Final project Report

Project Title: Wind Curriculum Development project at George Washington University

Award Number: DE-EE 0003548

Covering Period: Oct. 1, 2010 to December 31, 2013

PI: Prof. Stephen Hsu, 202-994-6069

stevehsu@gwu.edu

Recipient: George Washington University, Washington DC 20052

Date of Report: March 28, 2013

Working Partners: None

Cost-Sharing Partners: None

Date of Report: March 28, 2013

Acknowledgment: “This report is based upon work supported by the U. S. Department of Energy under Award No. DE-EE0003548.

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Executive Summary

The project aims to develop a wind energy curriculum suitable for adoption at the George Washington University, School of Engineering. Since the PI is located in the Mechanical and Aerospace Engineering Department, which has aerospace and mechanical engineering expertise, it may be the suitable home for such curriculum.

For any curriculum to be developed in a university, student survey is usually conducted to assess the potential interest of incoming and existing students. The assessment for potential job opportunities for graduates of such curriculum is also required. So surveys of student interest and industrial demand were conducted. Since GWU is located in the Mid-Atlantic region, off-shore wind energy development along the east coast of the US is of great potential as well as job opportunities. Therefore off-shore wind energy technology is of prime interest to industry and students.

Surveys of students and industry were conducted. Results suggested that the industrial demand for technical expertise training is a combination of mechanical, aerospace, and electrical engineering expertise. Student interests tend to align with their discipline and opportunity for jobs and income, with project management and design capture the most interest.

Based on these survey results, curriculum was created and tested in a series of graduate courses on energy engineering to solicit feedbacks and assess potential effectiveness. A prototype curriculum with various topics was developed and discussed at various engineering departments within the school for further actions.

Introduction: The project aims to develop a competitive wind energy curriculum at George Washington University (GWU) in the School of Engineering and Applied Science. The curriculum will be based on industry feedback, student interest, and analysis of national and regional demand for wind professionals.

Background

DOE 2030 wind Energy strategy plan has identified the lack of trained professionals in wind energy as one of the key barriers to reach the goal of 20% electricity from wind energy by 2030. GWU has an industrial consortium with 11 wind energy companies as part of the DOE Wind Academic Center proposal. This project is a direct outgrowth of the proposal. The scope is reduced to develop a wind energy curriculum in GWU's ABET accredited engineering school. The PI is a Professor in the Mechanical and Aerospace Engineering (MAE) Department, which is the appropriate home for a wind curriculum. A special departmental faculty meeting was called on April 19, 2010 to discuss the desirability of a wind curriculum in the department, the faculty voted unanimously to support such development.

University rules require for any new curriculum development effort, an investigation of student interest and industrial demand be conducted (including potential employers' inputs) to establish appropriate course content. Therefore, the following tasks were organized under this project:

- Task 1.0. Identify local wind energy training needs based on industrial and student survey results. Status: Completed, see 2011 Quarterly reports 1-3.
- Task 2.0. Identify programs best suited to potential student interest and local wind energy personnel needs. Status: completed, see 2011 Quarterly report 4 and 2012 Quarterly report 1.
- Task 3.0. Develop suitable course content best suitable for local needs. Status: completed, see 2012 Quarterly report 2, 3, and 4.
- Task 4.0. Create new courses and/or programs to implement such strategy. Status: Completed, see 2013 first quarter report

Results and discussion

The first phase of the project was to recruit a part time graduate student and/or a part time postdoctoral fellow interested in wind energy to work on the project. Since the project funding was insufficient to support any full time position, it took some time to identify and hire a graduate student to initiate the project. The first order of business was to obtain information on 1) student interest and expectations on wind energy; 2) wind energy industry needs in terms of technical training and hiring opportunities projected for the next decade. To obtain the necessary information, two surveys were planned, one for the students and one for the wind energy industry.

Two survey questionnaires were developed and beta tested on limited students and the industrial partners to refine the questions. Based on the answers obtained, the questionnaires were revised several times until they were deemed satisfactory. An interactive website was established to conduct the surveys. The student and the PI attended the annual AWEA meeting in Las Angeles in May 2011 to conduct personal interviews with wind energy professionals.

Student survey: A survey was conducted on students enrolled in the Mechanical & Aerospace Engineering Department (MAE) at GWU. Thirty-four Mechanical Engineering students responded to the survey. A total of 33 questions were asked based on a rating scale from 1 to 5 (5 being the highest). Major categories included US wind Resource; wind farms operations; offshore wind development; turbine design; blade design; wind energy output; control technology; environmental impact mitigation including sonic detection and ranging (SoDAR); modeling; and innovative integration of wind into the energy grid. The students were also asked to provide their current education level, future plans, and their current interest in wind career prospect. Interest level was highest on system integration of wind (average interest of 4.28). The survey also indicated that 91% of students responded are interested in learning more about wind energy.

Among the technical topics students showed great interest are (rating scale= 1-5, 5 being the highest): system integration of wind average interest of 4.28, followed by wind turbine design

with an average rating of 3.9. This was followed by modeling skills, wind resources assessments, power output estimation, and environmental impact abatement technologies. Majority of respondents intended to pursue higher-level degrees in the future with 71% interested in pursuing a wind turbine mechanical engineer, 54% wind engineer, 39% wind plant engineer or wind energy developer, and 29% wind construction management.

Industry survey: Several surveys were conducted with wind energy company chieftains and VPs on their near term and long term hiring needs and what they perceived as the necessary skillset to succeed in their companies, as well as their perspective on the technical training they valued the most. Website survey results were augmented by personal interviews with wind energy professionals during the AWEA annual meeting events. In addition, letters, phone calls were sent to many wind energy companies. A total of 50 companies responded to the interviews and questionnaires. The answers to the questionnaire were based on a scale from 0 to 100 (100 being the highest, and 0 being the lowest) with optional “others” for unanticipated answers. Categories include: available workforce skill level; computational fluid dynamics (CFD) skills; component design, fabrication, installation, and maintenance; projected hiring growth; workforce development; and critical curriculum topics (similar to student survey topics).

The answers were tabulated into various categories. When asked if University wind energy curriculum training could lessen the in-house training requirements for their company, 57% of the respondents said yes. When asked how well they believe the current industry is at performing site selection and analysis for onshore wind, the responses averaged at about 50 scale level (for offshore wind, the response is at the 28 scale level). When asked to rate their current company workforce’ knowledge, the responses were below the 50 scale level for wind turbine design, improving wind turbine power output, and wind farm analysis. Several companies did indicate that they are in need of engineers with training in blade pitch control, wind farm operation efficiency analysis, CFD, and SoDAR.

When asked what percentage increase in available engineers with background in wind engineering will be necessary for the next decade, 57% said 10-20%; 28% responded with 20-30% and 14% responded with greater than 50%. Higher needs were indicated for technicians

needed to service and maintenance in the next decade. Fig. 1 provides a detailed breakdown of the answers to the questionnaire.

Survey Summary Based on these results, an ideal wind energy engineering curriculum would consist of a combination of mechanical and electrical engineering curriculum. At the same time, because of ABET requirements; we decided to recommend undergraduate options for mechanical engineering in electrical engineering, and vice versa. This way, each curriculum can provide the core discipline training within its core curriculum yet allow the students to take options in the other engineering curriculum (mechanical students taking electrical engineering options and electrical engineering students taking mechanical engineering options).

In terms of the core curriculum topical area, wind turbine system integration, turbine design, wind resources estimate, power output and economic estimation of return of investment, environmental permitting and how to prepare environmental impact statements appear to be the topics of interest to both the industrial sector and the local student interest. Based on the industrial survey results and student interests, an initial core curriculum topic was selected: wind turbine system integration, turbine design, wind resources estimate, power output and economic estimation of return of investment, basic electric circuit design, power control, and grid interconnect inverters, and repair and maintenance technologies.

Fig. 1. Results of the industrial survey conducted this quarter on manpower needs

Since the industrial demand for wind professional centers on the combination of electrical engineering and mechanical engineering, an ideal wind energy engineering curriculum would be an interdisciplinary program based on the mechanical and electrical engineering departments. Because both departments at GWU are ABET accredited departments, creation of a separate interdisciplinary program will take a long time to establish. Therefore, for the purpose of this report, the conclusion was to recommend to each department to create an undergraduate BS options in wind energy. The aim is to provide electrical engineering training in the mechanical engineering department under the wind BS option and to provide mechanical design training in the electrical engineering BS degree program under a separate wind energy option. This will produce the combination that the wind energy industry desires.

In developing wind energy curriculum, the overall strategy is important, but the curriculum must have details in the technical topics and tested in the classrooms. The concepts and subsequent lecture materials were developed and tested in two graduate energy engineering courses over two semesters. The courses are MAE6263 and MAE6291 taught by the PI, Professor Hsu. The courses both include wind energy basics, applications, and designs.

In both courses taught over two semesters, several term project topics were offered to the students (70% graduate students and 30% undergraduate students taking the course as senior technical electives). The topics range from aerodynamics vortex control, wind farm design, and smart blade design, on site renewable energy development, and offshore wind development projects. The students invariably chose offshore wind project development in VA coast and on site renewable energy option development.

Off-shore wind energy has additional issues on corrosion, survivability during hurricanes, lightning surge, and the effect of waves on wind turbine stability. Therefore, new course materials were developed to provide additional training to the students, especially to cover the materials aspects in corrosion prevention and choice of materials. Some of the course materials were designed to focus on the effect of wind turbine size on aerodynamic

stability. Materials science aspects were reinforced to deal with off-shore wind operations. The students in MAE6291 were taught on small wind installation, and utility scale wind design and installation.

The students' choice of term project topics reflects the students' desire to be practical and relevant to the current real challenges rather than theoretical exercises. The main conclusion is that the curriculum has to be designed based on needs and relevancy. Students generally are not enthused about abstract wind energy topics but demand to know why the course materials are important to solve the energy challenges. This additional aspect adds to the scope and helps to define curriculum design and selection. I talked to the students trying to understand their motivation and reactions to the topics offered. They were concerned about future jobs, career choices, and the need to pay off the student loans. And energy is a hot topic but the implied needs do not substitute to know the current real needs.

Based on the experiences gained from teaching the basic principles of wind energy, the students need much more training on practical project implementation skills for them to function as effective project managers or supervisory engineers in the wind industry. So additional course materials in economic evaluation, present value calculations, geology, and atmospheric turbulence were added to the curriculum.

Business prospects aside, off-shore wind energy issues bring more technology uncertainty in estimating maintenance costs, stability control, and long term profitability. I compiled lectures on materials sciences (structural stability, nano-composites, anti-fouling treatments, and corrosion resistance technology), wind turbine drive technology (to include direct drive technology suitable for offshore applications), and wind resources assessment (difference between land based installations and offshore wind farms). Some materials have been tested during the 2012 Spring Semester courses but many new contents were added to provide a reasonable core competence for students to move into wind energy industry.

The wind curriculum and content materials were carefully reviewed and outlines of various lectures were developed. Some of the materials were used during the 2012 Spring Semester courses and some of the revised materials are to be used during the 2013 Spring Semester courses. Two graduate students were admitted into my research group who will be conducting research in renewable energy, which includes wind energy research. The final curriculum was reviewed with the two new graduate students and their inputs were incorporated into the final curriculum.

The emphasis on the curriculum has shifted towards the end of the project. While retaining the basic wind turbine design and materials of construction, economy, payback period calculations, the focus has been placed on offshore wind turbine design and offshore wind farm project training. This is because the rising offshore wind projects occurring along the Atlantic coast. Both Maryland and Virginia are planning offshore lease and the utility companies are sponsoring studies on offshore wind energy feasibility. Hence the students' interest in this area has increased dramatically. The passage of the PTC during the fiscal cliff compromise also boosted job prospect in wind.

Conclusion

The final curriculum is being submitted to the departmental faculty committee for consideration. This will take fair amount of time for deliberation and eventual revision and implementation. After departmental approval, the package will have to pass the College of Engineering curriculum committees. This modest grant has allowed GWU to carefully seek industrial and student inputs and design a wind energy curriculum based on stake-holders inputs. The quality of the energy curriculum has benefited significantly from this grant. We would like to acknowledge DOE for providing this workforce training grant to enhance the quality of our wind energy education.