The Effect of Tilt Angle on Solar Panel Output

A REEL Power [tm] (Renewable Energy Education Lab) Lesson

LESSON OVERVIEW

This lesson demonstrates how a solar panel reacts to the direct and indirect rays from the sun or an artificial light source in order to produce electricity. It shows that solar panels must be aligned directly into the light source in order to produce maximum power and energy and that current more than voltage are affected by tilt angle.

LEARNING OUTCOME

Students are shown that the angle at which a solar panel is oriented towards its light source is directly proportional to its ability to produce usable power.

Students come to understand that:

1. Solar panels must be oriented at the proper angle to the light source for maximum electrical output.

2. Orienting commercial solar panels outdoors are based on both geographical location and the season of the year.

3. A device called a Sun Tracker can keep solar panels correctly oriented at the sun all day long in order to generate the maximum power from the solar panel.

STUDENT ACTIVITIES

Students adjust the angle of the solar panel relative to the sun or artificial light source and measure electrical parameters such as voltage, current, resistance, power and energy flowing into a resistor load. They then correlate the tilt angle to the electrical parameters to determine the major differences in electrical generation caused by the angle of tilt.

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During the course of the lesson, students measure and record voltage, current, resistance, power and energy with the ***Smart Meter – Data Logger*** [tm]**.** Students are also charged with displaying the recorded data on the classroom computer and explaining the differences in readings. This is followed by printing out plots of the data on a printer or downloading data files gathered on the computer to be included in reports about the lesson.

GRADE-LEVEL APPROPRIATENESS

This lesson is appropriate as an introduction to solar energy data interpretation for students in grades 8–10.

LESSON TIME

This lesson should take between 30 minutes to 45 minutes depending on discussion time about the experiment.

SAFETY

No particular safety issues are deemed present in this lesson; however, particular attention to the setup and execution of the lesson is always prudent in order to avoid unintentional mistakes and the resultant possible harm to those involved.

REQUIRED MATERIALS

Qty	Description
1	Solar Panel
1	***Smart Meter – Data Logger*** [tm]
1	USB cable
4	Clip leads
1	10 ohm resistor
1	Classroom Windows PC computer with **REEL Power** [tm] software (MACs must have Parallel's "Desktop 3.0 for Windows")

PRELIMINARY STEPS

1. Install the graphical software on the classroom computer.
2. Install a fresh 9-volt battery in the ***Smart Meter – Data Logger*** [tm]
3. Refer to the ***Smart Meter – Data Logger*** [tm] **Tutorial** for extra help.

EQUIPMENT SETUP

1. Setup the equipment as shown in Figure 1 below. Wire the opposite side of the solar panel so that all three modules are in series in order to produce maximum voltage. You can use clip leads or the wires with looped ends to hookup the two inner solar modules together (+ to -). Then attach a clip lead from the left-most negative (-) post to the Black Input terminal on the ***Smart Meter – Data Logger*** [tm] and another clip lead from the right-most positive (+) post to the Red Input terminal on the ***Smart Meter – Data Logger*** [tm]. Also add a 10 ohm resistor to the Output terminals – the polarity doesn't matter.

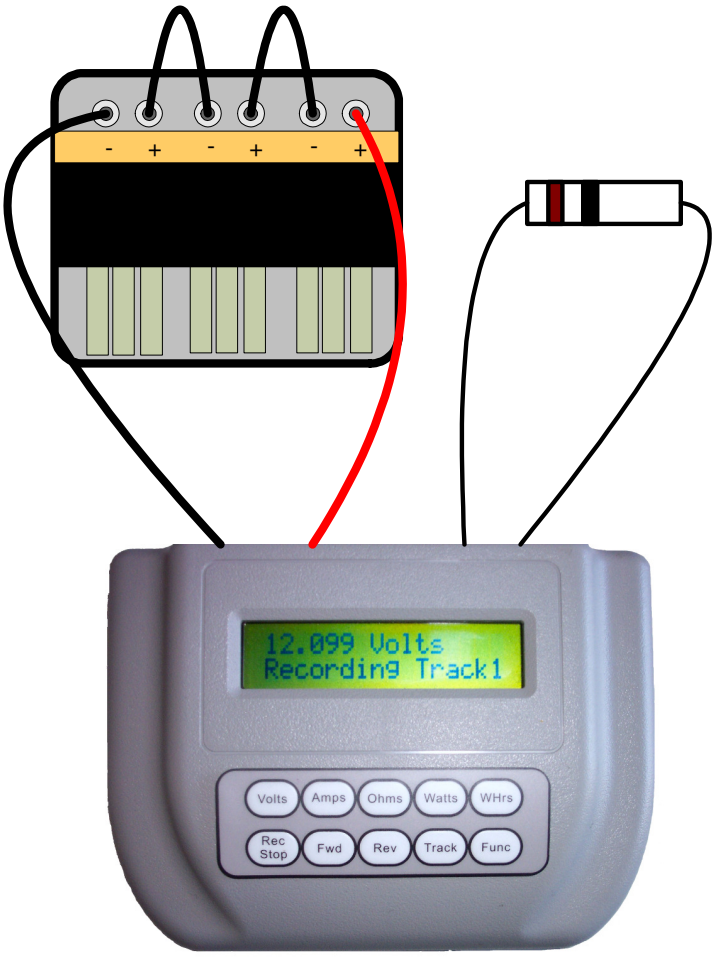
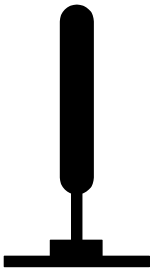


Figure 1 – Initial Equipment Setup

2. With the hookup in Figure 1 the students will adjust the solar panel tilt angle in seven positions from 0 degrees to 90 degrees. At each setting the voltage, current and power is recorded for a few seconds.

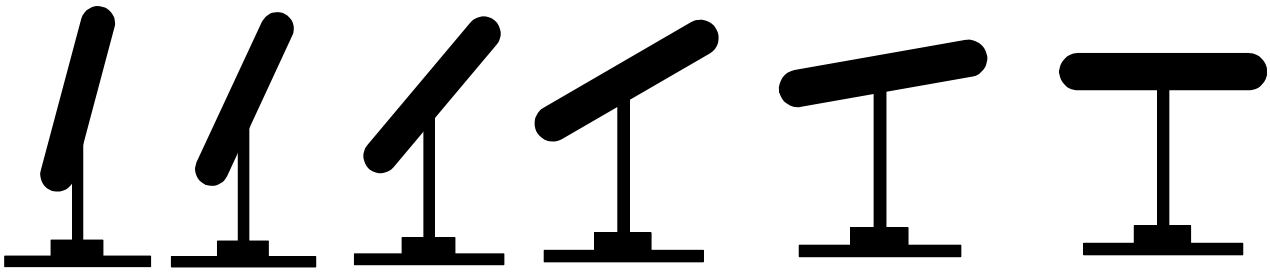
3. To begin, place the solar panel at a 0 degrees angle (vertical to the table).

4. On the ***Smart Meter – Data Logger*** ^{tm} push the **Track** key to set the Sample Time to 1 second then push the **Rec-Stop** key to begin recording the electrical data.



0 ^{0}

5. Allow 5 to 10 seconds to pass then adjust the tilt angle in 15 degree steps as shown below. Use a protractor to measure the tilt angle. Allow about 5 to 10 seconds of data gathering for each tilt angle. At each angle jot down the time and voltage reading so that you can come back to it when the data are displayed on the ***Smart Meter – Data Logger*** ^{tm} or computer.



15 ^{0} 30 ^{0} 45 ^{0} 60 ^{0} 75 ^{0} 90 ^{0}

TEACHING THE LESSON

1. Plug in a USB cable between the ***Smart Meter – Data Logger*** ^{tm} and the classroom computer and set the switch to the USB position so that it receives power from the computer's USB port. Set the power switch to the USB position and verify the sign on message on the LCD screen.

2. Click on the **REEL Power** ^{tm} icon to bring up the software menu. Then click on the **MPP Auto Trac – Data Logger** icon.

3. On the computer adjust the voltage (vertical) scale on the **REEL Power** ^{tm} software to 5.00 volts maximum.

4. Push the Track key on the ***Smart Meter – Data Logger*** ^{tm} until the **View Trackx Data** message is displayed where Trackx is the Track used to record the tilt angle data. The computer display should begin to display the recorded data as shown in Figure 2 below.

   Note: These readings were taken at mid morning in full sunlight. Your readings will certainly vary.

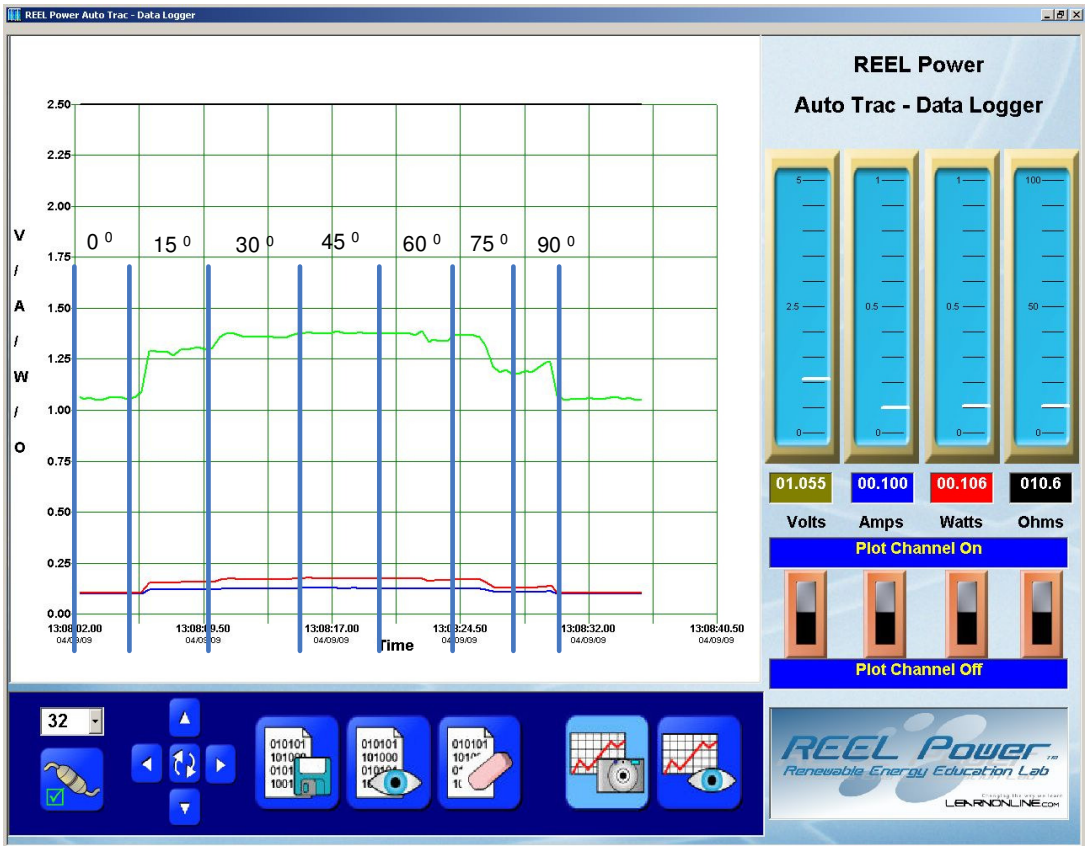


Figure 2 – Plot of Electrical Data Based on Solar Panel Tilt Angle

5. Have the students refer to the voltage readings they took at each tilt angle so that they can refer them to the voltage plot. Have them explain their own results.

6. An alternate way of viewing the data is to view it directly on the ***Smart Meter – Data Logger*** ^{tm} LCD screen. Start with pushing the **Track** key until the correct **View Trackx Data** screen is displayed. Wait 3 seconds until the first data sample is displayed.

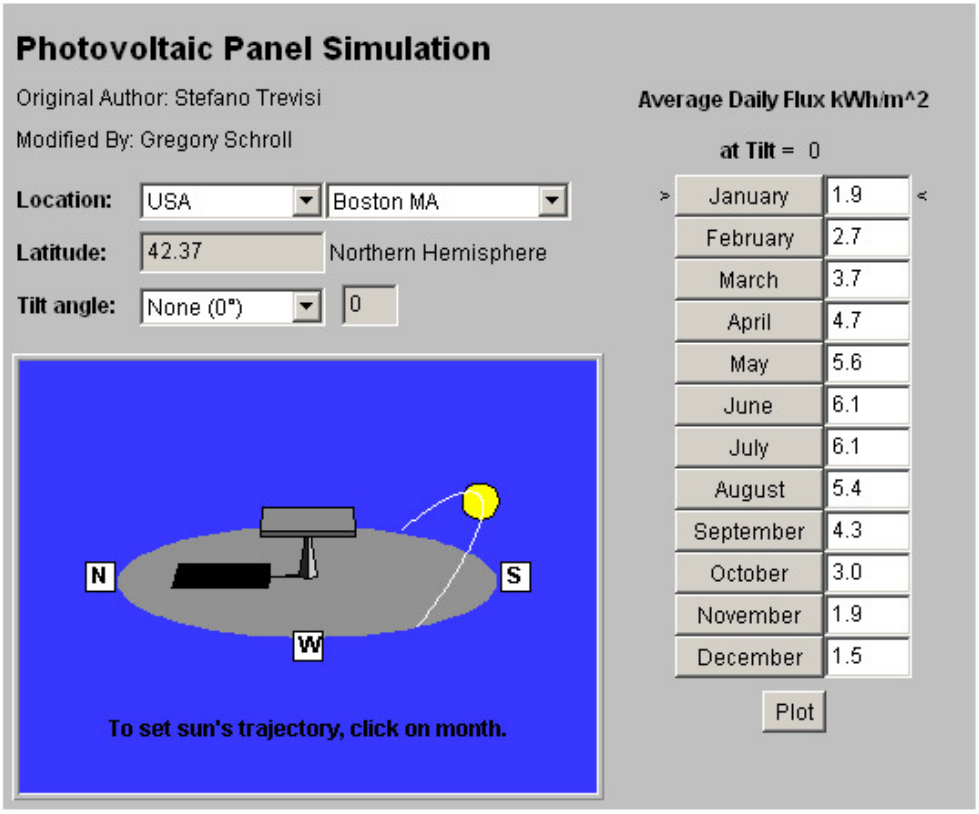
7. Push the **Fwd** or **Rev** keys to step through the data with the date and time it was recorded. Push any of the top keys for voltage, current, etc.

DISCUSSING THE LESSON OUTCOME

1. Discuss with the students the outcome of the resulting data. Ask why the voltage and current began to increase with the tilt angle and, also, why it decreased with even more tilt angle. The answer lies in the fact that the solar panel reacts best to direct light – light that is perpendicular to the panel itself. Indirect light does not have the same intensity and does not produce the desired voltage and current.

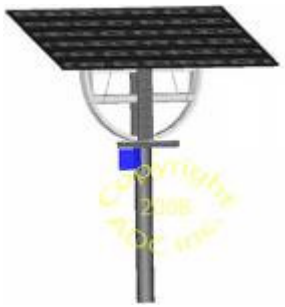
2. Next, ask them about commercial solar panels like those on buildings and homes. These panels are fixed in place at a certain tilt angle, so they can only receive the sun's energy during a short time frame during the day. Since the angle of the sun is also dependent on the season of the year, discuss what angle a solar panel should be fixed at for best performance during the entire year. For help in this discussion, refer to the following website:

   http://ocw.mit.edu/ans7870/SP/SP.769/f04/java/pvapplet/PVPanel.html



   Change the location to the nearest city and adjust the tilt angle to determine the best tilt angle for your geographic location.

3. While most commercial solar panels are fixed in place, others use a device called a “Sun Tracker” to constantly position the solar panel so that it receives the maximum sunlight all day. Discuss with students the advantages and disadvantages of using a Sun Tracker.



Advantages

- Generates maximum power from the solar panel
- Can adjust to the daily “apparent” movement of the sun (single axis tracker)
- Can adjust to the seasonal “apparent” movement of the sun (dual axis tracker)

Disadvantages

- Costs more to install and run
- Uses part of the solar panel’s power to operate
- Can ware out over time

4. Ask students what it would take to make a model Sun Tracker using common, off the shelf parts. Here is a YouTube video on such a home-made tracker (very interesting and informative).

http://video.google.com/videoplay?docid=-5210685489871293972

TEACHER GUIDELINES AND TIPS

There is a lot of information on solar panels and sun trackers on the web. Have students research this topic and generate reports based on what they find – and also, have them include a description of the experiment along with captured photos in the reports.