and developing and delivering a series of workshops and seminars for K-12 science teachers, corporate partners, and energy and automotive professionals. The course materials and laboratory specifications developed are posted online for dissemination, allowing the short course is made available for distance learning. This enables energy storage engineers and technicians across the country to receive the training courses on-site through the Internet. Experience gained from this curricula development can also prepare the collaborative team for the future projects on advanced energy storage technology.

This paper describes a funded project that addresses the critical need for energy storage trained engineers and technicians that currently exists, and will continue to grow, by creating a curricular program to train engineers and technicians for work specific to advanced energy storage systems. The developed curricula targets engineering/engineering technology students in 4-year universities and community colleges, engineers and technicians in industries, and K-12 technology teachers.

2. Objectives

It is not necessary to establish a new degree program in the advanced energy storage systems; however it is essential to integrate the energy storage courses and laboratory experiments into the existing alternative energy/automotive engineering curricula. An integrated or progressive learning system is proved to be the most effective approach for professional development [36-38]. This project develops an industry-based learning environment to help build a workforce of highly-trained engineers, engineering technologists, and service technicians to advance energy storage technologies for clean and sustainable energy development in stationary and vehicular sectors. The main objective stemming from this goal is to address the critical need for educating students in this new and emergent technology of advanced energy storages. To make a positive, continual, and lasting contribution to the advanced energy storage education, the following objectives were specifically set:

- To prepare students and returning engineers or technicians to be skilled advanced energy storages engineers or technicians.
- To enable students to acquire industry-based experience in advanced energy storage technology through a hands-on laboratory environment.
- To expose renewable energy and advanced energy storage technology to K-12 teachers, corporate partners, energy and automotive professionals.
- To prepare Macomb Community College and Henry Ford Community College students in Associate of Applied Science (AAS) programs to successfully transfer to Wayne State University's Engineering Technology program to earn a Bachelor of Science in Engineering Technology degree.

3. Environment Implementation

Leveraging the strengths of each institution - Wayne State University's experience in engineering research and producing talented Bachelor and higher levels graduates and MCC's and HFCC's reputation for innovation and educating highly-qualified technicians - and pooling their respective resources (i.e., their programs, faculty, facilities, location, and industry ties), a series of activities are planned and carried out the stated objectives. They are as follows:

- Create an advisory committee to oversee the program.
- Integrate advanced energy storage curriculum with existing programs in WSU, MCC, and HFCC.
- Develop advanced energy storage specific courses, and deliver these courses.
- Create an advanced energy storage specialized laboratory.
- Develop and delivered a two-day short course.
- Develop and delivered workshops and seminars.
- Create internship and co-op opportunities, plant visits, and an expert lecturer series.
- Provide transfer students advising by WSU faculty at MCC and HFCC.

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 all institutions and their industry partners was formalized through the creation of an advisory committee, which met regularly to develop and implement the planned activities and monitor progress.

3.2 Curriculum Integration

The primary objective of this curricula development is to prepare students and working engineers and technicians to be skilled advanced energy storage professionals. To achieve this objective, WSU, MCC, and HFCC in collaboration with their industry partners integrate energy storage education courses into their programs. WSU integrates two energy storage courses into the Bachelor of Science curriculum in Engineering Technology. MCC and HFCC in collaboration with WSU integrate one energy storage courses into the Associate of Applied Science curricula in Energy Technology and Automotive Technology.

The energy storage curriculum at WSU is shown in Table 1. The structured curriculum is divided into two sequential sections: Energy Fundamentals and Advanced Energy Storage Technology. Section I, Energy Fundamentals, consists of four basic courses of critical importance to energy systems. A student completes this section by completing at least three courses for nine credit hours. All courses are offered by WSU and are currently enrolling students. Section II, Advanced Energy Storage Technology, requires two new courses that were developed. Together they are total six credit hours, covering advanced knowledge in energy storage technology. Students must take both Section I and II (for a total of 15 credit hours) to complete the advanced energy storage training program and obtain an undergraduate certificate in advanced energy storage technology.

WSU faculty develops and delivers condensed course materials for advanced energy storage technologies to assist MCC and HFCC faculty in developing the course and workshops. Both MCC and HFCC offer Alternative Energy Technology and Automotive Technology (hybrid electric vehicle) programs, however no specific course and laboratory focuses on energy storage. The energy storage curriculum in MCC and HFCC is shown in Table 2 and 3 respectively. Students in Energy Technology, Automotive Technology, and other potential future certificate and degree programs have the option or requirement to complete the course in advanced energy storage.

Table 1. Curriculum for advanced energy storage technology in WSU-DET

WSU-DET	Section I: Energy Fundamentals - Current Courses	
Course No.	Course Title	Credit Hours
ETT 4150	Fundamental of Hybrid and Electric Vehicle Technology	3
ETT 4310	Energy Storage Systems for Hybrid and Electric Vehicles	3
MCT 4150	Applied Thermodynamics	3
MCT 5210	Energy Sources and Conversion	3
	Section II: Advanced Energy Storage Technology (new courses)	
Course No.	Course Title	Credit Hours
ETT 4410	Introduction to Advanced Energy Storages	3
ETT 4510	Power Management and Applications of Energy Storage	3

Table 2. Curriculum for advanced energy storage technology in MCC

MCC Program	Current Courses Course No.	Course Title	Credit Hours
Renewable Energy Technology	RNEW 1000	Introduction to Energy	3
	RNEW 1100	Principles of Wind Energy	2
	RNEW 1200	Principles of Solar Energy	2
	RNEW 1300	Principles of Biomass Technology	2
	RNEW 1500	Principles of Hydrogen Fuel Cell Technology	4
Automotive Technology	Auto 1440	Hybrid Electric Vehicle Fundamentals	3
	Auto 2440	Hybrid Electric Vehicle Power Management	3
	New course for Advanced Energy Storage Technology		
Course for both programs		Course Title	Credit Hours
		Advanced Energy Storage Systems	3

Table 3. Curriculum for advanced energy storage technology in HFCC

HFCC Program	Course No.	Current Courses Course Title	Credit Hours
Energy Technology – Alternative Energy	ENT 101	Introduction to Energy	2
	ENT 260	Energy Systems Management	4
	ENT 265	Energy Systems Design	5
	REEN 101	Survey of Renewable Energy Sources	2
	REEN 120	Wind, Solar, and Fuel Cell Technology	2
	REEN 140	Co-Generation and Back UP Power	2
Automotive Technology	Auto 260	Alternative Automotive Propulsion	3
	New course for Advanced Energy Storage Technology		
Course for both programs		Course Title	Credit Hours
		Advanced Energy Storage Systems	3

3.3 Course Development

To integrate the energy storage curriculum into the Engineering Technology Program, two new courses in advanced energy storage technology are developed. The two new courses that form the requirements for Section II of the curriculum are *Advanced Energy Storage Systems* and *Power Management and Applications of Energy Storage Systems.* These two courses target current students as well as returning or lifelong students already working in the alternative energy and advanced automotive propulsion fields.

The first new course, *Advanced Energy Storage Systems*, covers the fundamentals of advanced energy storage technologies including electro-chemical batteries, ultracapacitors, electro-mechanical flywheels, fuel cells/electrolyzers and regenerative fuel cells with hydrogen storage tank. The introduction of alternative energy systems and electric propulsion systems for transportation are also given. The second new course, *Power Management and Applications of Energy Storage Systems*, covers the design, control and power management of different energy storage systems including electro-chemical batteries, ultracapacitors, electro-mechanical flywheels, fuel cells/electrolyzers and regenerative fuel cells with hydrogen storage tank. The energy storage systems for applications in stationary alternative energy systems, and alternative vehicle propulsion systems are covered. The fundamentals of power electronics and system modeling and simulation are introduced as well. Table 4 lists the contents of two new courses in WSU-DET. The development of these courses is based on input from industrial partners, textbooks, manuals and training materials provided by the energy storage 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. WSU faculty has completed and delivered condensed course materials from *Advanced Energy Storage Systems* and *Power Management and Applications of Energy Storage Systems* to assist MCC and HFCC faculty in developing the course and workshops. WSU faculty collaborated with MCC and HFCC faculty to develop appropriate teaching materials in community college student level. WSU faculty also provided laboratory specifications for MCC and HFCC. Table 5 lists the contents for the energy storage course in MCC and HFCC.

Table 4. Course contents of the two energy storage courses in WSU-DET

Advanced Energy Storage Systems	Power Management and Applications of Energy Storage Systems
Introduction • Sustainable energy development • The need for energy storage	Introduction • Energy storage systems and sustainable energy development
Fundamentals of electro-chemical batteries	Review of different types of energy storage systems: batteries, ultracapacitors, flywheel, fuel cells, electrolyzers, and hydrogen storage.
Types of electro-chemical batteries • Lead-acid • Nickel-cadmium • Nickel-metal hydride • Lithium ion and Lithium polymer • Other (Sodium-Ni, Zinc-air, etc)	Power management of batteries and ultracapacitors • Fundamentals of power electronics • Energy characteristics of batteries and ultracapacitors • Charge and discharge management
Lab 1: Measurement of internal voltage and resistance of a battery	Lab 1: Battery test
Ultracapacitors • Fundamentals • Applications	Thermal management of batteries • Thermal modeling of batteries • Thermal management for durable and reliable operation of batteries • Thermal management of battery pack
Lab 2: Charging and discharging ultracapacitors	Lab 2: Thermal management studies of a battery pack
Electro-mechanical flywheels • Physics and features • Operation of flywheel	Control of flywheels

• Advantages and disadvantages	
Fuel Cells • Fundamentals • PEMFC and SOFC	Control of fuel cells • Stand-alone systems • Grid-connected systems
Electrolyzers and hydrogen storage Regenreative fuel cells	Control of electrolyzers with hydrogen storage Energy management of hybrid vehicles: case study
Lab 3: Simulation of hydrogen storage system	Lab 3: Hybrid vehicle lab
Introduction to alternative energy systems: wind, solar, and fuel cells. Introduction to electric propulsion systems for transportation	Design and power management of an alternative energy system with multiple sources: a case study Lab 4: Simulation of a hybrid wind/PV/energy storage system

Table 5. Course contents of energy storage course in MCC and HFCC

Advanced Energy Storage Systems
Introduction • Sustainable energy development • The need for energy storage systems • Basic categories of energy storage: flywheels, ultracapacitors, fuel cells, hydrogen storage, and batteries.
Fundamentals of batteries and Choices of battery • Lead-acid • Nickel-cadmium • Nickel-metal hydride • Lithium-ion
Fundamentals of other energy storage systems • Ultracapacitors • Electro-mechanical flywheels • Fuel cells and hydrogen storage systems
Introduction to Power Electronic circuits • AC/DC, DC/DC, and DC/AC.
Energy storage in alternative energy systems • Introduction to different alternative energy systems • Power management of energy storage devices
Energy storage in transportation applications • Introduction to hybrid, plug-in hybrid, fuel cell and pure electric vehicles • Energy management for hybrid vehicles
System integration and unit sizing of energy storage devices • Case studies for both electrical energy generation and vehicle applications

3.4 Two-Day Short Course Development

In addition to the two new courses, a two-day short course is developed for engineers, technologists, technicians, and community college instructors working in the alternative energy and alternative automotive propulsion fields who wish to gain an in-depth understanding of advanced energy storage and their energy management schemes. The course consists of three modules as listed in Table 6. A set of computer-based courseware is developed as a teaching and learning tool. MATLAB/Simulink is used for simulations of energy system control and integration.

3.5 Development of Workshops and Seminars

MCC and HFCC offer a variety of workshops and seminars to various groups with a stake in learning more about alternative energy and advanced energy storage systems. These workshops and seminars are tailored to meet the specific needs of each group. More specifically:

1. *Workshop for K-12 science teachers*: MCC is a founding member of the Southeast Michigan Automotive Teacher Association (SEMATA), which represents 40 secondary schools and approximately 120 teachers and provides a forum for this project to educate 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 high voltage battery pack in HEVs and EVs.
3. *Informational seminars for corporate partners*: These seminars are made available through the Detroit Automobile Dealers Association and other industry connections.
4. *Informational seminars for the general public:* These seminars focus on safety, which may be offered for credit or non-credit.

Education of K-12 teachers, corporate and academic partners, renewable energy and automotive professionals can broaden the reach of the activity and contribute to the service mission of each institution. Extended contact with these important stakeholders can also create a flow of energy storage-relevant information that may impact the content of the curricular offerings.

Table 6. Course contents of the two-day short course

Modules	Contents	Lecture Hours
Alternative Energy and Energy Storage	• Introduction to alternative energy storage systems including wind, solar and fuel cells. • Fundamentals of batteries, ultracapacitors and flywheel. • Power electronics and system integration • System safety, design, control and power management.	4
Electric Machines and Power Systems	• Operation principles of different electric machines including DC machines, AC synchronous and asynchronous (induction) machines. • Introduction to power generation, transmission and distribution. • Power system operation and control • Energy storages in power systems	4
Modeling and Analysis of Energy Storage Systems	• Fundamentals of different energy storage systems including batteries, ultracapacitors, flywheels, and fuel cells. • Modeling energy storage systems: case study on modeling battery and fuel cell.	6

	• Modeling alternative energy systems with energy storage devices • Modeling electric propulsion systems in vehicles

3.6 Student Transfer Credit Evaluation and Advising

WSU-DET is a two-plus-two program with the expectation that students enter with an associate degree. The WSU-DET, MCC, and HFCC have been working together successfully for a number of years to provide a seamless transfer of students from MCC and HFCC to WSU-DET. With this collaborated curricula development for energy storage technology, WSU, MCC, and HFCC can further provide students the opportunity to expand their skills and knowledge in this emerging technological field to specialize their degrees.

4. Energy Storage Laboratory Development

Along with the courses development, an energy storage laboratory with different types of energy storage devices is developed. The modeling packages, controlling and interfacing circuits, and various energy storage application systems are also developed. Hence, students can consolidate their knowledge of operation principles of different energy storage systems and their performance characteristics, and also learn how to test, model, control and integrate them with other energy sources to form a real energy system. Table 7 lists the components for the lab setup and Table 8 summarizes the laboratory experiments that were developed.

Table 7. Laboratory equipment in WSU-DET

Lab Component	Description
Wind turbine	50 W wind turbines. It is used for the energy storage application in wind power generation system.
PV panel	10 W. It is used for the energy storage application in solar power generation system.
Batteries	
Regular lead-acid battery	12V. Typical lead-acid battery such the cranking battery in the vehicle.
Deep VRLA battery	12V. Commonly used for wind, solar, and UPS sustainable systems. It is also used for PHEV.
NiMH battery	12 V. It is mainly for HEV and PHEV
Li-ion battery	12 V. It is mainly for EV and PHEV
Battery tester	
Fuel cell unit	Educational demo unit
Electrolyzer	Educational demo unit
Hydrogen storage tank	Educational demo unit
Electro-mechanical flywheel	Educational demo unit
Ultracapacitor	
Power electronic devices	

Power electronics system test bench	DC/DC converter, DC/AC inverter, AC/DC rectifier, and PC with LabView data acquisition card.
Oscilloscope	
Electric Fan	Wind source for the wind turbine
Light source	For the PV panel

Table 8. Laboratory experiments in WSU-DET

Experiment Topics
Energy storage system operation principles and characteristics
Electrical storage: charging and discharging characteristics of batteries and ultracapacitor
Electrochemical storage: fuel cells and electrolyzers
Mechanical storage: flywheel and kinetic energy
Energy storage system control and test
Battery SOC test and management
Charging and discharging ultracapacitor
FC and electrolyzer modeling and control (demonstration and simulation study)
Energy storage applications
Wind/battery or ultracapacitor system
PV/battery or ultracapacitor system
Wind/PV/battery system
Wind/PV/FC-electrolyzer system
Electric propulsion systems in vehicles (demonstration and simulation study)

Conclusions

The escalating demand for energy and the increasing concerns over the environment have called for clean and sustainable energy development. Generating electricity from renewable, clean energy sources such as solar and wind power as well as driving ultra fuel-efficient vehicles are promising solutions to the energy development strategies. There is a great need of electrical energy storage for the effective commercialization of renewable energy resources, load-leveling, and transportation electrification. The steadily increasing capacity of generating power from renewables and production of electric drive vehicles by the industry coupled with the specialized set of skills required to accommodate the energy storage systems in both the stationary and transportation sectors, have created an urgent and continuous demand for more knowledgeable energy storage engineers and technicians. The required education includes safety, regulations, maintenance, system integration and control for energy storage devices. There is a clear need for a systematic educational program on energy storage technology, particularly in regions where the sustainable energy development in electricity generation and automotive manufacturers and their advanced battery suppliers are highly concentrated.

In order to establish energy storage systems learning environment, a partnership was formed between faculty at WSU, MCC and HFCC. The partnership also includes industrial partners from major battery manufacturers, solar energy developer, automobile manufacturers and suppliers. The activities included (1) Creating an advanced energy storage curriculum; (2) Setting up an industrial-based energy storage laboratory; (3) Developing and delivering a short course for on-site training of engineers, technologists, and community college instructors working in the alternative energy and alternative automotive propulsion fields; (4) Developing and delivering a series of workshops and seminars for K-12 science teachers, corporate partners, and energy and automotive professionals; and (5) Providing transfer student advising by university faculty.

It is our intent to develop collective effort, among educators, industry, and government agency, to make positive, continual, and lasting contribution for engineering education on the emerging technology for advanced energy storage systems in both the stationary and transportation sectors. The implementation of the energy storage learning environment is a resounding success. The work is still ongoing and initial student reaction has been quite enthusiastic.

Acknowledgements

This work was supported in part by the U.S. National Science Foundation (NSF), CCLI-Phase I: Exploratory, under grant number DUE-0941809.

Bibliography

1. P. Jennings, 2009, "New directions in renewable energy education," *Renewable Energy*, Vol. 34, No. 2, pp. 435-439.
2. M. Taleghani, H.R. Ansari HR and P. Jennings, 2010, "Renewable energy education for architects: lessons from developed and developing countries," *International Journal of Sustainable Development and World Ecology*, Vol. 17, No. 5, pp. 444-450.
3. D. Tate, T. Maxwell T, A. Ertas, et al. 2010, " Transdisciplinary approaches for teaching and assessing sustainable design," *International Journal of Engineering Education*, Vol. 26, No. 2, Special Issue, pp. 418-429.
4. C. Veganzones, D. Ramirez, F. Blazquez, et al. 2009, " New platform for experimental education in electrical generation based on wind energy systems," *International Journal of Engineering Education*, Vol. 25, No. 4, Special Issue, pp. 841-848.
5. O. Hurtado and C. Hunte, 2007, "Educating engineers in sustainable energy development: an interdisciplinary approach," *International Journal of Engineering Education*, Vol. 23, No. 2, pp. 266-375.
6. R.P. Hesketh, C.S. Slater, M.J. Savelski, et al. 2004, "A program to help in designing courses to integrate green engineering subjects," *International Journal of Engineering Education*, Vol. 20, No. 1, pp. 113-123.
7. R. M. Counce, J.M. Holmes, R.A. Reimer, et al. 2003, "Sustainable development in future process design and analysis education," *International Journal of Engineering Education*, Vol. 19, No. 1, pp. 158-162.
8. F. Yildiz and K. Coogler, 2010, "Development of a renewable energy course for a technology program," *Proceedings of ASEE AC2010-1232*.
9. F. Falcone, T. Davidovits, E. Schacht, et al. 2010, "Integration of modern energy storage design practices into university automotive engineering programs," *Proceedings of ASEE AC2010-1388*.
10. H. Foust, 2006, "Developing an energy mechatronics laboratory," *Proceedings of ASEE 2006-108*.
11. Statement of Steven Chu Secretary of Energy Before the Committee on the Budget United States Senate Washington, D.C., March 11, 2009. http://www.congressional.energy.gov/documents/3-11-09_Final_Testimony_(Chu).pdf/. Accessed April 13, 2010.
12. Granholm Applauds GM Plans for Lithium-Ion Battery Assembly Operations in Michigan, January 12, 2009, Michigan Economic Development Corporation. http://www.themedc.org/News-Media/Press-Releases/Detail.aspx?ContentId=e6be3d27-3711-4bf2-88e4-7e6e6dc2e3c7/. Accessed April 13, 2010.
13. http://www.dsireusa.org/library/includes/topic.cfm?TopicCategoryID=6&CurrentPageID=10&EE=1&RE=1/. Accessed April 13, 2010.
14. http://www.whitehouse.gov/the_press_office/Remarks-of-President-Barack-Obama-Address-to-Joint-Session-of-Congress/. Accessed April 13, 2010.

15. J. Makansi and J. Abboud, 2002, "Energy storage: The missing link in the electricity value chain," An ESC White Paper, May, 2002, Energy Storage Council.
16. S. Teleke, M.E. Baran, S. Bhattacharya, et al. 2010, "Optimal control of battery energy storage for wind farm dispatching," *IEEE Trans. Energy Conversion*, Vol. 25, No. 3, pp. 787-794.
17. J. Wang, K. Li, Q. Lv, et al. 2010, "Hybrid energy storage system integration for vehicles," *Proceedings of the 16th ACM/IEEE international symposium on Low power electronics and design*.
18. C. Abbey and G. Joos, 2007, "Supercapacitor energy storage for wind energy applications," *IEEE Trans. Industry Applications*, Vol. 43, No. 3, pp. 769-776.
19. U.S. Energy Information Administration, 2010, "Annual Energy Outlook 2010 with Projections to 2035," Report No. DOE/EIA-0383, http://www.eia.doe.gov/oiaf/aeo/cafe_stds.html/. Accessed August 15, 2010.
20. T. Bartley, 2005, "Ultracapacitors and batteries for energy storage in heavy-duty hybrid-electric vehicles," The 22nd International Battery Seminar and Exhibit, Fort Lauderdale, Florida, March 14-17.
21. J. Park, B. Raju, and A. Emadi, 2005, "Effects of an ultra-capacitor and battery energy storage systems in a hybrid electric vehicle," *SAE Paper 2005-01-3452*.
22. A.P. Rousseau, R. Rajesh, and Q. Zhang, 2004, "Energy storage requirements for fuel cell vehicles," *SAE Paper 2004-01-1302*.
23. I. Menjak, P.H. Gow, D.A. Corrigan, S.K. Dhar, and S. Ovshinsky, 2000, "Ovonic power and energy storage technologies for the next generation of vehicles," *SAE Paper 2000-01-1590*.
24. Y. Hisamitsu, T. Abe, T. Kinoshita, H. Miyakubo, and H. Horie, 2008, "Research and development work on high-performance lithium-ion batteries for EV application," *SAE Paper 2008-01-1332*.
25. The Batteries for Advanced Transportation Technologies (BATT) Program, U.S. Department of Energy, Office of Vehicles Technologies, http://batt.lbl.gov/. Accessed April 13, 2010.
26. 2008 Annual Progress Report, "Energy storage research and development," Vehicle Technology Program, U.S. Department of Energy.
27. Bottling electricity: storage as a strategic tool for managing variability and capacity concerns in the modern grid, The Electricity Advisory Committee, U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, December 2008. http://www.oe.energy.gov/DocumentsandMedia/final-energy-storage_12-16-08.pdf/. Accessed April 13, 2010.
28. M.W. Howard, 2009, "Energy storage: an enabling technology," Electric Power Research Institute, National Association of Regulatory Utility Commissioners, February 16. http://www.narucmeetings.org/Presentations/NARUC%20EPRI%20Energy%20Storage%20FINAL.pdf/. Accessed April 13, 2010.
29. Electric transportation, 2008 Portfolio, Electric Power Research Institute, http://mydocs.epri.com/docs/Portfolio/PDF/2008_P018.pdf/. Accessed April 13, 2010.
30. F. Yildiz and K. Coogler, 2010, "Development of a renewable energy course for a technology program," *Proceedings of ASEE AC2010-1232*.
31. D. Rouch and A. Stienecker, 2007, "A delphi study to project the future of alternative energy and its implication to engineering technology," *Proceedings of ASEE AC2007-1614*.
32. H. Foust, 2006, "Developing an energy mechatronics laboratory," *Proceedings of ASEE 2006-108*.
33. D. Tallon, R. Streit, C.Y. Wang, C. Bakis, C. Randall, M. Lanagan, et al, 2001, "Graduate Automotive Technology Education in energy storage systems - GATE Penn State," *International Journal of Continuing Engineering Education and Lifelong Learning*, Vol. 11, No. 4/5/6, pp. 534-541.
34. F. Falcone, T. Davidovits, E. Schacht and M. Wahlstorm, 2010, "Integration of modern energy storage design practices into university automotive engineering programs," *Proceedings of ASEE AC2010-1388*.
35. Y. Guezennec, G. Rizzoni, G. Washington, and S. Yurkovich, 2001, "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*.
36. M. Taherenzhadi, P. Billman, M. Hajisheikh and P. Vohra, "Nanotechnology udergraduate certificate: a novel approach," Chap. 12, W. Aung, et al. (eds.), *Innovations 2010: World Innovations in Engineering Education and Research*, Int. Network for Eng. Ed. and Res. (iNEER), Arlington, VA, 2010, pp. 139-148.
37. N. S. Edward, "A progressive approach to professional development", Chap. 14, W. Aung, et al. (eds.), *Innovations 2008: World Innovations in Engineering Education and Research*, iNEER, Arlington, VA, 2008, pp. 145-156.
38. S. Petrovic, and L. Munukutla, L., "An integrated alternative energy technologies program", Chap. 22, W. Aung, et al. (eds.), *Innovations 2008: World Innovations in Engineering Education and Research*, iNEER, Arlington, VA, 2008, pp. 243-250.