Design and implementation of a renewable energy laboratory course

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Abstract — Renewable energy attracts more and more attention as evidenced by the tremendous amount of investment from the federal government, automotive industry, and fuel cell/photovoltaic cell manufacturers. To prepare our future workforce for the emerging renewable energy technology field, a renewable energy lab course has been developed. The experiment design and the lab setup are presented in the paper. The issues from our teaching and the possible solution are also discussed.

Keywords: renewable energy, power electronics, hydrogen fuel cell, solar energy, microgrid.

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1. **Introduction**

Renewable energy is helpful for a stable development of the economy and the protection of our environment. In the past, insignificant effort in the education, research, or development was put on this field in the U.S. due to the concerns about the costs and job market, etc. Fortunately, the situation is changing now. Renewable energy attracts more and more attention and it is playing an important role in the recovery of our down-turn economy and the creation of new jobs.

In the near future the increasing nationwide demand for well-qualified professionals in the renewable energy can be predicted. Thus, in order to educate and prepare the technical and scientific workforce, many courses in this field are offered in lots of universities. Our department also offers 8 courses listed in Table 1.

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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<tbody>
<tr>
<td>Fuel Cells</td>
<td>3</td>
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<tr>
<td>Solar Energy and solar cells</td>
<td>3</td>
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<tr>
<td>Sustainable Energy</td>
<td>3</td>
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<td>Nuclear power</td>
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<td>Hybrid Vehicles</td>
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<td>Power system analysis</td>
<td>3</td>
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<td>Power Electronics</td>
<td>3</td>
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<td>Sustainable Energy Lab</td>
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Although the lecture in a classroom is still an important way for the students to learn pertinent skills, there should be some other teaching strategies in the education of renewable energy. One is experiment, a kind of active learning to help students understand the concepts, inspire their interest, and stimulate their creativity [1-3]. To design and implement a renewable energy lab course is a challenge because of the cost, interdisciplinary nature of the energy, and the lack of the educational kit on the market.

In this paper, the design and implementation of a renewable energy lab course are presented. The issues in our teaching and the possible solution are also discussed.

2. **Lab experiments**

![Figure 1 The site of the lab](image)

Figure 1 shows the site of the lab. The roof (10,800 ft²) of the UB Technology Building is big enough for a 500 W solar panel (120 ft²), two 1kW wind turbine (100 ft²), and a fuel cell system (10 ft²). The rest of the system, e.g. computers, web server, rechargeable battery stack, and power electronics will be set up in the lab (Room 213)
on the second floor. Currently, a 1 kW wind turbine and a 45 W solar panel of the Renewable Energy Research Laboratory are being set up by the UB facility office.

There are five experiments designed for this lab and the lab manuals are provided. The experiments are done by groups, normally less than three students. The students in one group can only share their data and each member should submit his report.

Experiment 1 Solar energy

Figure 2 shows a 45W solar panel on the roof. This big solar panel is connected to an electronic load and the current-voltage curve can be obtained through a Labview program. A solar meter is used to measure the solar irradiance, thus the efficiency of the solar panel can be calculated. There is also a single-axis solar tracker and it consists of a motor, a Arduino Uno R3 board, a SainSmart L293D Motor Drive, four photoresistors, and a small solar panel. Students can change the panel tilt angle and the rotation step of the motor to optimize the operating parameters. This will help them understand the importance of the tracking system.

Experiment 2 Hydrogen fuel cell

The parts in this experiment include a hydrogen fuel cell, a electrolyzer (see Figure 3), a DC power source, a electronic load. A Labview program is also developed for the system control and DAQ.

In this experiment, students will learn how to operate an electrolyzer and a hydrogen fuel cell. They also need to know how to characterize a fuel cell and to determine where is the maximum power point. Furthermore, they will investigate the effect of the oxygen concentration on the output voltage [4]. In the lab, there is also a setup to obtain the impedance spectrum from the fuel cell. This can be used to determine the effect of the electrodes on the performance of the cell.
Experiment 3 Power Electronics

Figure 4 shows a power pole board [5]. With a DC power source and an oscilloscope, experiments on different DC/DC converters can be conducted. Students can change different parameters, such as duty ratio, to change the output. This greatly helps them understand the working principles of the converters.

Experiment 4 Rechargeable batteries

Figure 5 shows the setup of the battery system. In this system, there is one 12V lead-acid rechargeable battery, one electronic load, and one programmable DC power source. A Labview program is developed for the system control and data acquisition.
In this experiment, students can learn how to maintain a battery, determine the state-of-charge (SOC), and to estimate the SOC through a Kalman filter based on a state-space model [6]. Eventually, they can develop program to monitor the SOC online.

**Experiment 5 Microgrid with renewable energy resources**

Figure 6 shows the control panel of the microgrid with the structure of this system. This microgrid consists of a solar panel, a wind turbine, two rechargeable lead-acid batteries, two inverters (one is grid connected), and different loads. A Labview program was developed with three functions: (1) to monitor the voltage and current, (2) to estimate the SOC of the batteries, and (3) control the flow of the electricity. On this mimic power system, it is straightforward for the students to understand how to utilize the renewable energy and store it. They can also modify the Labview program, for instance, use their own parameters for the SOC estimation.

![Microgrid diagram](image)

**Figure 6** The wind turbine (a) and the control panel of the system (b)

3. **Conclusions**
This lab course has been offered for three times from 2010. The number of the students fluctuates between 8 and 13. In the mean time, a lecture, Sustainable Energy, is also offered with this lab course and this makes it easy for the students to know the principles. Students show much interest in the lab and some of them are from mechanical engineering and technology management departments. Some of them, around 4 students, continue their work in their theses or final projects and two students are hired by a local energy company as summer intern.

In our teaching, some issues are observed. (1) The nature of renewable energy is interdisciplinary. To fully understand the operation of the setup and analyze the experimental data, the knowledge in thermodynamics, semiconductor, electrochemistry, mechanics, and power electronics is necessary. Therefore, new generations of engineers must be trained at working effectively in many disciplines and it is necessary to tailor this education through the multidisciplinary synergy to keep the cost and time required for a degree manageable. (2) The experiments on renewable energy are strongly affected by weather and this makes it hard to maintain a schedule for an efficient use of the equipment. With advances in high-speed internet, the laboratory can be transformed to remote laboratory cyber-physical system, or web-based experiment which allows user to perform experiment remotely through a generic web browser. Thus, a remote laboratory is promising without the constraints mentioned in the traditional laboratory. This lab also can significantly enhance the distance learning for the full-time employees to update their knowledge.

We keep updating the setup, hardware and software, and the information is available on our website.

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REFERENCES