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Fellowships for Students Pursuing Interdisciplinary MS with a Focus on Wind Energy

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Introduction

The production of electricity from wind has grown rapidly in the U.S. and abroad. A problem generated by this rapid growth is the need for a highly trained workforce as has been discussed openly in recent workshops and in discussions with wind energy manufacturers and developers. In addition, the 20% by 2030 report[1] lists workforce development as among the critical needs if the initiative is to succeed. This report also identified that, for this initiative to succeed, many of the wind energy related technologies needed to advance. As a result, a critical component of the workforce development is the highly trained personnel that can contribute to this technology advancement.

The objective of this effort was to attract several highly qualified candidates to pursue a wind-energy focused interdisciplinary degree at the Masters Degree level. Since it was desired to produce these candidates as quickly as possible, fellowships were to be provided to the best candidates so that they could complete their degree quickly and transition to the workforce in the minimum time possible. In the course of advertising for these high quality candidates, it was hoped that other students would also be made aware of the educational and research opportunities offered by the Wind Energy Research Center (WERC). To ensure a wind energy focus for the students, a curriculum focused on wind was encouraged, but the curriculum was sufficiently flexible to allow the students to tailor the experience to meet their interests. Options for the students included internships or a thesis in addition to coursework only programs.

The results of this effort are considered to be an overall success. Six students started the program and all have either completed or are in the last stages of completing the program. Individuals with a broad range of backgrounds started the program demonstrating that students from many areas can successfully complete such a program. On average, the students took longer than the expected three semesters and summer to complete the program, but this was largely due to the choices they made in their degree programs. All of the students completing their degree have either moved on to employment, graduate school, or are finishing up their degrees and actively looking for their next position. The outcomes of this program can thus serve to guide institutions looking to develop a similar program

In the section below, the curriculum and the six students that completed the program are described in detail. Following that, a discussion of lessons learned and suggestions for improvement are made.

Overview of Curriculum

The curriculum was designed to allow the maximum amount of flexibility possible to the students. Studying disciplines outside the home department was encouraged. The curriculum options are given in Table 2. Options 1 and 2 are non-thesis options and primarily rely on coursework to provide the students with wind energy background. Option 2 includes a 3-6 month internship and requires two less courses than Option 1. Both Options 1 and 2 were anticipated to take no more than 15 months: Option 1 would take 3 semesters, and Option 2 would take 2 semesters plus duration of the internship. Option 3 was designed for those that wanted more of a

research experience. Due to the nature of research, this degree was expected to take a full 2 years.

Table 1 – Curriculum options for the students receiving this fellowship

	Option 1	Option 2	Option 3
Courses (3 credit equivalent)	10	8	8
Project (1 credit equivalent)	X		
Internship (6 credit equivalent)		>3 months	
Thesis (6 credit equivalent)			X

The choices of the students in the program were interesting. None of the six chose the Option 1 (coursework only) and only 1 student chose Option 2. The reasons for this are discussed further below. The range of coursework chosen by the students was also interesting from staying primarily within their home department's course offerings to taking half of the courses from outside their home department. Finally, their choice of future employment was interesting with only one continuing on to a Ph.D. program and the others seeking employment in industry.

This curriculum was expected to demonstrate the possibility of offering a more integrated M.S. degree in wind energy, such as that given in Appendix A. The results of this initial effort and lessons learned are discussed below.

Students Enrolled in the UW Wind Workforce Development Program

Each of the six students involved in the program are described briefly here. Their background, area they chose to study, and employment or employment plans are described. The students are sub-divided into the year they started: 2010 – First Year Students, and 2011 – Second Year Students.

First Year Students

Student 1

Student 1 graduated with a B.S. in Mechanical Engineering from the University of Wyoming. The student chose to work with a Professor in the Mechanical Engineering Department, and pursued a thesis-based Masters degree. The student's area of study was in high performance computing, specifically considering the use of a spoiler on a wind turbine blade for improved performance. In the process, the student gained important experience with high performance computing and effective use of computer systems. In addition, The student gained further computer programming skills and increased understanding of aerodynamics, computational methods, and optimization. The student won an award for a poster presented at a high performance computing workshop held in Colorado, and this work is expected to result in two journal articles. The student is currently employed at the University of Wyoming in the Information Technology department for High Performance Computing Research Support.

Student 2

Student 2 graduated from University of Michigan with a B.S. in Earth Systems Science and Engineering. The student then attended graduate school at the University of Oklahoma and studied wind energy potential mapping. After a couple of semesters, the student chose to transfer to University of Wyoming to complete a graduate degree. The student chose to work with a professor in Mechanical Engineering and another faculty member in Atmosphthe studentScience, and pursued a thesis-based Masters degree in Mechanical Engineering. The student's research involved setting up a 50 m meteorological tower and analyzing the first data available from it. In the process, the student gained valuable experience both in hardware and analysis techniques for wind resource assessment. Having recently completed their degree, the student is pursuing jobs in industry that can combine his interests in meteorology and wind energy.

Second Year Students

Student 3

Student 3 also graduated with a B.S. in Mechanical Engineering at the University of Wyoming. The student immediately started working on a thesis-based M.S. concentrating in experimental fluid dynamics. Working with a professor in the Mechanical Engineering Department, the student studied the unsteady aerodynamics of compliant wind turbine blades. Specifically, the student has created a two-dimensional compliant blade model that is coupled to a driving system through a set of torsional springs. The student has gained experience in the development, carrying out, and analyzing the results of wind tunnel tests. The student will present the results of his work at a fluid mechanics conference in summer 2013, and it is expected that several publications will result from work that he and several student collaborators have performed. Upon completion of his degree in summer 2013, the student will be looking for employment that uses his skills in the wind energy or aerospace industries.

Student 4

Upon completion of a B.S. degree in Electrical Engineering from the University of Wyoming, Student 4 started an M.S. in Electrical Engineering working. The student's research focuses on increasing the reliability of wind turbines by reducing unwanted loading of the system. At the same time, this research seeks to maximize the power output from the wind turbine. Specifically, the student investigates control algorithms for the wind turbine to accomplish these goals. Using the skills he has developed as part of this work, the student plans to continue on to a PhD working on similar topics related to wind energy. The student hopes to use these degrees to gain a position in the alternative energy field.

Student 5

Student 5 completed his B.S. in Mechanical Engineering at the University of Wyoming in 2011. He immediately began his thesis-based M.S. degree working with a professor in that department. The student's work focuses on blade aero-elastics with a specific focus of scaling 50 m blades down to laboratory scale blades (1-2 m). In the process of carrying out this research, the student has developed his skills in wind turbine blade aerodynamics, wind turbine blade structural dynamics, and wind turbine blade materials. It is expected that this research will result in several publications, but, maybe more importantly, it should provide an economic means of

testing new commercial wind turbine blade designs. After completing his degree in summer 2013, the student plans to look for work in the wind energy field.

Student 6

Student 6 received a B.S. in Physics from Furman University in Greenville, SC in 2011. The student pursued the non-thesis M.S. focusing her course works in atmospheric courses and mechanical engineering courses. The student participated in an internship with Science Applications International Corporation (SAIC) working on renewable energy project development. The combination of coursework and internship allowed the student to gain both a theoretical understanding of wind farm siting and performance as well as practical experience in developing such facilities. Although her background was likely to be attractive to industry, the student accepted a Ph.D. position at Iowa State University in their Wind Energy Science, Engineering, and Policy program.

The students' backgrounds, focuses during their graduate study, and future plans are summarized in Table 2. Although many of the students are looking for positions, several are still finishing up their degrees.

Table 2 – Summary of student's degrees and future plans

Name	Undergraduate Degree	Graduate Degree	Future Plans
Student 1	Mechanical Engineering	M.S. in M.E., thesis option	Degree complete. Employed in HPC at University of Wyoming
Student 2	Earth System Science and Engineering	M.S. in M.E., thesis option	Degree complete. Searching for a position in the wind energy industry
Student 3	Mechanical Engineering	M.S. in M.E., thesis option	Degree in progress. Searching for a position in the wind energy or aerospace industry
Student 4	Electrical Engineering	M.S. in E.E., thesis option	Degree in progress. Searching for a position in the alternative energy industry
Student 5	Mechanical Engineering	M.S. in M.E, thesis option	Degree in progress. Searching for a position in the wind energy industry
Student 6	Physics	M.S. in M.E., internship option,	Degree complete. Ph.D. Student at Iowa State U. in Wind Energy Science, Engineering, and Policy program.

Observations and Suggestions for Improvement

After almost three years that the students supported by these fellowships have been involved in our wind energy program, there are some valuable observations that can be made concerning the program.

Adding six students had a significant impact on the growing program in wind energy at the University of Wyoming. In our nascent program, these students represented a significant percentage (~30%) of the graduate students involved in the wind energy program through the Wind Energy Research Center. This bolstered the number of students taking classes, particularly those closely related to wind energy. It also resulted in adding numbers to our research program – something not anticipated when the program was proposed.

The coursework options, research projects, internships, and other opportunities offered to these fellowship students impacted their experience. First, the program was set up to accommodate students with a wide range of background in mathematics, science, and engineering. Despite their varied backgrounds, all the students that started in the program have or will successfully finish the program. Demonstration of this success was one goal of the program. The students with non-engineering undergraduate degrees were challenged particularly in the first semester. However, these students made the necessary adjustments that allowed them to complete, and in one case excel, in the program. In addition to coursework, the students were given the opportunity to choose a thesis or non-thesis option. When they chose a thesis option, research projects were made available to them and the faculty advisors committed significant times to these projects. In the case of the one student who took the non-thesis with internship option, the student was paired with a company that provided her with valuable experiences in the renewable energy development industry. In addition to these opportunities, most of the students had the option to attend workshops, conferences, or trade shows. Among the venues that the students attended were the AWEA Windpower Conference, the ASME/AIAA Wind Energy Symposium, the Front Range High Performance Computing Symposium, and the Sandia Blade Workshop. The sum of the opportunities related to wind energy listed above that were available to the students resulted in a positive experience for all.

A real benefit of the program as it was offered was how it encouraged students to take courses from a variety of fields. Almost all of the students took at least one atmospheric science class, and a few took several. This occurred even though none of the students obtained degrees in atmospheric science. Because of the program's flexibility, the students performing research were exposed to a variety of projects including high performance computing to field meteorological measurements.

One surprise to us was that the students took longer to complete their degrees (24-30 months) than anticipated (15 months). This was primarily a result of the students selecting to do research projects and the extra cost was partially borne by the research projects. However, even the student that chose the internship route took 3 semesters to finish coursework added to a 3 month internship. Having now observed these students in the program, particularly those with non-engineering programs, the 3 semesters + 1 summer is probably a reasonable period in which to complete the degree. It is expected that, if a program like this grew to larger numbers, fewer

faculty would choose to take on students for research projects, and thus a larger fraction would complete the non-thesis option. This would actually have a more beneficial effect on workforce creation as they would obtain their degrees and move on to industry.

Opportunities for Improvement

Running this pilot program also gave us the opportunity to observe some features of the program that we would now like to change. In the longer term, the wind energy program envisioned for the students would be a truly interdisciplinary degree as opposed to students working on wind within a home department (see Appendix A). The program would be simpler to run if all the students were taking a common curriculum, a result that would be important as the number of students grows larger. A standard program for all the wind energy students would likely avoid some of the problems we encountered when student's programs differed significantly from those typically offered by the departments. For example, one program had no easy way to provide credit for a graduate level internship, even though this was developed as a primary option for the students to choose.

Another issue that was obvious from this pilot effort was that the program would be more efficient if a larger number of students were enrolled in the program. There was ample room in all the classes that were taught to accommodate additional students. Thus, the incremental cost to include more students in the program rapidly decreases beyond 8-10 students. The one downside of involving more students in the program is that there would necessarily be less flexibility in doing a thesis option with a research project. Out of necessity, most students would be steered toward the non-thesis option. From a workforce training perspective, this would be a positive development as the non-thesis option students should finish more rapidly and moving on to industry leaving room for new students to take their place. However, non-thesis option students have a harder time obtaining funding (in general, but not in this particular case), so funding opportunities to cover their expenses would be needed to provide an incentive to go this route.

Conclusions

In summary, this initial attempt at offering an interdisciplinary degree focused on Wind Energy was a success. It demonstrated that students from outside a traditional engineering undergraduate program could succeed in obtaining an M.S. in an engineering field. The flexibility in the program options seemed attractive to the students. It would be interesting to see if the options the students chose would have the same distribution held if there were 30 students in the program. Although some of the students are either just finished or are in the process of finishing their degrees, it appears as though they will be successful in finding challenging jobs based on the students who have landed new positions. With the economic downturn experienced by the country over the past 5 years and the associated slowdown in expansion of the wind energy industry, the wind energy companies are adding personnel at a slower rate than may have been expected 5 years ago. On the down side, this pushes our graduates to other fields. However, on the positive side, their ability to obtain jobs outside the wind sector indicates the desirability of their highly technical interdisciplinary degree.

References

[1] "20% Wind Energy by 2030, Increasing Wind Energy's Contribution to U.S. Electricity Supply" Report DOE/GO-102008-2567, July 2008.

Appendix A

Table 3 – Interdiscipinary M.S. degree with a focus in wind energy – recommended requirements

Course Requirement				
Core Courses (Choose 4) (12 credits)	ATSC 5330 Boundary Layer Meteorology	EE 5210 Linear Control	ME 5442 Fluid Mechanics	
	CE 3200 Structural Analysis 1	EE 5700 Power Systems	CE 4610 Foundation Engineering	
Wind Integration Courses (Choose 4) (6 credits)	ATSC 5??? * Wind Resource Modeling	EE 5??? * Wind Turbine Dynamics and Control	ME 5??? * Wind Turbine Unsteady Aerodynamics	
	CE 5??? * Wind Turbine Towers and Foundations	ENR 5??? * Wind Energy Economics and Regulatory Issues	ME 5??? * Wind Turbine Aeroelastics	
Recommended Electives (Choose 2) (6 credits)	ATSC 5100 Atmosphthe studentDynamics	CE 3600 Soil Mechanics	EE 5470 Optimal Control	ME 5422 Advanced Vibrations
	ATSC 5008 Mesoscale Meteorology	CE 3400 Structural Analysis 2	EE 5475 Adaptive Control	ME 5431 Analysis of Comp. Materials
	ATSC 5160 Synoptic Meteorology	CE 4250 Structural Steel Design	EE 5720 Advanced Control Systems	ME 5442 Adv. Fluid Mechanics
	ATSC 5370 Meteorological Instrumentation		EE 5770 Non-Linear Systems	ME 5446 Turbulence
				ME 5448 Exp. Fluid Dynamics
		ENR Courses related to permitting		ME 5461 Comp. Fluid Dynamics I
		Economics Courses related to Energy Economics		ME 5472 Continuum Mechanics
Options (choose 1) (6 credits)	Coursework	Internship	Thesis	
	Complete an additional 2 courses from the list above	Complete an approved internship with a company, government lab, or university	Complete a research project and thesis in accordance with thesis option	

* - Course that are not yet official courses at the University of Wyoming.