121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014

Paper ID #9028

DEVELOPING A RENEWABLE ENERGY TECHNOLOGY COURSE FOR A MASTER OF TECHNOLOGY (MTECH) PROGRAM

Dr. Omonowo David Momoh, Indiana University Purdue University, Fort Wayne

Omonowo (David) Momoh is an Assistant Professor in the Department of Computer, Electrical and Information Technology at Indiana University-Purdue University, Fort Wayne, Indiana. He received his PhD in Electrical Engineering from Prairie View A&M University, Prairie View, Texas. He received the MSc and BSc in Electronics and Electrical Engineering from Obafemi Awolowo University, Ile-Ife, Nigeria. He worked for SIEMENS Nigeria Limited as an Electrical Power Project/Service Engineer from 1994 to 2000. His research interests include Electrical Power System Analysis, Electric Machine Drives, Renewable Energy Technology, and Numerical Techniques in Electromagnetics. He is a senior member of IEEE and a member of ASEE.

DEVELOPING A RENEWABLE ENERGY COURSE FOR A MASTER OF TECHNOLOGY PROGRAM

Abstract:

A course on renewable energy has become more of a requirement in MS programs. This is the result of continuously shrinking global energy resources. The importance of creating a course that will provide the knowledge of how to efficiently manage the world's dwindling finite energy resources cannot be overemphasized. As the world is confronted with an unprecedented energy crisis, there is the need for industry drivers to have a fundamental knowledge of energy systems operation/management. The Master of Technology (MTECH) program at Purdue University, Fort Wayne regional campus is designed to meet the technological manpower needs of the industry within the Northeast Indiana region and beyond. The program has two tracks – Industrial Engineering Technology and Information Technology. Students are encouraged to take an elective in renewable energy technology. This is to sharpen their knowledge/awareness on energy related issues since most students are in mid-career managerial positions in their organizations. Energy is a prime mover of every business and would be more efficiently and profitably utilized when policy makers have adequate knowledge of the basics. In most cases, the profit margin of an organization depends largely on how much is being spent on energy. With the knowledge acquired from the course, students have the knowledge to determine types of feasible, available renewable energy sources that could be harnessed to supplement the conventional energy usage of their company. The renewable energy technology course was designed for students with engineering technology and non-engineering technology backgrounds. The course was first taught in the Spring Semester of 2011. It offers traditional and non-traditional methods of pedagogy. To add practical flavor to the course, an excursion to a local renewable energy company is usually made. In 2011, the class visited Water Furnace Incorporation, a geothermal based space heating / cooling company. This paper presents a detailed description of the various topics covered in the course, nature of projects given to students as well student evaluation of the course.

1. Introduction

Energy has always remained an indispensable component of and a key requirement for human existence/activities. Many of the conflicts that have bedeviled humanity can be linked directly or indirectly to energy acquisition. There is a direct correlation between the economic wellbeing (per-capita gross domestic product) of a nation and the per capita energy consumption. Consequently, the world today is witnessing a paradigm shift regarding acquisition and control of energy resources. There is a more intense and fiercer competition among nations for energy acquisition. While the developed nations account for the larger portions of the world's total energy consumption annually, the industrialization going on in some developing countries such as India and China has also contributed to the astronomical increase in global energy demand. Furthermore, the heat engine technology presently used for converting the chemical energy contained in the fossil fuels into other forms of usable energy (such as heat) is grossly inefficient owing to the Carnot efficiency limitation. From the foregoing, one can justifiably conclude that a great burden is being placed on the earth energy resources and the present method and habit of energy usage is unsustainable. We are also borrowing deeply from the energy capital of our future generations.

Fossil fuels which account for about 85% of the global primary resources for producing energy are nonrenewable (finite) in nature. Their exploration, processing and utilization are fraught with negative environmental consequences. They are buried biomass of the ancient past that has been subject to high temperatures and pressures inside the earth for a prolonged period of time. Depending on the details of the starting material and the formation conditions, the resulting fossil fuel can be solid (coal), liquid (oil), or gas (natural gas) [1, 2, 3]. In the United States of America for instance, fossil fuels account for about 72% of primary energy resources used for producing electricity. As a result of the low energy conversion technology being used presently, for every watt of electrical power delivered to the end user, about two or more are lost in the production process. Oil and natural gas which are primarily used for transportation and heating respectively also suffer from this low efficiency syndrome during exploration, processing and utilization. The U.S. used an estimated 97.3 Quads of energy in 2011. The four broad energy demand sectors are transportation, industry, residential, and commercial. Their rates of energy consumption as of 2011 are 27.75%, 24.25%, 11.72%, and 8.83% respectively [4]. As can be seen, transportation and industry are the two major energy consuming sectors in this country.

The rising global energy demand, the continuously rapid depletion of the finite global energy resources (fossil fuels), and the attendant negative impacts on the environment associated with the conventional energy resources have occasioned policy makers and leaders of government institutions, decision makers in the industry, research institutions and academia to start searching for alternative energy resources that are sustainable and environmentally friendly. At present, such sustainable energy resources that have attracted active consideration globally include wind, solar, micro hydro, tidal, geothermal, solar, and biomass. In most cases these sustainable energy resources are converted into electrical energy that is delivered either to the utility grid or isolated loads [5]. In addition to research being carried out on energy sustainability in academia, it has become necessary that more courses on energy sustainability be created in our institutions of learning. It is in light of this that the renewable energy technology course was developed as a graduate elective course for the Master of Technology program at Purdue University, Fort Wayne regional campus. Undergraduate Engineering technology major students with senior standing status are also eligible to take the course.

2. Course Development/Contents

The renewable energy technology course was first offered in Spring 2011 as a 3 credit hour course. It comprises of 30 lectures, two class projects, one field trip to a local energy company, three research oriented take home tests, and a final examination. Since the course is open to people from diverse technical backgrounds, emphasis is placed more on applications and concepts rather than the core technical engineering principles and details.

The objectives of the renewable energy course are:

i. Understand the fundamentals of electrical power system engineering in view of the fact that electricity has been the only feasible means of harvesting energy from the renewable energy resources.
ii. Understand fundamentals of Electrical Power Generation, Transmission, and Distribution.
iii. Be knowledgeable about the environmental consequences of conventional energy conversion and utilization processes.
iv. Be knowledgeable about the emergent renewable energy technologies and their storage systems.
v. Have basic knowledge of energy pricing and economics of energy generation and conservation systems.
vi. Understand the concepts of electrical power deregulation and distributed generation.
vii. Know how distributed generation is serving as a means of integrating renewable energy systems into the conventional electrical power system grid network.
viii. Be able to simulate the economic optimization of a grid connected renewable energy system using Homer software.

The course is broken down into five modules and the brief details of each of the modules is described below.

2.1 Module 1: Electricity 101

Under this module, the fundamentals of electrical power system engineering are covered. This is started with a brief review of units of electrical quantities and energy. Single-phase and three-phase electrical power systems are treated. The two methods of three-phase power system representation – wye connection and delta connections are presented. The concept of power triangle is introduced and the inter-relationship between real, reactive and apparent power as illustrated in equation 1 and figure 1 is discussed.

$$S = P + jQ \qquad (1)$$

where

S = Apparent Power (VA)

P = Real Power (W)

Q = Reactive Power (VAr)

θ = Phase angle between the line current and the line voltage

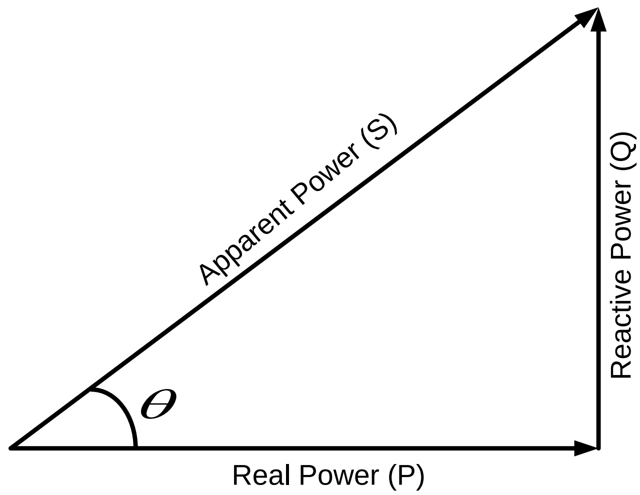

Figure 1: Power triangle

The importance of the cosine of the phase angle also known as the power factor is emphasized. The students are made aware of the implications of low power factor. For instance, it has been estimated that lagging power factor is responsible for as much as one-fifth of all grid losses in the United States. This is equivalent to about 1.5% of total national power generation and costs on the order of $2 billion per year [6]. Various methods of power factor correction such as the use of capacitor banks and synchronous compensators are also covered.

2.2 Module 2: Electrical Energy System Technology and Operation

This module encapsulates the fundamentals of electricity generation, transmission and distribution. The students are introduced to coal fired power plants and nuclear power plants. The two constitute the thermal power plants. Gas turbines, combined-cycle power plants, and combined-cycle cogeneration are treated as a group of modern and more efficient thermal power plants. Finally, hydroelectric power plants are presented as a primary energy source that is conventional and renewable in nature. The categorization of the afore-mentioned power plants into baseload, intermediate, and peaking power plants is also covered. The concepts of load-duration curve, capacity factor (CF) as it relates to electrical energy supply side, and load factor (LF) as it relates to energy demand side are presented along with a brief introduction to economic dispatch.

The second module also discusses the negative impacts on the environment of the exploration and processing of the primary energy resources used for electricity generation via any of the power plants listed above. This includes chemical and particulate pollution. The rise in the soil and ocean acidic level as a result of acid rain, CO_2 emission, greenhouse effect and the controversy surrounding global warming are hot topics discussed in the class. From the hydroelectric power plant perspective, environmental issues such dam failure, flooding from the impounded dam water, and fish migration problem are examined. Radioactive release during normal operation and storage of spent nuclear fuel rods are among the environmental challenges facing nuclear plants that are treated in this course.

The national transmission grid in the United States and its organization around three major power grids – the Eastern Interconnect, the Western Interconnect, and Texas Interconnect also known as Electricity Reliability Council of Texas (ERCOT) is presented in this module. Also discussed is the classification of high voltage transmission system into primary transmission voltage (138 – 765 kV), secondary transmission voltage (34.5 – 138 kV) and the distribution voltage (4.16 – 34.5 kV).

2.3 Module 3: Renewable Energy Technology

Having acquired knowledge about the conventional energy resources and the attendant limitations/environmental consequences associated with their exploration, processing, conversion and utilization, the students are now presented with the emergent renewable energy systems and the technology involved in their production (harvesting) and utilization. Renewable energy systems discussed in this course include solar, wind, biomass, micro-hydro and geothermal. Each of these renewable energy resources is discussed in details.

Both concentrated solar power (CSP) and photovoltaic (PV) systems are discussed. Grid connected and stand-alone PV systems are considered. Students are given homework assignments to design PV system based on some given specifications such as load profiles, local solar insolation, PV panels nominal power/open circuit voltage/short circuit current, storage system type, and system components' (battery, inverter, and charge controller) operating efficiency etc.

Offshore wind turbine and onshore wind turbine systems are presented under this module. Average wind power modeling and estimation using statistical methods is covered. Also considered in this module are the effects of tower height on wind speed, types of wind turbine generators (synchronous and asynchronous), role of power electronics and factors affecting wind turbine spacing in a wind farm.

Other mentioned renewable energy resources are treated similarly to solar and wind power. The role of biomass as CO_2 neutralizer is emphasized. Intermittency, energy and power density issues as they affect each of the renewable energy systems and other mitigating factors that prevent them from being able to compete economically with fossil fuel resources are discussed. Possible environmental issues are also presented.

2.4 Module 4: Energy Economics

This module presents an economic assessment of renewable energy and energy conservation systems. The capital cost of equipment, the operation and maintenance costs, and the fuel cost (if any) must be combined in some manner so that a comparison can be made with the costs of not doing the project [6, 7]. In light of this, students are acquainted with the following economic terms:

- Time value of money
- Interest and Inflation
- Present worth/ Net present value (NPV)
- Total life cycle costs
- Internal rate of return (IRR).

- Cash-flow analysis.
- Cost of energy (COE).

One of the two projects for this course involve the use of a software (HOMER) to simulate an economic optimization of a grid connected renewable energy system where these afore-mentioned economic terms become relevant.

Different types of rate structure (tariff) such as standard residential rate, residential time-of-use rate, and demand charges for commercial and industrial customers are discussed under this module. The impacts of the following factors on electricity tariff are discussed:

- Amount of energy (kWh) consumed.
- Peak power demand.
- Load factor.
- Power factor.

2.5 Module 4:Deregulation/Distributed Generation

In this module, students are introduced to the regulatory side of electric power system in the U.S. The evolution of the electric power regulations reflecting various energy policy acts up until the Energy Policy Act of 1992 that opened the way for the emergence of competitive markets otherwise known as electric power industry deregulation are discussed. The gradual transformation of the electric power grid network from the vertically integrated to horizontally integrated infrastructures is covered. Modeling of renewable energy resources as distribution generations (DGs) and how deregulation has facilitated the integration of renewable energy sources to the traditional grid network via DGs are presented in this module. Also covered are the challenges facing deregulation and how they can be mitigated.

3. Course Projects

There are two projects assigned in this course. In the first project, students are given the option to conduct literature search/review on one of the following topics and thereafter write a term paper on their findings.

- Renewable energy storage technologies
- Biofuels and other transportation fuels.
- Emissions Impacts and Benefits of Plug-in Hybrid Electric Vehicles
- Impacts assessment of Plug-in Hybrid Electric Vehicles on electric utilities.

The second project involves the use of HOMER software to implement economic optimization of a grid connected (hybrid) renewable energy system. The inputs required for simulation include system daily load profile, system components' power ratings and costs (e.g. PV, wind turbine, Battery, Power Electronics Converter, Diesel Generators), and resource availability. The simulation results allow for the comparison between different system designs and configurations and the ability to evaluate them based on their economic and technical merits [8]. One tool used for the evaluation is the net present cost of each of the design configurations. Students are divided into a group of two or three members. Each group is asked to contact any industrial or commercial establishment of their choice. They are to obtain the load profile of such establishments. Using the load profile and any potential renewable energy resources in the vicinity of such establishment, the students are to implement system optimization simulation using HOMER software with the ultimate goal of lowering the cost of energy (COE) of the establishment. Figure 2 is a typical daily load profile obtained by a group while Figure 3 is the generated optimization results for the establishment.

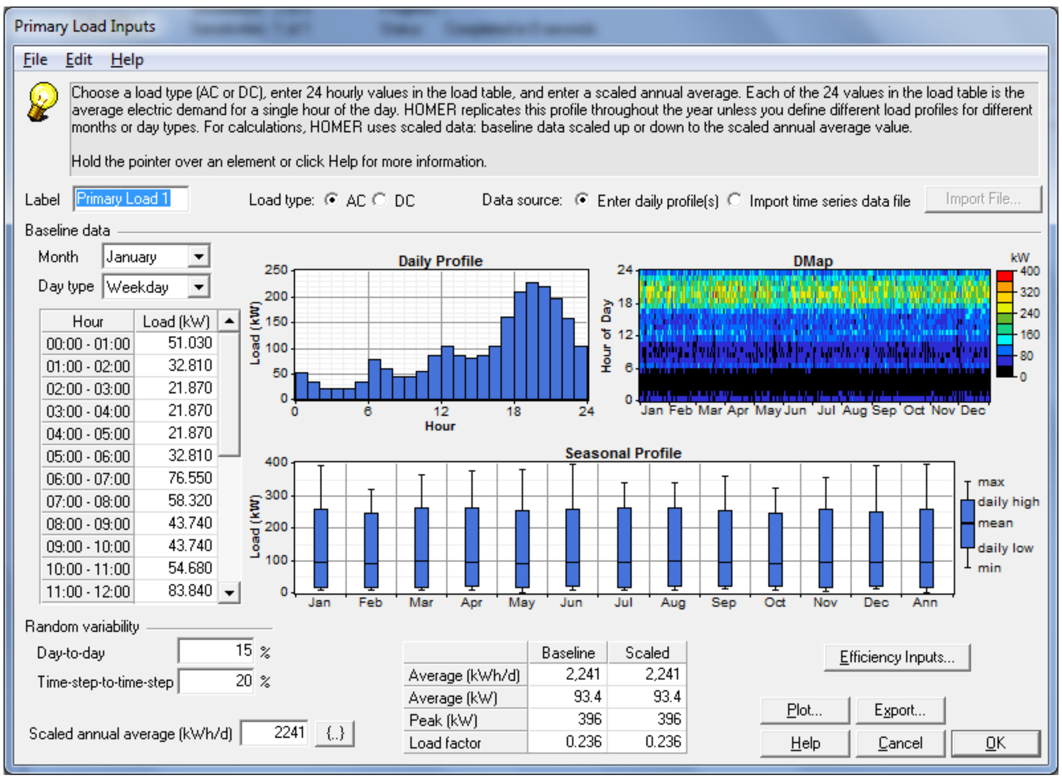

Figure 2: Daily load profile

Based on the load profile and the component costs provided, Figure 3 shows that the system configuration with the lowest net present cost (NPC) and cost of energy (COE) is the one with the grid, eight units of battery and 3 kW of power electronic converter. Homer can also perform sensitivity analysis on a system. Sensitivity analysis helps to show the effect that changes in factors such as resource availability and economic conditions might have on the cost-effectiveness of different system configurations.

PV (kW)	Label (kW)	L16P	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
		8	3	70000	$ 3,350	65,634	$ 703,977	0.081	0.00		
		8	12	70000	$ 5,720	65,693	$ 706,979	0.081	0.00		
		16	3	70000	$ 5,910	65,811	$ 708,427	0.081	0.00		
		16	12	70000	$ 8,280	65,870	$ 711,429	0.081	0.00		
		24	3	70000	$ 8,470	65,988	$ 712,876	0.082	0.00		
		24	12	70000	$ 10,840	66,047	$ 715,879	0.082	0.00		
10		8	12	70000	$ 23,901	64,928	$ 716,994	0.082	0.02		
10		8	3	70000	$ 21,531	65,159	$ 717,092	0.082	0.02		
		32	3	70000	$ 11,029	66,165	$ 717,326	0.082	0.00		
		32	12	70000	$ 13,400	66,224	$ 720,328	0.082	0.00		
10		16	12	70000	$ 26,461	65,105	$ 721,443	0.083	0.02		
10		16	3	70000	$ 24,091	65,336	$ 721,542	0.083	0.02		
		40	3	70000	$ 13,589	66,342	$ 721,776	0.083	0.00		
		40	12	70000	$ 15,960	66,401	$ 724,778	0.083	0.00		
10		24	12	70000	$ 29,021	65,282	$ 725,893	0.083	0.02		
10		24	3	70000	$ 26,650	65,513	$ 725,991	0.083	0.02		
10		32	12	70000	$ 31,580	65,459	$ 730,342	0.084	0.02		
10		32	3	70000	$ 29,210	65,690	$ 730,441	0.084	0.02		
10		40	12	70000	$ 34,140	65,636	$ 734,792	0.084	0.02		
10		40	3	70000	$ 31,770	65,867	$ 734,890	0.084	0.02		
	450	8	3	70000	$ 78,049	64,638	$ 768,042	0.088	0.00		0
	450	8	12	70000	$ 80,419	64,697	$ 771,044	0.088	0.00		0
	450	16	3	70000	$ 80,609	64,815	$ 772,491	0.088	0.00		0

Figure 3: System economic optimization result

4. Course Assessment

The course has been taught for three years (Spring 2011 – Spring 2013). Students' feedback and evaluation of the course have been good. Table 1 shows the summary of student evaluation of the course. MTECH is a relatively young program at the Fort Wayne regional campus of Purdue University. This is reflected in the number of student enrolment. There is however a potential for increase in enrollment as the program is getting more popular.

Table 1

Semester	Student Enrollment	Instructor Overall/ Department Mean	Course Overall/ Department Mean
Spring 2011	9	3.33/3.35	3.11/3.25
Spring 2012	8	3.75/3.35	3.50/3.17
Spring 2013	8	3.38/3.32	3.25/3.17

Some of the student comments in their unedited form are listed below:

- The course explored different energy technologies
- The homework allowed us to research on our own.
- The course is relevant to today's emerging technologies.
- All of the material covered in this class was relatively new and interesting to me.
- There should be more field work
- More HOMER project

- It is very helpful in understanding renewable energy.
- I like the fact that expanded my knowledge about renewable energy resources.
- More practical application or display
- More projects.

Generally, the students expressed their desire to have more projects that will involve the use of software that are more popular in the energy industry. To this end, ETAP software has been acquired through donation from Operation Technology Incorporation, an Electrical Power Engineering Company based in Irvine, California.

5. Conclusion.

This paper describes the development of renewable energy technology course for a Master of Technology program. The ever increasing importance of energy and the critical role it continues to play globally provided the incentive for development of the course. The course objectives and details of the material covered in the course are presented in this paper. Overall, based on the student feedback and evaluation, the development of this course can be judged to be successful. It is however imperative to mention that the course is still evolving. New material will be added in future while the present content will be continuously improved and modified to keep abreast with technological transformation. With the knowledge acquired in this course, the students are in a better position to manage energy utilization in a more optimal and efficient manner.

References:

[1] R. A. Dunlap, Sustainable Energy. Stamford, CT: CENGAGE Learning, 2015.

[2] J. W. Tester et al. Sustainable Energy – Choosing among options. Cambridge, MA: MIT Press, 2005.

[3] M. A. El-Sharkawi, Electric Energy – An Introduction. 3rd ed. Boca Raton, FL: 2013

[4] www.eia.gov

[5] O. D. Momoh, Nine-Phase Squirrel Cage Induction Machine: Sustainable Energy Application. Encyclopedia of Energy Engineering and Technology, Taylor and Francis, 2013.

[6] G. M. Masters, Renewable and Efficient Electric Power Systems. Hoboken, NJ: 2004

[7] F. Kreith and J. F. Kreider, Principles of Sustainable Energy. Boca Raton, FL: 2011

[8] http://homerenergy.com/software.html