Determining The Maximum Power Point (MPP)

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

LESSON OVERVIEW

This lesson demonstrates how solar panels in either series or parallel have a maximum power operating condition known as the Maximum Power Point or MPP. The maximum power point is where the solar panels can deliver the maximum power into a load. MPP is a dynamic condition that varies based on external influences such as light intensity, tilt angle and either a series or parallel arrangement of the panels.

LEARNING OUTCOME

Students are shown that the Maximum Power Point (MPP) is achieved when the resistance of the solar panels matches the load resistance. Students vary the load resistance to produce maximum power with solar panels in series and parallel configurations.

Students come to understand that:

1. Maximum power is not maximum voltage or maximum current by itself but when voltage and current combine to produce maximum power.

2. More power can be achieved with solar panels in parallel as compared with solar panels in series.

STUDENT ACTIVITIES

Students hookup solar panels in both series and parallel configurations and measure the power output into a five resistor loads ranging from 50 ohms to 10 ohms. Students monitor the power output of the solar panel to determine the load resistance that produces maximum power from the solar panel.
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 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 10 - 12.

LESSON TIME

This lesson should take between 45 minutes to 90 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
10	Clip leads
5	10 ohm resistors
1	Classroom Windows PC computer with **REEL Power** **tm** software (MACs must have Parallel's "Desktop 3.0 for Windows")
1	Printer (optional)

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 solar panel modules in series and attach them to the Input terminals of the ***Smart Meter – Data Logger*** ***tm***.

2. Attach five 10 ohm resistors in series to the Output terminals – the polarity doesn't matter. Use clip leads to attach the resistors together.

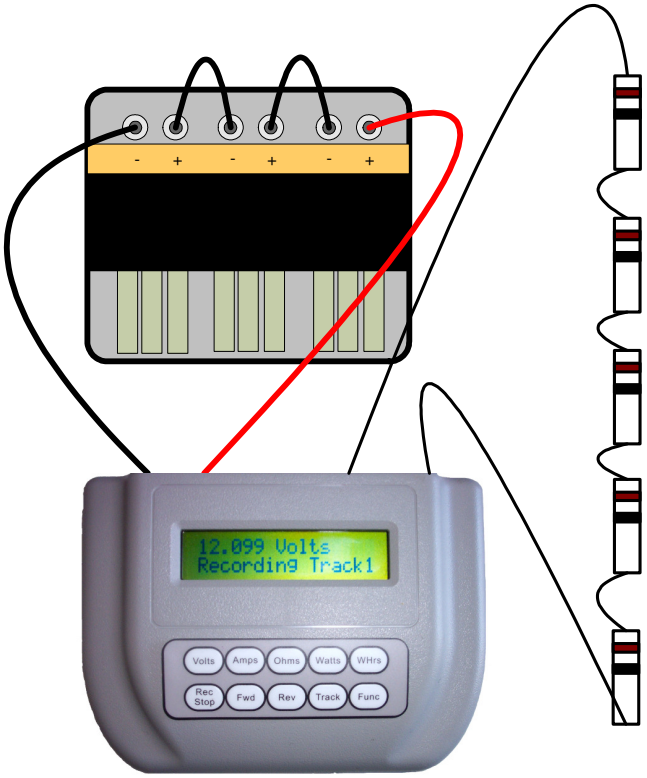

Figure 1 – Solar Panels in Series with 50 ohm Resistor Load

TEACHING THE LESSON

1. On the ***Smart Meter – Data Logger*** ***tm*** push the **Track** key until the **Set Sample Time** message is displayed. Wait 3 seconds and then push the **Fwd** or **Rev** keys to set the Sample Time to 1 second.

2. Push the **Watts** key to monitor the power level.

3. With the solar panel tilted at an appropriate angle to the light source to capture the maximum light, begin the data recording by pushing the **Rec-Stop** key. Notice the Track number being recorded.

4. Allow the recording to proceed for about 30 seconds then remove or jumper one of the resistors making the total resistance 40 ohms. **Hint – you can use a clip lead to jumper or short out the resistor(s) rather than physically removing them.**

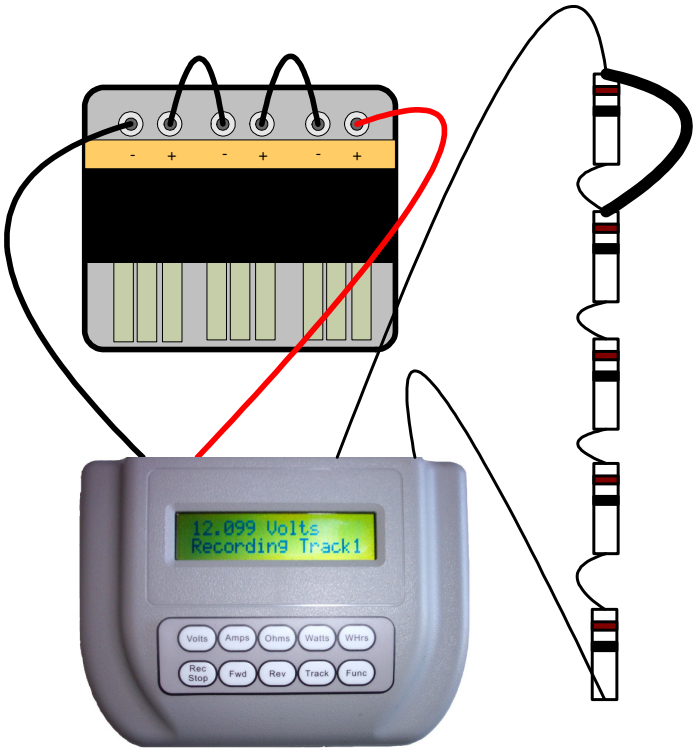

Figure 2 – Shorting Across A Resistor to Reduce Resistance

5. Allow the recording to proceed for about 30 seconds then remove or jumper another resistor making the total resistance 30 ohms.

6. Allow the recording to proceed for about 30 seconds then remove or jumper another resistor making the total resistance 20 ohms.

7. Allow the recording to proceed for about 30 seconds then remove or jumper another resistor making the total resistance 10 ohms.

8. Now place a clip lead across the entire resistor string effectively placing a short circuit across the solar panel.

9. Allow the recording to proceed for about 30 seconds.

10. Push the **Rec-Stop** key to halt recording after 30 seconds.

11. Hookup the solar panel in parallel along with five 10 ohm resistors as in Figure 3.

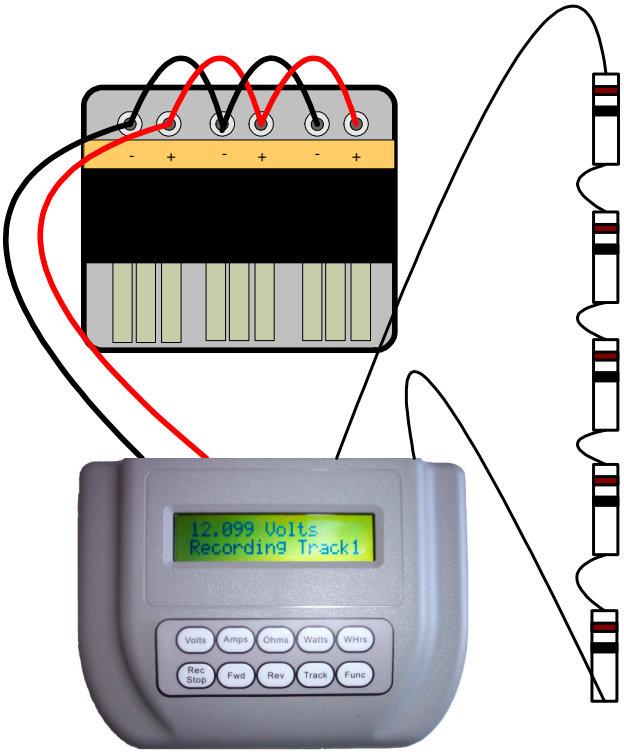

Figure 3 – Solar Panels in Series with 50 ohm Resistor Load

12. With the solar panel tilted at an appropriate angle to the light source to capture the maximum light, begin the data recording by pushing the **Rec-Stop** key. Notice the Track number being recorded.

13. Repeat the previous steps removing one resistor every 30 seconds.

DISCUSSING THE LEARNING OUTCOME

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 10 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 first exercise with the solar panels in series. A plot similar to Figure 4 should appear.

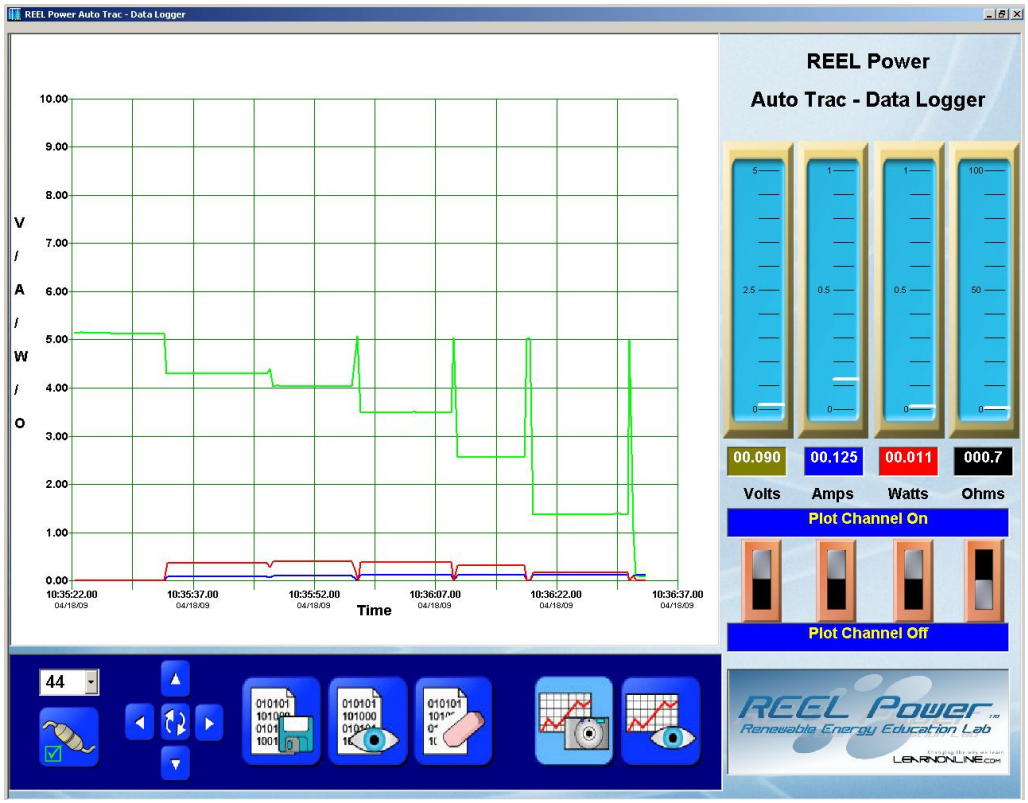

Figure 4 – Plot of Maximum Power Point with Solar Panels in Series

5. Begin the discussion by having students look at the plot in Figure 4 in more detail. Have them make a table of voltage, current, resistance and power for each resistor value used including the open and closed circuit hookups. The table should look like this. Based on the readings it appears that the wattage with the 40 ohm resistor value produces the most power. Your results may differ.

Load	Volts	Amps	Watts
Open circuit	5.132	0	0
50 ohms	4.298	0.087	0.374
40 ohms	4.027	0.98	0.395
30 ohms	3.492	0.112	0.391
20 ohms	2.569	0.122	0.313
10 ohms	1.374	0.124	0.170
Short circuit	0.090	0.125	0.011

6. 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 second exercise with the solar panels in parallel. A plot similar to Figure 5 should appear. Adjust the vertical voltage scale to 2.5 volts.

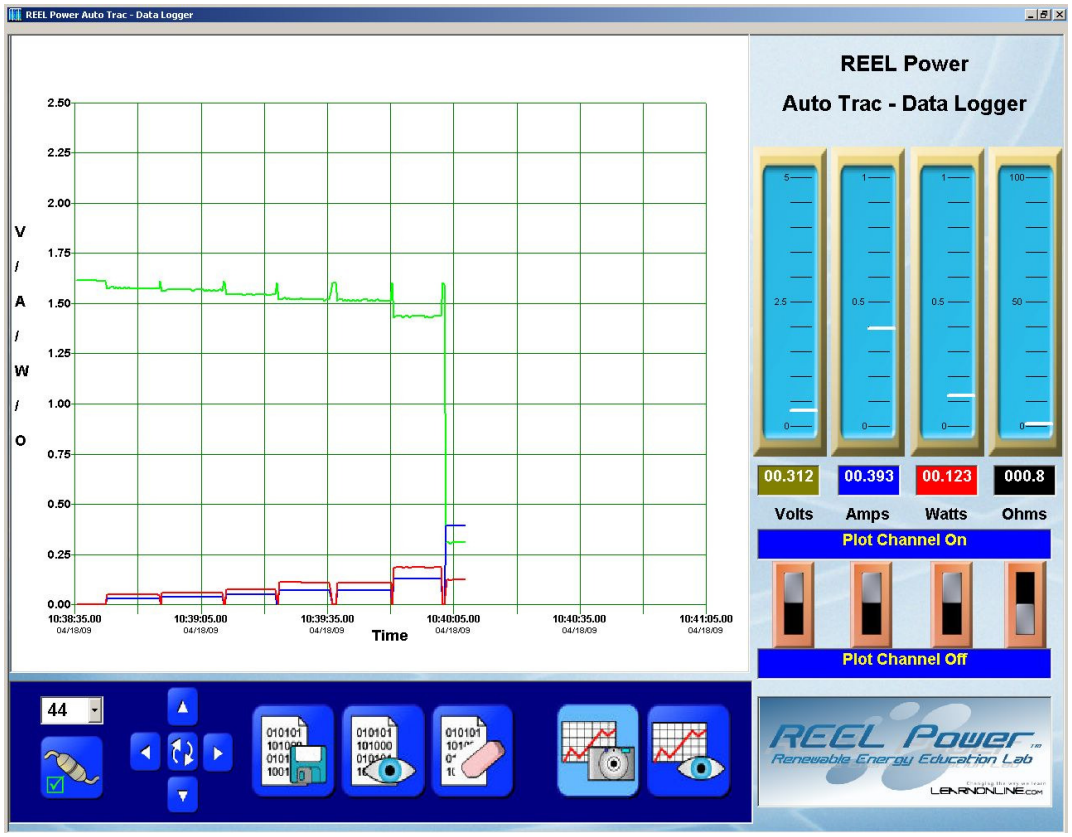

Figure 5– Plot of Maximum Power Point with Solar Panels in Parallel

7. Again have the students make a plot of the voltage, current, resistance and power. It appears from the readings that the maximum power is generated with a 10 ohm load.

Load	Volts	Amps	Watts
Open circuit	1.617	0	0
50 ohms	1.575	0.032	0.050
40 ohms	1.569	0.038	0.060
30 ohms	1.547	0.050	0.077
20 ohms	1.521	0.073	0.111
10 ohms	1.436	0.129	0.185
Short circuit	0.312	0.393	0.123

8. However, it also appears that the solar panel is capable of even more power if the load were between 10 ohms and zero ohms (a short circuit). Therefore, have the students repeat the exercise with resistors in parallel instead of in series. Then create a table like the one below to determine if maximum power can be achieved between 10 ohms and zero ohms.

Load	Volts	Amps	Watts
10 ohms	1.472	0.132	0.194
5 ohms	1.339	0.232	0.311
3.3 ohms	1.207	0.290	0.350
2.5 ohms	1.068	0.331	0.354

Recall that two 10 ohm resistors in parallel make 5 ohms; three 10 ohm resistors in parallel make 3.3 ohms and four 10 ohm resistors in parallel make 2.5 ohms and so on. You can double check these figures by using the following equation for resistors in parallel.

1/R total = 1/R1 + 1/R2 + 1/R3 + 1/R4 …….

9. Based on the new readings it appears that the power keeps climbing as the resistance is lowered. And that the maximum power is most likely to be achieved between 2.5 ohms and zero ohms. So continue to repeat this portion of the exercise to find the maximum power point for the solar panel in parallel with resistance between 2.5 ohms and zero ohms.

10. The major element that can be learned from this exercise is that solar panels in parallel produce significantly more power compared with the same panels in series. This should be evident, since solar panels in parallel can supply more current – but at less voltage.

TEACHER GUIDELINES AND TIPS

1. Before performing the exercises, have students make a drawing of the resistors in series and parallel and have them explain exactly how they will remove or short out the resistors to achieve the desired load. This will help when actually doing the exercise, since confusion will be avoided. This seems like a simple task but rehearsing an exercise is always recommended to avoid errors.

2. Instead of the computer plots, have the students review the same data on the LCD display. The computer plots are great visualization tools, but knowing how to use the ***Smart Meter – Data Logger*** ^{tm} is also important.