Work in Progress – Evolution of a Survey of Alternative Energy Systems Course

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Abstract - **As alternative energy demands more attention it will be important for a new generation of engineers to be educated in the current status of alternative energy technology. "Survey of Alternative Energy Systems" is a new course taught in the Department of Mechanical Engineering at Grove City College. The course is designed to give students exposure in design, research, social/economic status of alternative energy generation and energy recycling. The course is split into three main topics; heat exchanger design, fuel cell technology, and alternative energy generation including nuclear energy. Each topic has an associated project. The projects are designed for the students to; (1) design a program to analyze proposed heat exchanger designs; (2) perform in depth study of a fuel cell research article, and (3) research the current technological and economic status of various alternative energy technologies. The purpose of this paper is to present the current development of the course after three years. The paper reports the content and requirements of the projects, lecture material, and student feedback with future considerations for alterations of the course.**

Index terms – alternative energy, heat exchanger, project based

INTRODUCTION

Alternative Energy is a topic that is demanding more and more attention. According to the Mineral Management Service of the U.S. Department of the Interior the definition of Alternative Energy is: "Fuel sources that are other than those derived from fossil fuels. Typically used interchangeably for renewable energy" [1]. This definition of alternative energy generally applies to power sources such as biomass, wind, solar, geothermal, and hydro-electric. Statistics show that alternative energy power generation is growing. The Energy Information Administration stated that "Renewable energy consumption grew by 7 percent between 2007 and 2008, despite a 2 percent decline in total U.S. energy consumption (see Table 1)" [2]. In addition to alternative energy, nuclear power has spurred on debate as a viable clean energy source. But as can be seen in Table 1, nuclear power generation has not grown as much as other alternative energy sources over recent years.

As a response to the growth of private and government alternative energy programs many institutions are including alternative energy into their curriculum. Examples of this include alternative energy specific courses and/or laboratories [3-5], and launching new B.S. programs in Renewable Energy [6]. The purpose of this paper is to present the current development of a course titled "Survey of Alternative Energy Systems" (MECE 416) offered as a senior year elective in the Department of Mechanical Engineering at Grove City College.

TABLE 1
U.S. ENERGY CONSUMPTION BY ENERGY SOURCE, 2004 – 2008 (QUADRILLION BTU) [2].

Energy Source	2004	2005	2006	2007	2008
Total	100.349	100.485	99.876	101.552	99.305
Fossil Fuels	85.83	85.817	84.69	86.174	83.436
Coal	22.466	22.797	22.447	22.748	22.421
Coal Coke Net Imports	0.137	0.045	0.061	0.025	0.04
Natural Gas[1]	22.931	22.583	22.224	23.628	23.838
Petroleum[2]	40.294	40.393	39.958	39.773	37.137
Electricity Net Imports	0.039	0.084	0.063	0.106	0.113
Nuclear Electric Power	8.222	8.16	8.214	8.458	8.455
Renewable Energy	6.26	6.423	6.909	6.814	7.301
Biomass[3]	3.023	3.133	3.361	3.597	3.884
Biofuels	0.513	0.594	0.795	1.025	1.413
Waste	0.389	0.403	0.414	0.43	0.431
Wood Derived Fuels	2.121	2.136	2.152	2.142	2.041
Geothermal Energy	0.341	0.343	0.343	0.349	0.358
Hydroelectric Conventional	2.69	2.703	2.869	2.446	2.453
Solar/PV Energy	0.065	0.066	0.072	0.081	0.091
Wind Energy	0.142	0.178	0.264	0.341	0.514

[1] Includes supplemental gaseous fuels.
[2] Petroleum products supplied, including natural gas plant liquids and crude oil burned as fuel.
[3] Biomass includes: biofuels, waste (landfill gas, MSW biogenic, and other biomass), wood and wood derived fuels.
PV=Photovoltaic

COURSE DEVELOPMENT AND DESCRIPTION

The course was originally titled "Design of Thermal Systems," which was a course on thermal optimization. In spring 2007, the content of the course was changed to cover heat exchanger design and fuel cell technology. It was found, due to lack of content, that another topic should be added. As a result, subject matter titled "survey" of alternative energy generation was added in spring 2008. In spring 2009, nuclear energy generation was also added.

The course is therefore currently divided into three main topics: heat exchanger design, fuel cell technology, and survey of alternative energy generation (including nuclear power generation). For each topic it is required that the students complete a project designed to expand the content presented in lecture. This course is similar in philosophy to a project based course given at Michigan State University (MSU) titled "Design of Alternative Energy Systems" (ME 417) [5]. Each lecture topic is expanded upon by adding a project. The projects given at MSU are largely design based. In the current offering of "Survey of Alternative Energy Systems" (MECE 416), the projects are designed to focus in on one of three areas; design, research, and social and economic issues. The lectures and homework assignments are designed to aid the students in completing their projects. Each project is worth 25% of the total course grade (75% total for the 3 projects). Homework assignments count as 15%, and a final exam is 10%. Lectures for the course take place twice each week for 75 minutes (28 total class meetings).

TEACHING METHODOLOGY AND PROJECTS

The course is taught with a series of lectures, guest lecturers, and projects. The lecture content is given to aid the students with their projects. The projects for this course are intended to give the students an experience in technical report writing and/or oral presentation. Below is a description of each topic taught in the course along with its associated project.

Heat Exchanger Design

Heat exchangers are used for several purposes; recycling heat for an HVAC process, power plant cycles, etc. The purpose of this component of the class is to give students an idea of how to design a heat exchanger from a theoretical basis. The students are assigned a project to design three different shell and tube, and three different plate heat exchangers. The designs are required to meet performance specifications for a heat exchanger used at Duquesne University's new cooling system [7]. Figure 1 shows the performance criterion.

CUSTOMER	:	QUOTATION NO. :	
REFERENCE	:	DATE :	2-Apr-2007
PROJECT	:		
SERVICE OF UNIT	:		
MODEL	: S-149-3000L-364		
SURFACE PER UNIT	: 6,542.21 ft²	NO. OF UNITS:	CONNECTED IN : Single

PERFORMANCE OF UNIT		COLD SIDE		HOT SIDE	
FLUID CIRCULATED		ethylen glycol 25%		water	
TOTAL FLUID ENTERING		3,900.0 gpm		3,554.0 gpm	
		2,040,390.5 lb/h		1,779,060.1 lb/h	
FLUID TYPE		Liquid	Gas	Liquid	Gas
DENSITY	lb/ft³	66.27	0.0	63.41	0.0
SPECIFIC HEAT	Btu/lb·°F	0.911	0.0	1.003	0.0
THERMAL CONDUCTIVITY	Btu/h·ft·°F	0.28	0.0	0.333	0.0
DYNAMIC VISCOSITY	cP	3.499	0.0	1.421	0.0
LATENT HEAT	Btu/lb				
TEMPERATURE IN / SAT.	°F	35.0	→	53.5	→
TEMPERATURE OUT	°F		→	→	38.0

FIGURE 1
PERFORMANCE OF HEAT EXCHANGER USED AT DUQUESNE UNIVERSITY (USED WITH PERMISSION).

During lecture the students are taught to use the NTU-Effectiveness and LMTD method for plate, and shell and tube heat exchanger performance analysis as described by Janna [8]. The two methods were used to predict the outlet temperatures of their proposed heat exchanger designs. The students used Microsoft Excel or MatLab to develop a program that uses either the NTU-Effectiveness or the LMTD method for predicting the outlet temperatures of their proposed designs. Fluid mechanic equations were also incorporated to compute the resulting pressure drop for each of the two fluids in the heat exchanger. The shell and tube heat exchanger designs were limited to specifications laid out in Janna [8]. The plate heat exchanger designs and constraints were limited to plates and plate frame product specifications determined by Invensys APV (www.apv.com). After the program was completed and the code verified with problem sets by Janna [8] the students were required to hand in a written report. The report was required to contain the three following sections:

- Product Design Specification - A short section explaining the task that the heat exchanger needs to perform. Students are also required to indicate the performance limits for both the shell and tube and plate heat exchanger designs (i.e. pressure drop, dimension limits, etc.)
- Product Performance – A section to discuss the performance of each heat exchanger design. It is required to use tables (and graphs if applicable) to indicate the performance of each of the heat exchanger designs. Additional text is required to explain the advantages and disadvantages of each proposed design. In addition a comparison of the overall performance of the shell and tube vs the plate heat exchangers is required.
- Recommendation – A brief section to recommend one shell and tube and one plate heat exchanger and briefly explain why that design was chosen.

Fuel Cell Technology

The history of fuel cells can be traced back to the first demonstration of a fuel cell by lawyer and scientist William Grove in 1839 [9]. The recent history of the fuel cell can be thought of as beginning in the early 1960s when NASA was looking for a way to power a series of upcoming manned space flights [10]. Since then the application of fuel cells has expanded and continues to expand. Research in fuel cells is not limited to exploring possible applications but also involves improving performance, exploring the feasibility of using alternative fuels for hydrogen extraction, etc.

The purpose of this component of the course is to allow students to research the current state of fuel cell technology as documented in scholarly research articles (technical journals or conference proceedings). The lectures consist of presenting the fundamentals of fuel cell operation as described by O'Hayre et al [11]. The students are also taught to use literature search data bases (Engineering

Village 2, Science Citation Index) to search for technical articles of interest. The purpose of the project is for each individual student to become familiar with a specific fuel cell research topic or application. They are free to investigate in any area of fuel cell research or application of interest. When a student selects an article they are required to obtain professor approval. The students are then required to present the content of the research article as if the student was first author. The goal is to allow the students to gain an understanding of what the author did, why the work was done, and how the research or project furthered science. The grading of the project is based upon the criterion indicated below.

- Meeting I (5%): Students are required to meet with the professor with three possible articles they would like to report on. The student is required to prepare a brief description of why those articles are of particular interest. Professor approval is then given for one of the three articles.
- Meeting II (10%): Students are required to show a proposed outline for the presentation of the articles' content. The outline is used to prepare an evaluation rubric for the presentation.
- Peer evaluation (20%): Each student in the class is given a presentation evaluation (different than the one used by the professor) to score each presenter. The grade for this portion is based on the average of peer ratings for each question in the evaluation.
- Professor evaluation (65%): The evaluation is based on the student's proposed outline given during Meeting II.

Survey of Alternative Energy Conversion

Renewable energy sources are those that will replenish themselves; i.e. the tide, water flowing downhill in a river, the wind, and the sun. As the technologies to use these natural energy resources evolve, the expense of using renewable energy to generate electricity is coming more in line with traditional fuels. Emissions constrictions on fossil fuels, research and development efforts, and government subsidies are bringing this niche market toward the mainstream in the United States [12].

The purpose of this component of the course is to expose the students to different alternative and renewable energy conversion such as; Wind Power, Solar Energy, Water and Geothermal power, and Biomass / Biofuels / Biodiesel. For this component of the course the definition of alternative energy was expanded to include Nuclear Power. The lectures are designed to give students a background on the technical and economic status of these alternative energy technologies. The purpose of the project for this component of the course is for the students to research a more detailed background of the status of the alternative energies discussed in lecture. The students are separated into five different groups and assigned an alternative energy topic (Wind Power, Solar Energy, Water and Geothermal power, and Biomass / Biofuels / Biodiesel, and Nuclear Power). Each group is responsible to present findings based on research using library and valid internet resources to answer each of the questions.

1. What is the current state of the technology?
    a. This includes which countries are exploiting the technology more than others and their current associated capacities.
    b. What may be the limiting capacity and what factors limit the capacity?
2. Which countries is on the front lines in development this specific alternative energy?
    a. What factors (political, geological) drive the development of the technology?
3. What are the costs associated with using this technology?
    a. These costs include dollar amounts.
    b. The environmental costs (i.e. emissions, habitat loss, thermal and noise pollution, impact on the surrounding scenery).
    c. Also comment on the overall feasibility, in your group's opinion, in launching the technology.

The grading for the project is based on a group presentation of their findings (50%), and a group report (50%). Each group is given 30 minutes to present in which each group member is required to present a portion. The grading of the presentation is based on professor and peer evaluation. The group report is required to be less than 5 pages, which is formatted to answer the questions listed above. It is required that at least 5 references be used.

STUDENT FEEDBACK

At the end of the semester the course is assessed by the students through an internally developed questionnaire. The overall rating of the course is based out of a scale of 7. In addition students are allowed to give anonymous written responses. The overall student rating for the course was 6.1/7 in 2007, 6.17/7.00 in 2008, and 5.82/7.00 in 2009. Students generally commented that the projects gave them a good understanding of the material. The fuel cell project and alternative energy project received more praise than the heat exchanger project. The students generally appreciated the freedom to research the topic more on their own through the project assignments. Some criticisms of the course included that some of the lecture material was too complicated, namely fuel cell fundamentals. The students also mentioned that they would like more guest speakers from the alternative energy field.

CONCLUSIONS

The course has been well received by students. Enrollment has increased from 7 in 2007 to currently 22 enrolled for 2010. Students expressed that the projects allowed them to have a further in depth knowledge of the material taught in lecture. Future considerations for changes in the course include the following:

- Include a total of 5 or 6 guest lecturers for the fuel cell and alternative energy component.
- Decrease the amount of lecture content on fuel cells.
- Instead of a final exam quizzes may be given at various times to test students on lecture material.

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