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ALTERNATIVE ENERGY SYSTEMS

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Abstract

This paper reviews some of the alternative energy systems which are being used today for generation of electrical energy as well as other forms of energy. Various configurations of alternative energy systems and their suitability for the domestic as well as commercial use are discussed. Though these systems are very rapidly gaining acceptance and are being encouraged by governments at the state as well national level, these topics are not as yet being adequately covered in the curriculum for most programs of electrical engineering and technology at colleges and universities. Several recommendations are made for possible inclusion of these topics in the curriculum for the engineering and engineering technology programs, at the associate's level, baccalaureate level as well as at the master's level.

1. Introduction

The ever increasing requirement of energy coupled with the reducing availability of sources for fossil-fuel, and concern for the environment are rapidly encouraging wide spread approval for non-conventional, sustainable, alternative energy. The most common alternative energy sources today are solar, wind, and geothermal. Other sources including tidal are under development and it will be a few years before they become commercially viable and are deployed in sizeable numbers. In most of these systems, they can be decentralized and therefore the transmission and distribution losses as associated with a centralized power generation system can be avoided.

For any nation, the quality of life of its citizens and its security has a great dependence on the availability of cheap and plentiful energy. The topic of alternative energies has been gaining increasingly more importance and wide spread acceptance over the past few decades. What seemed a few years to be a distant dream, or a work of science fiction, is now possible, and even more importantly becoming commercially viable. Due to the associated high costs with implementing most alternative energy solutions, in the past few years, most initiatives for using non-conventional energy were considered only to be of research value and limited commercial viability. The situation today is very different and there is encouragement by both federal and state governments to employ alternative forms of energy including solar, wind, geothermal, and tidal.

Alternative or non conventional forms of energy are something to be understood, appreciated, encouraged and implemented. This is something which will directly impact each one of us in the not so distant future. It is likely to be so commonly implemented and wide spread that it will not be treated as non-conventional or an alternative form of energy. Rather, it will be considered as a conventional form of energy which is in day to day use and an integral part of the society.

It is pertinent therefore that the topic of non conventional energy be incorporated into the curriculum for engineering and engineering technology programs, at the Associate's, baccalaureate as well as at master's levels. There are various types of non-conventional energy systems, and an overview of these is given in this paper which may enable us to appreciate the topics that should be included in the program curriculum.

For centuries traditional sources of energy have continued to be fossil fuels including coal, petroleum and natural gas, and hydroelectric power. Recently nuclear power stations have also been contributing as a source of energy. Over the years, the search continued for alternative sources of energy which would be sustainable, and for which there would never be a concern that they would be depleted from the face from the earth based on excessive consumption. Researchers have worked tirelessly for years to identify possible sources of sustainable energy, and techniques to convert these sources of energy into a required form of energy. Today, collectively we as the human race can be proud of many inventions which will enable us and our future generations to very meaningfully harness the energy from several sources of sustainable energy. These sources of energy include solar, wind, geothermal and tidal among others. The next step in the future towards alternative energy is likely to be clean, and affordable biofuels, which may be derived from non-food biomass resources, such as switch grass, wood waste, agricultural residue, and algae. It is hoped that this may lead to a wide range of biofuels, including cellulosic ethanol, biobutanol, green gasoline, jet fuel, and renewable diesel. But it seems that is still a few years away, and when it does we can revisit the topic of incorporating changes in the curriculum.

In this paper, the terms alternative energy and non-conventional energy have been used interchangeably in the spirit of these terms, implying sustainable sources of energy, rather than in the theoretical rigor of the subtle differences between these three terms. There is large amount of literature available today which is addressing many of these technologies, including various concepts of theory, government role and encouragement, and the distant future [1-16].

2. Solar Energy

Solar Energy is renewable energy source that is freely available everywhere there is sunlight. Solar technologies use the sun to provide heat, light, hot water, and electricity. Large numbers of solar energy installations are driving costs of these installations low, and in many areas the payback time is approximately 25-30 years. Systems which harness solar energy have significant federal and state incentives, which are greatly promoting the growth of these systems. This is turn is helping the economy by creating large numbers of new jobs related to solar energy in terms of installations, manufacturing, and maintenance. The U.S. Department of Energy (DOE) seeks to make electricity generated by using solar technologies cost-competitive with grid electricity by 2015 [1]. That will be a major achievement which will very significantly reduce our dependence of fossil fuels. Also, the DOE in partnerships with industry, academia, and national laboratories, has setup the DOE Solar Energy Technologies Program (SETP) which undertakes various activities which may help reduce the cost of solar power. These activities include research and development in the areas of Photovoltaic's (PV), Concentrating Solar Power (CSP), and Systems Integration to facilitate connecting solar technologies to the electric grid.

A key attribute of CSP systems is thermal storage which allows these systems to generate electricity on demand, not just when the sun is shining. CSP technologies are best suited for utility-level power generation. DOE-sponsored improvements during the past 15 years have reduced the cost of this technology by two thirds. With DOE's continued support, industry hopes to achieve cost competitiveness with other intermediate power supplies by 2015 and with base load power providers by 2020. CSP has seen a tremendous resurgence worldwide in the last 2 years, especially in U.S. and Spain.

Solar systems include PV systems for domestic use as well as for commercial applications. For domestic applications, the PV systems typically consist of a series of solar panels placed on a roof and connected to an inverter whereby the DC electricity generated by these solar panels is converted to AC electricity which is used in the house. These systems could be tied to the grid as well so that when more electricity is being generated than needed by the house, the surplus could be fed back to the grid of the utility company.

For commercial applications, vast farms of solar panels, which are ground mounted in frames, could generate electricity which could be transmitted using the existing distribution networks and grid lines.

Photovoltaic electricity is still generally more expensive to produce than the conventional electricity, but increase in production capacity and latest research and developments are leading to major cost reductions. Among the renewable energies, PV technology is the one with the highest long term potential, and some experts predict it will be the cheapest option for electricity generation in the mid and long term [2]. The solar electric system cost varies depending on several factors including system size, manufacturer, installer, retailer, and whether it is a roof integrated systems, or a system mounted to top of an existing roof [5]. The cost of electricity from PV has dropped more than tenfold from 1976 to today. The cost for installing a PV based system was approximately $8 to $10 per Watt in 2008, and has reduced even more today to about $6 to $7 per watt.

2.1 Net metering

The concept of net metering is a fairly new concept that has arisen recently due to the fact that there are electric customers who generate their own electricity. Net metering allows for the flow of electricity both to and from the customer through a single, bi-directional meter. When the electricity generated by the customers solar panels is in excess of the requirement, electricity from the customer's installation flows back to the grid, offsetting electricity consumed by the customer at a different time. In effect, the customer uses excess generation to offset electricity that the customer otherwise would have to purchase at the utility's full retail rate. Net metering is now required by law in most U.S. states, even though these policies may vary from state to state. Another major issue involved with this is the interconnection from the home to the grid as more and more customers begin to generate electricity and would like to send excess back to the grid.

Standards for interconnection specify the technical and procedural process by which electric customers can connect an electricity-generating system to the grid.

2.2 Smart grid

A new system is beginning to be defined, called the smart grid. Presently a large number of agencies, including federal and state government agencies, researchers, utility companies and international agencies are working towards defining the concept of smart grid and getting suggestions from all stakeholders involved in this initiative. A smart grid is the use of sensors, communications, computational ability and control in some form to enhance the overall functionality of the electric power delivery system [7]. A dumb electric power delivery system becomes smart by sensing, communicating, applying intelligence, exercising control and through feedback continually adjusting.

3. Wind Energy

Based on the present estimates, United States has abundant wind resources, with a land based, economically- developable resource of 8,000 Gigawatts [8]. Due to improved technology and lower cost, among other factors, there has been a very rapid expansion of the wind industry in the past few years. Total installed wind capacity in U.S. now approaches 120 GW, which is significantly higher than the wind installed capacity of 25 GW towards end of 2008. The present goal is to have wind energy be able to supply about 300 GW, which is about one fifth of the total nation's electricity needed in the year 2030. According to the American Wind Energy Association, plants in 33 states now provide enough wind electricity to power approximately 7 million households while avoiding nearly 44 million tons of carbon emissions. The industry invested $17 billion in the U.S. economy in 2008 and employed 85,000 workers. Advances in turbine technology have lowered the cost of wind energy tenfold since 1980, to about 8 cents per kilowatt-hour today. There are several advantages of installing wind based systems off shore [12].

4. Geothermal Energy

Geothermal energy is the energy contained within the earth, which is a sizeable, nationwide energy resource that has been left virtually untapped. Geothermal energy is a clean, reliable and renewable resource that can be used as a direct source of heat and to generate base load electric power. Geothermal energy offers a number of advantages over traditional fossil fuel-based sources. The heat source requires no purchase of fuel and is reliable and secure. Very negligible greenhouse gases are emitted by geothermal energy use. This form of energy is likely to be a major player as an energy source in the future as the Enhanced Geothermal Systems (EGS) energy potential in the U.S. is enormous. EGS reservoirs are created by drilling wells into hot rocks, fracturing the rock, and circulating a fluid through the fractured rock to extract the heat. As of March 2009, the United States was the largest geothermal electricity producer in the world with installed hydrothermal power capacity of about 3 GW [11]. The goal of DOE is to have 50 GW of geothermal energy by 2030. Low-temperature geothermal resources with fluids that are not hot enough to boil water also present an enormous opportunity for geothermal power generation. These systems, known as Low-Temperature Geothermal Energy systems, employ binary cycle technology to generate electricity. Direct Use and Ground Source Heat Pumps present yet another opportunity to utilize heat from the earth through direct use and ground source heating and cooling.

5. Tidal Energy

Energy from water resources can broadly be classified into marine (ocean thermal energies) and hydrokinetic (technologies capable of generating electricity from waves, tidal, ocean and river currents) [8]. Of these, most development has been done in the area of tidal energy, while others are in early stages of development. Tidal energy is produced through the use of tidal energy generators, which are very large underwater turbines, placed in areas with high tidal movements, and are designed to capture the kinetic motion of the ebbing and surging of ocean tides in order to produce electricity. Tidal power has great potential for future power and electricity generation because of the enormous size of the oceans and the fact that tidal energy harvesting is regular and predictable. The tidal current is not affected by climate change, lack of rain, or snow melt [3]. However, tidal power generation is very new technology, and needs significant investigation and developmental work before it can become commercially feasible. A large number of technologies have been proposed for the capture of electrical energy from tidal currents [13].

6. Encouragement by Government

The American Recovery and Reinvestment Act of 2009, which was signed into law by President Obama on February 17th 2009, includes $16.8 billion for energy efficiency and renewable energy's (EERE) programs and initiatives [6]. In addition to this, there are several other federal and state incentives for investing in infrastructure for alternative energies. These vary from state to state, from time to time, and on type of installation. These go a long way in helping the citizens make a decision regarding installation of solar, wind or geothermal systems at the domestic level. There are still some aspects of this which lead to public outcry whereby the people feel it may affect migratory birds or marine wildlife etc. To counter these, there are various laws which prevent these installations from interfering path of migratory birds, etc. Solar and wind access laws are designed to establish a right to install and operate a solar or wind energy system at a home or other facility. Some solar access laws also ensure a system owner's access to sunlight.

In addition to this, the DOE/EERE weatherization and intergovernmental program (WIP) increases awareness and accelerates adoption of practices and technologies that cost-effectively increase energy, and develop information and tools that facilitate a more energy-efficient economy [14]. Information regarding latest state incentives is now freely available at www.dsireusa.org . DOE's Energy Efficiency and Conservation Block Grant (EECBG) program represents a Presidential priority to invest in the cheapest, cleanest and most reliable energy technologies for immediate adoption.

7. Courses on alternative energy systems

The history of technology diffusion is filled with cases of slower than expected diffusion [4]. Absence of a market infrastructure which includes trained people is one of the major barriers to this diffusion. A trained workforce is critical in exploiting the full potential of alternative energy systems. These topics are presently not covered in the curricula at most colleges or universities at the associates, baccalaureate or masters level in engineering or engineering technology. Passing reference is made to these topics in some courses, but now that these forms of energy are on the verge of mass deployment, it will be helpful if the students learn about this as a part of the curriculum in the form of one or two courses. Most engineering and engineering technology programs are structured to include one or two elective courses or technical electives in their curriculum.

The process to design a course and to have it accepted by the curriculum committee in the catalogue at an institution may vary from one to three years before it is actually offered. With that in mind, the time is now ripe for thinking about these courses, designing the lectures and labs, procuring the material for labs, and faculty themselves getting trained in these subjects. The lead time required for this may be in the vicinity of one or three years, due to capital requests for establishment of such labs and procurement of lab equipment, getting budgets approved, time for procurement of equipment, establishment of these equipment, writing labs for them, and actually getting approval to include these courses in the course catalog.

Due to the encouragement being provided by the government for establishing alternative energy systems, there are going to a large number of Requests For Proposals (RFP) for projects like establishment of solar energy farms, wind energy farms, tidal energy systems etc. Some of the calls (RFP) for these have already been issued and companies are looking to hire people who have some knowledge or interest in these technologies. This is bound to grow over the years, along with the widespread installation of these technologies, at the industrial as well as domestic level. Companies are beginning to approach academic institutions to include alternative energies in the curricula in some form.

As educators, it is imperative that we are sensitive to the changing needs of the industry and the environment, and that we design the curriculum which meets these changing needs. One of the important needs of the hour is integration of alternative energies in our curriculum, even if it be simply one or two courses. With this in mind, it may be useful to include some of the following topics while designing the courses in alternative energy or sustainable energy or non-conventional energy at various levels.

7.1 Associate’s level

A lot of the concepts of alternative energy, or non-conventional energy relate to electrical and mechanical engineering, and therefore in the Associate’s program related to engineering, engineering technology, electrical engineering technology, mechanical engineering technology, or similar programs, these topics could be introduced, in the form of theory and possibly hands-on lab work. Topics which could be included are:

1. Basic theory of photo voltaic cells,
2. Construction of solar panels, and connectivity of solar panels
3. Solar thermal heating systems
4. Stand alone systems for generating electrical energy from solar energy
5. Battery backup based stand alone systems for storing energy from solar energy
6. Grid tied Stand alone systems for generating electrical energy from solar energy
7. Wind based systems including horizontal axis wind turbines (HAWT), vertical axis wind turbines (VAWT), stand alone and grid tied
8. Hybrid systems using combination of wind and solar energy (stand alone, and grid tied)
9. Introduction to geothermal systems and their applications
10. Maintenance aspects of different types of alternative energy systems

7.2 Baccalaureate level

For courses at the baccalaureate level, the content could include all the topics recommended for inclusion at the Associate's level and possibly some of the following topics:

11. Types of photovoltaic cells
12. Types of solar panels, conversion efficiencies of various types of solar panels
13. Net metering
14. Maximum Power Point Tracking (MPPT)
15. Factors to be considered for layout of such systems and data to be used including solar paths, wind patterns etc.
16. Tidal energy systems
17. Economic feasibility of installation of non-conventional energy systems, and payback period

7.3 Masters level

For courses at the master level, the content could include all the topics recommended for inclusion at the Baccalaureate level and possibly some of the following topics:

18. Latest developments in PV cells
19. Design of roof mounted solar energy systems
20. Design of solar farm systems
21. Modern solar energy applications including electric vehicles, naval and space applications
22. Design of wind farm systems
23. Smart grid
24. Design of Tidal energy systems
25. Ocean wave and ocean thermal energy harvesting
26. Ocean thermal energy harvest
27. Economic feasibility of installation of non-conventional energy systems by utilities and related aspects

7.4 Recommendations for experiential learning, coop, or internships

In addition to having students do this course work to give them a basic platform for understanding alternative energy systems, it will be very helpful if they can spend a semester or a summer interning (or doing a co-op or an experiential learning experience) at an industry related to design, installation, or maintenance of such systems. This is especially significant in this evolving field of alternative energy systems, because the technology is evolving rather quickly, and the market is getting flooded with the related products almost instantaneously since may of these will be commercially viable due to the large incentives being given by governments to promote them. In many cases, it will not be possible for the academic institutions to equip the laboratories with the latest developments, due to rapid rate of introduction or obsolescence, and therefore it will serve the students well to do internships or experiential learning in an industry involved in this field.

8. Conclusion

It may not be an exaggeration to say that what is being considered an alternative or non-conventional form of energy today may well be treated as a conventional energy in the future generations. This paper has attempted to present a summary of the developments of the various types of alternative energy systems which are becoming prevalent today, and made recommendations regarding the topics which should be included in the curriculum for various programs regarding these systems. After all, any curriculum is designed to meet the changing needs of the various constituencies that the program serves, and the industry and the students are two of the most important constituents!

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