Chapter 6

Sustainability and Renewable Energy
6.1 Introduction

The Sustainability and Renewable Energy field addresses global technological challenges balancing societal needs with environmental and economic tradeoffs. Topics addressed include energy conservation through more efficient electronic systems, intelligent energy management through smart grid approaches, and renewable technologies including solar PV, wind, and wave for energy generation and distribution. Students pursuing the Sustainability and Renewable Energy are of interest will engage in leadership development and demonstrate their leadership through community service related to sustainability. It is recommended that the leadership service take place as part of an international experience.

6.2 Section Overview

A number of activities have been done in lab that deal with the various electrical and computer engineering tracks here at OSU. However, many problems you'll deal with in the future will involve multiple electrical engineering disciplines. This lab involves using photovoltaic cells (sometimes known as solar cells), which encompasses two of the areas of interest that were covered before: Materials and Devices and Energy Systems. Ideas from these two areas are combined to use a green form of energy and relate to the new Sustainability and Renewable Energy area of interest.

The completion of this project will result in a solar cell positioning system. The Teensy will rotate a motor with a solar cell attached to it. The voltage of the solar cell will be read using the ADC (Analog-to-Digital Converter) in the Teensy, and storing that data. Then, the motor will rotate back to the point where the voltage from the solar cell was highest (where it is converting the most energy).

6.3 Objectives

- Solar Energy and the integration into electronics
- Analyze efficiency tradeoffs

6.4 Materials

- Teensy
- USB to mini cable
- Protractor
- ECE 111 Kit
  - Photovoltaic cell
  - Rectangular piece of protoboard with single drill hole
  - Cut motor adaptor
  - 1” screw and nut
- Tool Kit
6.5 How Light is Affected by the Angle

The amount of light and heat energy received at a point on the globe is directly affected by the angle the sun’s rays strike the earth. This angle is affected by location, time of day, and season because the Earth is constantly orbiting around the sun and revolving upon its tilted axis. As shown in Figure 6.1 Sun’s Rays hitting the Earth, the reason that the poles are colder and have greater fluctuating day lengths than the rest of the earth is because the sunlight is spread over a greater area in those regions, and because the light also has to go through twice as much atmosphere, further dissipating the rays and reflecting more of the energy back into space.

6.6 Photovoltaic Cells

A photovoltaic (PV) cell is a device that converts light directly into electricity. Many photovoltaic cells are made of silicon, which is a type of semiconductor. The energy from the light knocks electrons loose, allowing them to flow freely. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off to use externally. For example, the current can power a calculator. Understanding PV cells is important, because alternative energy is a rapidly expanding field of engineering.

6.7 Modeling Concepts

The concept of the sun’s rays hitting the earth at different angles can be simplified and modeled in lab using a photovoltaic cell and directed light source as shown below in Figure 6.2 Flat PV Cell, and mathematics can support it. This is important, because while everything must start as a concept, for it to be accepted and proven, engineers rely heavily upon mathematics and physics to support their ideas.
6.7.1 Mathematical Support

\[
\text{Shadowwidth} = \text{SolarCellWidth} \times \cos(\theta)
\]

Basic trigonometry shows us that the cosine of a 60° angle is 0.5, whereas the cosine of 90° is 0. Therefore, with a lamp beam of approximately 4 inch width directly hitting a 4 inch wide PV cell as shown in Figure 6.2 Flat PV Cell, there will be maximum voltage output, because the most light is hitting it. The PV cell is at a 0° angle with the ground, and therefore the cosine is 1. In Figure 6.3 Angled PV Cell, the PV cell is at a 60° angle with the ground, and therefore the cosine is 0.5, meaning that only half the amount of light is hitting the PV cell, and therefore the voltage output will be less as well.

6.7.2 Experimental Support

Now that there is mathematical support of the concept, there needs to be observational support as well through experimentation. A protractor is helpful but not required. Measure the voltages produced by the PV cell at no less than 7 different points between 0° and 90°. 0° being what is shown in Figure 6.2 Flat PV Cell. Graph these points on Figure 6.4 Voltage Output vs. Degrees and analyze the resulting line.

Distance between Lamp and PV Cell (at 0°): __________________________
6.8 Characterization

To characterize the solar cell there are a few tests that need to be completed. The open circuit voltage and short circuit current will be found in these tests.

1. Using the DMM, hook up each of the leads to the points on the solar cell. Turn the DMM knob to the “20 volt” setting. Place the solar cell by the window and then in a darker area. Record each individual voltage below.

   Sunlight Voltage \( V \)  
   Dark Voltage \( V \)

2. Following the same procedure as above except now turn the DMM knob to the "2mA" setting. Record both results below.

   Sunlight Current \( A \)  
   Dark Current \( A \)

6.9 Assembly of Tracking Device

In this part of the lab, the goal is to create a light tracker using the servo motor circuit built in a previous lab in conjunction with a photovoltaic cell. The PV cell will need to attach to the servo so that the PV cell can still rotate approximately 180 degrees when placed below one of the lab lamps. After the PV cell is attached to the motor, program the Teensy. This code will turn the circuit into a light tracker. Basically, the PV cell will periodically scan the surrounding light area by rotating and recording the voltages at each point. Then, it will go to the point at which the voltage was highest and stay there until the solar cell isn’t receiving enough light. This way, the device will always find the strongest light source and can be the most efficient in its energy conversion.

To assemble the solar tracking device, a GM-8 motor along with a cut motor adaptor will be required. The code has been provided on the ECE 111 page on the TekBots website under the lab. What to attach to GND on the solar panel is marked with a sharpie. The schematic is in Figure 6.5 (Hint: We will be using the same motor driver as in the Energy Systems Lab).

Mounting the Photovoltaic Cell to the motor

1. Place the 1 inch bolt through the hole on the protoboard.
2. Set the protoboard and bolt against the hub of the motor so the protoboard is resting on the side of the circle that has been cut flat and the bolt is resting in the slot on the face of the hub.

3. Put the nut on the end of the bolt and slowly tighten the bolt while holding the nut with a pair of pliers. (Hint: This might work better with two people.)

4. Make sure you tighten the bolt just enough to make a snug connection, but not so much that the bolt isn’t flat against the hub.

5. The protoboard mounted to the hub is shown in Figure 6.6 Completed Solar Servo figure 6.6.

6. Mount the solar cell onto the protoboard with hot glue. Make sure not to cover up the mounting bolt on the protoboard.

7. Wait for the glue to dry before running the motor or moving the system around.

![Completed Solar Servo](image)

Figure 6.6: Completed Solar Servo

6.10 Controlling Solar Tracker with a GUI

In this section, the solar tracking data will be viewed with a Python GUI. As the tracker cycles through its range, the servo position and light intensity can be viewed in the Python window. Use steps similar to lab 3 to program the Teensy with Lab6GUI.hex and open the GUI. For full lab credit, demonstrate the project working with the GUI.

TA Signature: ________________________
(Lab Work Complete and Circuit Works)
6.11 Study Questions

1. Name at least 3 applications that would benefit from solar cells or solar power in everyday life.

2. Explain in your own words why the voltages generated during lab created that kind of curve when graphed. Theoretically, it should be close in shape to a bell curve. What are some potential reasons why the graph isn’t perfectly smooth?

3. Transparent electronics is something that has been developed here at OSU. One use they are being developed for is the creation of clear solar panels that can be used as windows. Using what you have learned from this lab about photovoltaic cells and light angles, discuss the pros and cons of using this new technology on skylights versus windows on the sides of buildings. Which one would be more efficient at energy conversion and why?