Integration of Renewable Energy in Electrical Engineering Curriculum

Abstract

Climate change, global warming and increasing in oil price issues have been the major concerns of every human being lately. Conventional sources of energy such as coal, oil, and natural gas will remain part of our energy sources for decades to come. The negative effect of such sources is very clear, especially on air quality. In addition, these sources are non sustainable. Thus, the idea of establishing a safe and efficient environment for new generations has led to the search for alternative energy sources. These sources should not only have zero emission but also be lasting and non-depletable.

Sources such as solar, wind, geothermal, and biomass have recently been identified as renewable energy. The idea now is to see how these sources can be deployed in an efficient manner. For this, expertise in this field must be provided. The new generation must be educated and knowledgeable to elevate expertise in this field. This is accomplished by exposing the young generations (if not at the high school level, at the college level), to such sources and the related technologies. Such learning experiences will raise the awareness of the environment in our young generation as well as develop their thinking and analytical skills in finding solutions to problems raised by such issues. This paper describes the experience of introducing renewable energy into the curriculum of the United Arab Emirates (UAE) and the steps taken to enhance the learning process. It also highlights the impact of this experience on the students with respect to the environment and the community. Such experience is an example that can be followed in order to promote renewable energy technologies and to develop expertise in this field.

I. Introduction

The United Arab Emirates (UAE) is an important oil producer with the fifth largest proven oil reserves in the Middle East. In 2004, natural gas supplied 64 percent of the country’s total energy consumption, and oil supplied the remaining 36 percent. However, approximately 97 percent of the UAE’s electricity production is fueled by natural gas, with the remaining three percent produced by diesel generation and steam turbines.

![Fig. 1 Total energy consumption in the United Arab Emirates in 2004](image-url)
Even though non-oil sectors grew during the last three years, the country remains dependent on oil revenue, and the government has announced large oil production capacity increases within the next seven years. Hydrocarbon revenues account for around one-third of the UAE’s Gross Domestic Product. UAE power demand is among the largest in the region due to financial and tourist projects as well as a growing population. According to Global Insight, UAE has added 24 percent electricity-generating capacity at an annual rate over the last 30 years. Current total capacity for electricity production is around 16.7 Gigawatts (GW), but will need to increase further considering the 10 percent per year demand rise expected through 2010. Nearly all UAE power comes from conventional thermal generation. In 2004, consumption reached over 0.45 Terrawatt-hours (TWH). By mid-2006 the total capacity for electricity production in the UAE was 16,220 Megawatts. The demand for electricity in the UAE has been growing at double-digit rates for many years and will continue to do so, according to projections, until at least 2010. To meet this demand, the UAE must increase its electricity generation capacity by as much as 60 percent over the next three to five years.

As the country is developing more and more, energy demand will increase which will cause higher carbon emissions. Thus for environmental protection purposes as well as awareness that such sources (oil and gas) will sooner or later deplete, and based on the Kyoto Protocol which aims to stabilize the content of greenhouse gases in the atmosphere at a sustainable level, the Government of Abu Dhabi has initiated a new program based on development and promotion of renewable energy and resource sustainability. Masdar, Abu Dhabi’s government-owned renewable energy development body, has ambitious plans for solar, biomass, wind, and other renewable energy projects. So does the Dubai Electricity and Water Authority, which has launched a pilot project using wind energy to supplement conventional energy sources. But because the UAE public is not charged market rates for energy consumption, policymakers in the UAE will need to make some challenging decisions – involving raised tariffs – if these alternative energy sources are to be available on a commercially viable basis. Unfortunately, in this part of the region, there is a lack of coverage of such topics in the engineering and technology curriculum. The question which rises then, is how can our future engineers coop with such technology when their background lacks the primary knowledge and technical aspects of these resources?

Fig. 2 UAE’s Electricity Generation and Consumption, 1994-2004

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Sunshine, the major source of alternative energy, is available for 300 days for an average of nine hours per day. The gulf region is one of the richest in that domain. The UAE has been singled out as one of the world’s highest per capita emitters of carbon monoxide and other greenhouse gases [table 1]. The UAE has especially high energy demands to maintain a luxurious lifestyle of air-conditioning, chilled swimming pools and even an indoor ski slope. At the same time, the UAE is the serious among Persian Gulf oil-producing countries whose thirst for electrical power has spawned efforts to find other sources of energy to save high value fossil fuels for export. Most Persian Gulf states get their water from desalinating the gulf waters, an energy-intensive process. “We realize that the world energy markets are diversifying, so we need to diversify too,” said Sultan A. Al-Jaber, chief executive of the Abu Dhabi Future Energy Company, the government arm that manages the Masdar Initiative. “We see the growth of renewable energy as an opportunity, not as a problem.”

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Table 1: Metric tons of CO₂ emission per capita per year per country

For this reason, as educators, it is our responsibility to educate the future generations of our engineers to become capable of designing, implementing and operating renewable energy based
projects. To start implementation of the first systems, it is well understood that the UAE will have to import the expertise. However, in the short and long term, we must educate our future engineers to plan, build, and operate these renewable energy technologies.

What is needed is not just technical expertise, but rather competence combined with a broader understanding of the policies, economics as well as the institutional aspects of energy. We must begin integrating this in our educational system, at least in our engineering curriculum or courses. It is time to produce engineers with a more thorough knowledge to work and excel in developing the suggested projects. In no time, newer, more efficient and more practical projects will be developed for use in this part of the world. For decades, engineering curricula have been tailored according to both industrial and social needs and since sustainable energy is an engineering area that must be introduced at an early level, several US and European universities have modified their engineering curricula accordingly and added courses related to renewable technologies.

II. Integration of renewable energy in curriculum

Energy is one of the most fundamental matters of our universe. The concept of Energy and its transformation is extremely useful in explaining and predicting most natural phenomena. One form of energy can often be readily transformed into another with the help of technology. Recognizing the importance of such technologies and the consequences of integration in the curriculum in a suitable way, the goal was to initiate such programs carefully in a well designed manner, for an efficient and successful outcome.

The mission of any respectable engineering school is to develop first class engineers and leaders in their field, empowering them with the best engineering tools and exposing them to the latest technologies. Modern society relies on stable, readily available energy supplies. Renewable energy is an increasingly important component of the new energy mix. Anyone can easily see that the world is leaning toward renewable energy sources and in this region, solar and wind energies are the next generation sources to come after oil and gas. After an extensive search and readings of how this could be implemented, the first step toward integrating such technologies into the curriculum was attending workshops in the United States (US) on renewable energy to seek out the most efficient method for introducing these topics in the core of the electrical engineering program. Since our target was to teach such technologies to the largest number of students possible, and since these are energy sources, then it made great sense to integrate these topics into the energy engineering course. The course covers energy conversion and utilization. The course also touches upon the environmental consequences of energy conversion and how renewable energy can reduce air pollution and global climate change. Below is a short syllabus of the course. Renewable energy as a whole was introduced however solar energy and in particular Photovoltaic technology (PV) and concentrated solar power (CSP) were covered in detail. In addition to that wind turbines and the internal structure were also taught.

<table>
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<th>Course #:</th>
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<td>Course Name:</td>
<td>Energy engineering</td>
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<tr>
<td>Instructional methods:</td>
<td>Lecture, class discussion, in-class group and individual problem solving, field trips, projects, seminars and reports</td>
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<td>Textbooks:</td>
<td>Electric Machinery Fundamentals, 4th ed</td>
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Objectives:

1. Understand and analyze energy conversion and utilization
2. Develop the students’ ability to apply specific procedures and techniques to analyze energy conversion
3. Understand the environmental consequences of energy conversion and how renewable energy can reduce air pollution and global climate change.

Grading

Seminar Attendance and report 5%
Field Trips attendance and report 5%
In-class group activities 5%
Homework 10%
Project and presentation 10%
Midterm Exams 20% each
Final Exam Comprehensive 25%

Measurable Outcomes:

1. Students have a qualitative knowledge of the main sources and the means by which the sources can be exploited for energy generation. (Qualitative Analysis)
   Assessments: Homework, Class participation, project and field trips

2. Students have a quantitative understanding of the energy generating potential of renewable energy sources and can perform analyses of energy conversion from these sources, and determine analytically the power requirements, power output, and efficiency (Quantitative Analysis)
   Assessments: Homework

3. Student can identify and locate relevant information sources on energy conversion elements and assess the quality of the information and the information source. (Lifelong Learning)
   Assessments: Internet Search, field trips, Project

4. Students can produce written and oral analyses of problems relating to energy conversion that are clear, concise and elegant. (Communication and Team work)
   Assessments: Homework, Internet, Projects and Journals

Tentative Schedule:

<table>
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<tr>
<th>Week 1:</th>
<th>Introduction to machinery principles</th>
<th>Week 9:</th>
<th>Motors</th>
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<td>Week 2:</td>
<td>Transformers</td>
<td>Week 10:</td>
<td>Motors</td>
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<td>Week 3:</td>
<td>Transformers</td>
<td>Week 11:</td>
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<td>Week 4:</td>
<td>AC Machinery Fundamentals</td>
<td>Week 12:</td>
<td>Renewable Energy</td>
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<td>Week 5:</td>
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<td>Week 13:</td>
<td>Solar Energy</td>
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<td>Week 6:</td>
<td>Generators</td>
<td>Week 14:</td>
<td>Solar Energy</td>
</tr>
<tr>
<td>Week 7:</td>
<td>Generators</td>
<td>Week 15:</td>
<td>Wind Energy</td>
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<tr>
<td>Week 8:</td>
<td>Generators</td>
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Table 2: Short Syllabus
What was really surprising was the students’ excitement to learn about energy conversion, in particular, renewable energy. In order to achieve the goals of this course and to finish this heavily charged schedule, the students attended extra lectures every week. By week 11 they were right on schedule. The history of renewable energy, climate change, CO₂ emissions was introduced and all types of renewable sources were explained to some extent. However a greater emphasis on both wind and solar energy sources took place since they were found to be the most potential sources for this region.

The most important issue is not only that such material was covered for the first time, but the method deployed was innovative also for this region. The course as a whole was not only based on regular lecturing using power point slides, but new tools were used such as field trips, seminars and team presentations. Prior to reaching these topics, students teamed in groups of three where they were required to search, understand, write a report, and make a presentation at the end of the semester about one of the technologies available and its application. Their presentations highlighted the practical aspects of the source discussed and its application in the UAE.

III. Teaching approach

Before the semester started, attempts to contact industries dealing with equipment related to the material taught were made. The reason behind this was to invite technical experts to give presentations related to the topics covered throughout the course on a weekly basis. The students were required to attend (part of the course grade), take notes and write a report of what they had learned and relate it to the course material.

Moreover, four field trips were organized, three locally and one internationally. The first local trip was to Emirates transformer & Switchgear limited (transformer manufacturing company [5]), in Dubai (Fig. 3).

![Fig. 3 Visit to Emirates Transformer & Switchgear](image)

The students were shown the step-by-step manufacturing of transformers. The second trip was to Dubal (Dubai Aluminum⁶) a leading company in Dubai. The visit occurred during a maintenance period, where most of the transformers and generators were disassembled. Students were then able to relate to the material covered in class about electric machinery. The third trip was to the solar cells manufacturing company, Microsol International FZE⁷, where students were exposed to the complete line fabrication of cells starting from the wafer.
All these trips were very informative and added great practical understanding to the theory taught in class. One great point that is worth noting is that these trips were not made during weekdays. Students volunteered to join and visit these companies on weekends so no classes were cancelled. The willingness to learn, the excitement to see the real engineering and the dedication of the students made these trips so fruitful. The question that was raised then is what else could be done to help the students. There was an enormous interest within the student body to learn and see renewable energy technology. External speakers came and presented topics related to this such as General Electric (GE) for wind turbine applications and Microsol on how silicon is extracted (Fig. 4) and wafers are fabricated to form solar cells. But that was not enough.

What they wanted to see is how these are being used practically. Solar energy is not deployed yet on a large scale in the UAE and only one wind turbine was installed in Sir Baniyas Island for investigation purposes only.

Contacts with some companies in Germany and Spain were established. Most of the students showed great interest in traveling to learn more about these technologies. Germany was the choice. Lahmeyer International, a leading consulting Company in Renewable Energy in Germany, was contacted to organize a trip where solar and wind energy technologies were the topics of interests. In order to promote such technologies, Lahmeyer organized a full one week schedule were site visits for both solar and wind technologies took place. They also partially sponsored the trip and dedicated one of their engineers to accompany the group on all visits. In addition to industrial and plant visits, a trip to Kassel University took place where applied research laboratories (ISET) were visited. The trip took place during spring break. Even though this trip was not mandatory, 80% of the class attended. The willingness to learn more was unlimited. Below are some of the pictures taken during the trip showing some of the sites visited.
Fig. 5  Wind Farm Visit in Retzstadt owned by Conergy

Fig. 6  Getting ready to be escorted to the top of the wind turbine.

Fig. 7  12.5 MW Photovoltaic Power Plant at the Vine Farm Erlasee

Fig. 8  SMA Inverters Manufacturing Company Visit
This trip was extremely beneficial to all. It developed in the students a great interest in such technologies and an eagerness to raise awareness of global warming and climate change as soon as they go back to the UAE. The students were amazed of the German government’s initiatives to promote such technologies even though the amount of sunshine is much smaller than that of the UAE. One of the students developed a much greater interest and requested to join Lahmeyer in July for a six month internship to learn ways of employing these technologies in the UAE.

IV. Impact of such experience

After their return, some students decided to go to schools to raise awareness about the environment and explain global warming and the technologies being applied to help save the environment. Others helped organizing the first workshop on solar energy in the UAE. This workshop invited speakers from different countries to speak on what has and should be done to promote solar energy. The students were happily and heavily involved and shared their experiences with the attendees.

The efforts the students put in to organizing this workshop were beyond recognition. Their enthusiasm about this topic has been remarkably noticed by several companies who have recently developed interests in this area. They have taken them under their wing and offered them summer internships as well as possible full time employment.
This was really the greatest experience in introducing new topics into the curriculum. The addition of all these tools to enhance the learning process was like an invitation to the new generation to be more involved in their community in helping protect the environment. The outcome of such experience exceeded by far the expectations and showed the thirst of our students for learning and working toward developing the country by using the latest technologies as well as providing a safe environment to the new generations to come.

The success of this course was measured by the amount of information the students gathered about the different energy sources and their applications. Students have acquired excellent knowledge in each of the topics taught. Such information was delivered to us during the summer internship where students were placed in different companies. During the final presentations of these internships, in the presence of the engineers and managers of the hosted companies, these students received excellent reviews. “If all your students have the knowledge that Basel, an electrical engineering junior student, acquired prior to working with us, Dubal will be more than happy to host more students for internship” said Mr. Al Madani. Moreover, the students’ presentation at the solar energy workshop in front of many experts in this field was so impressive that it has led to a closer collaboration between the University and the industry, a model that barely exists in this region. The impact of this experience has been recently measured by the fact that this course was full at the first week of registration, a trend that was not seen. Students have approached me asking me to develop some undergraduate research opportunities in the area of solar energy. Two students who are graduating this year got accepted for a Masters degree in the United States of America (USA) in the area of photovoltaics. A study tour to Spain is currently being organized with the emphasis on CSPs and wind turbines. At the end of this semester, a survey will be conducted to see the impact of this course on the students and to study the possibility of offering more related courses.

V. Conclusion

It is a fact that not only will conventional sources of energy remain dominant for quite some time, but also that sustainable sources are still more expensive for energy production compared to traditional sources. However, Global warming as well as climate changes have raised great concerns for all of mankind. Several developed countries have started to enhance the use of renewable energy and have set up plans in order to move forward toward such technologies. One of the most important factors is to produce expert engineers in these areas. If you are the early bird you will have the technology ready when it is needed. Hence you will have technology transfer. Countries under development like the UAE are steering toward such technologies and it is our role as educators to produce engineers who have knowledge in designing or maintaining such technology. To date, most universities in the region have not yet introduced or integrated this discipline into their curriculum. However the experience described above definitely shows that students are eager to learn more about the latest in technology. This experience has shed light on several issues and has enhanced students’ awareness of the environment they live in and how to make it more secure for their future. The methodology applied above was so successful that it is being implemented in other courses. Local field trips as well as weekly seminar presentations by industrial engineers are scheduled to enhance the learning of our students. Renewable energy has become an important issue in this area where
oil and gas are major sources of energy and contributors to the growth and development of the country. The experience presented has led to a great interest in this area and now more related courses are on their way.

VI. References

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Lana Chaar has received her BS., MS, and Ph. D. in electrical engineering from the University of Minnesota. During her studies she worked as a Design Engineer at Schott Power Inc. while her main work was to develop an efficient battery charger for the electric vehicle. In 1997 she moved to Lebanon where she became an assistant professor at Beirut Arab University and a Lecturer at the American University in Lebanon. In 2002, she joined the Business and Computer University College as the Chair of the Communication Engineering Department and became a senior Lecturer at the American University in Beirut. In August 2005, she joined the Electrical Engineering Department as Assistant Professor at the American University in Dubai, UAE. She is currently an assistant professor at the Petroleum Institute, in Abu Dhabi, UAE. lelchaar@pi.ac.ae