X.3 Hydrogen and Fuel Cell Education at California State University, Los Angeles

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Objectives

California State University, Los Angeles, has partnered with the Department of Energy in addressing the workforce preparation and public education needs of the fuel cell industry and the U.S. economy through a comprehensive set of curriculum development and training activities:

- Developing and offering several courses in fuel cell technologies, hydrogen and alternative fuels production, alternative and renewable energy technologies as means of zero emissions hydrogen economy, and sustainable environment.
- Establishing a zero emissions proton exchange membrane (PEM) fuel cell and hydrogen laboratory supporting curriculum and graduate students' teaching and research experiences.
- Providing engaging capstone projects for multi-disciplinary teams of senior undergraduate students.
- Fostering partnerships with automotive manufacturers and energy providers.

Technical Barriers

This project addresses the following technical barriers from the Education section (3.9.5) of the Fuel Cell Technologies (FCT) Program Multi-Year Research, Development and Demonstration Plan:

(A) Lack of Readily Available, Objective, and Technically Accurate Information

(B) Mixed Messages

(D) Lack of Educated Trainers and Training Opportunities

Contribution to Achievement of DOE Education Milestones

This project will contribute to achievement of the following DOE milestones from the Education section of the FCT Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 11: Develop set of introductory materials suitable for a non-technical audience. (4Q, 2006)
- Milestone 21: Launch new university hydrogen education program. (4Q, 2009)
- Milestone 27: Launch high school teacher professional development. (4Q, 2008 through 3Q, 2011)

Accomplishments

- In the 2009-2010 academic year, we continued to offer course modules and hydrogen fuel cell technology dedicated courses: ME 454-Renewable Energy and Sustainability (enrollment 26); ME 554-Fuel Cell Systems (graduate course; enrollment 10); TECH 478-Fuel Cell Applications (enrollment eight technology, seven mechanical); TECH 250-The Impact of Technology on the Individual and Society (detailed in the next section). M:21.
- TECH 250-The Impact of Technology on the Individual and Society course is a general education required course, which contains one week module on fuel cells and hydrogen economy. It is open to all majors in the university and is selected to deliver our message to the university-wide student body. Enrollment was as following: 2008-2009–186 students; 2009-2010–206 students. M:21.
- Work has continued within the Zero Emissions Fuel Cell and Hydrogen Laboratory (ZEFC). Major equipment purchased last year has been integrated into courses: Heliocentris -- Dr. Fuel Cell, Nexa Training System Complete, Nexa Integration Kit; and Proton-Hogen GC600 Electrolyzer. Two graduate and several undergraduate students

worked on educational and research projects in the laboratory. M:21, M:11.

- ECST assembled a multidisciplinary senior design team which is solving the problem of calibrating the amount of hydrogen dispensed at 5,000 psi by building a prototype for the 10,000 psi unit.
- The initial solar installation has grown from 2 kW to 10 kW. The system consists of 56 Sharp and 23 Solec modules. The ECST building is a 3-phase building which requires three inverters per each type of modules. However, SMA has come out with a Tripower inverter which is capable of dual maximum power point tracking and is 10 kW unit. This type is schedule for production in summer 2010 and CSULA is waiting for an available unit. The funds are being provided by Southern California Edison. M:21.
- ECST assembled a multidisciplinary senior design team to design and build a Hydrogen Safety demonstrator. The team consisted of two mechanical engineering and two electrical engineering students. The enabled experiments produced spectacular performance. For safety, the explosions are activated with a wireless remote. M:21.
- There has been an appreciable number of public outreach and educational activities through which fuel cell and hydrogen technologies and the new curriculum at CSULA were promoted. M:11.
- CSULA has raised funds and initiated the construction of a hydrogen station with 60 kg/day generation capacity. That will enable further development of educational program. M:21.
- Multidisciplinary team of CSULA faculty, including the principal investigator (PI), received National Science Foundation funding to establish the Center for Energy and Sustainability. One of the projects is to design and evaluate miniature direct-methanol fuel cell. This will contribute to the longevity of the research program. M:21.

Introduction

Our interest in developing hydrogen and fuel cell education stems from the recognition of the urgent need for workforce development and public education in the entire spectrum of alternative and renewable energy technologies (ARET). ECST is taking steps to graduate more students fluent in ARET as well as to raise campus and state-wide awareness of green technologies. This includes the ongoing construction of a Hydrogen fueling station on campus. The comprehensive nature of the university, its strategic location in the hydrogen and fuel cell abundant industrial region and a historically minority-serving charter make it an ideal candidate to carry out the tasks listed in the objectives.

Approach

Design of a comprehensive engineering and technology curriculum addressing fuel cells and hydrogen technologies is the foundation for our contribution toward green workforce training. This is accomplished through a mix of new courses or special modules in existing courses to introduce the concepts of fuel cell technologies, hydrogen and alternative fuels, alternative and renewable energy technologies as means of zero emissions hydrogen economy, and sustainable environment. ECST has established ZEFC to support curriculum, undergraduate and graduate students' teaching and research experiences. Further, enrichment of student experiences is accomplished through projects and fostering partnerships with automotive manufacturers and industry.

Community education and public outreach goals are met through a series of on campus and off-campus public events and demonstrations.

Results

Four courses either with integrated modules or fully dedicated were continued to be offered within the interdisciplinary curriculum at ECST: ME 454-Renewable Energy and Sustainability, ME 554-Fuel Cell Systems, TECH 478-Fuel Cell Applications, TECH 250-The Impact of Technology on the Individual and Society. TECH 478 continued as flagship of the program. The class hosted the Honda Clarity fuel cell vehicle team that gave a lecture and a demonstration on Honda fuel cell vehicles as well as a visit by a renowned fuel cell researcher Dr. Subbarao Surampudi of the Jet Propulsion Laboratory. As part of the mid-term exam, students attended the 2010 National Hydrogen Association conference which was available locally.

Active work has continued within the ZEFC. The laboratory is designed to provide hands-on activities supporting fuel cell courses offered in the program. One graduate student developed: Lab1 a-b, Characteristic Curve and Efficiency of the Electrolyzer; Lab2 a-b, Characteristic Curve and Efficiency of the Fuel Cell; Lab3, Nexa Training System Complete: Fuel Cell Power Potential; abbreviated operating manuals for Nexa Training System Complete and Hogen Electrolyzer. He also assisted with teaching labs for undergraduate and graduate courses. The same student provided leadership for the "Hydrogen Community" design project sponsored by National Hydrogen Association. The project was called Soaring Eagle and five technology and two mechanical engineering students participated, see Figure 1.

The PI and the graduate student attended an intensive 3-day fuel cell course offered at Los Alamos National Laboratory. The training benefited student's

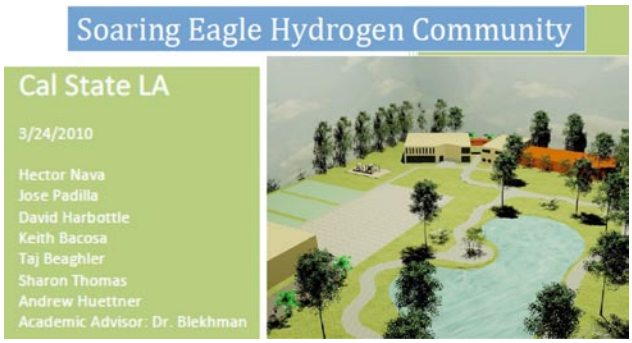

FIGURE 1. Title page for the National Hydrogen Association sponsored Hydrogen Community project by CSULA students.

graduate research and the PI's course materials. Later, this student presentation "Root Cause Analysis of Low Fuel Cell Voltage Generation" was awarded the first place oral presentation in Engineering and Computer Science I at the CSULA 18th Annual Symposium on Research, Scholarship and Creative Activity. Among the winners from other disciplines, the student has been invited to the CSU statewide competition in San Jose.

CSULA has actively pursued public outreach and educational activities through which the DOE-sponsored fuel cell and hydrogen curriculum at CSULA is promoted. During the fall of 2009, ECST hosted a Boeing open house for middle and high-school students, about 150 of whom toured the ZEFC. ECST is executing its 2010 Research Experience for Undergraduate program in ZEFC through which two students are working on a photolysis shark project and five are building a fuel cell vehicle to demonstrate solar-hydrogen-to wheel efficiencies. Multiple industry sponsored projects are supported by the PI and ZEFC facility. CSULA hosted 15 East Los Angeles College students for a week-long workshop where a LEGO Mindstorm robot powered by a Horizon 20 W fuel cell was built, see Figure 2.

CSULA has initiated the long awaited $4.5 M hydrogen station on campus, see Figure 3. It will deploy the latest technologies with the capacity of 60 kg/day, sufficient to fuel 15+ vehicles or a bus and five more vehicles. The station will be utilizing a Hydrogenics electrolyzer, first and second stage compressors capable of fast-filling at 5,000 psi and 10,000 psi, 60 kg of hydrogen storage. The station will be grid-tied and powered by 100% renewable power. The station construction has commenced and full operation is expected in January-March 2011.

The PI attended the 2010 Annual Merit Review in Washington DC; 2010 American Society for Engineering Education conference in Louisville, KY; and, 2010 National Hydrogen Assocation conference, Long Beach, CA.

FIGURE 2. The very first in the world LEGO Mindstorm robot powered by a 20 W Horizon fuel cell.

FIGURE 3. Proposed design for CSULA Hydrogen Station.

Conclusions and Future Directions

CSULA has methodically pursued the stated objectives in executing the grant. The team has offered a comprehensive suite of courses addressing fuel cell and hydrogen technologies. In the second year significant improvements were made integrating experimental experience through ZEFC. The work in ZEFC is continued with the solar installation and student/industry projects far beyond those proposed initially.

Next year efforts will focus on further development of student research and projects to assure the long-term viability of the hydrogen and fuel cell program at CSULA. Significant activities will also be associated with the construction, operation and utilization of the hydrogen station for public outreach and education. Next level of the program development will take place in commissioning the station and raising support for hydrogen infrastructure related curriculum, data collection and research. The team plans to file for project extension beyond September 15, 2010.

Special Recognitions & Awards/Patents Issued

1. Best Paper Award (2nd place) in the Energy Conversion Division of American Society for Engineering Education, see below for full reference. The PI was the main co-author.

2. Education Award by Looking Green Magazine at Rose Bowl Green Expo, Pasadena, CA July 2010.

FY 2010 Publications/Presentations

1. Blekhman, D., J. Keith, A. Sleiti, E. Cashman, P. Lehman, R. Engel, M. Mann, and H. Salehfar "National Hydrogen and Fuel Cell Education Program Part I: Curriculum," 2010 ASEE Annual Conference &Exposition, Louisville, KY. (Best paper nomination in the Energy Conversion and Conservation Division)

2. Blekhman, D., J. Keith, A. Sleiti, E. Cashman, P. Lehman, R. Engel, M. Mann, and H. Salehfar "National Hydrogen and Fuel Cell Education Program Part II: Laboratory Practicum," 2010 ASEE Annual Conference & Exposition, Louisville, KY.