Solar Energy Power System

DC/AC Circuits

Student Name: ____

Acknowledgements
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Purpose
The purpose of this lab is to be able to measure and calculate basic values such as voltage, current, power, and efficiencies for a power system. Alternative energy is a hot topic these days and much emphasis is being placed on being “green.” A “green” system is one that was intentionally designed with high-energy efficiency in mind and also that it be more environmental friendly that previous systems. As time passes more and more alternative energy systems will be placed “on-line.” A technician must have the skills to measure such systems and determine if components are in need of replacement and if the systems are operating within operating specifications.

Systems Rationale
This lab exposes you to a real-world application from which you will perform measurements and calculated efficiencies. This lab incorporates DC/AC voltages and currents, an alternative energy source, voltage regulation, storage, energy conversion, and energy consumption.

Prerequisite Knowledge & Skills
- Define Ohm’s law.
- Solve power equations for efficiency.
- Given a multimeter, measure voltage and current.

Student Learning Outcomes
Relevant skill (S) student learning outcomes include:

S1. Given measured values such as voltage and current, calculate efficiencies of an energy power system.

Process Overview

In the process of completing this lab, you will:

- Perform measurements and/or calculations after each block of the Process Overview diagram, shown in figure 1 below.

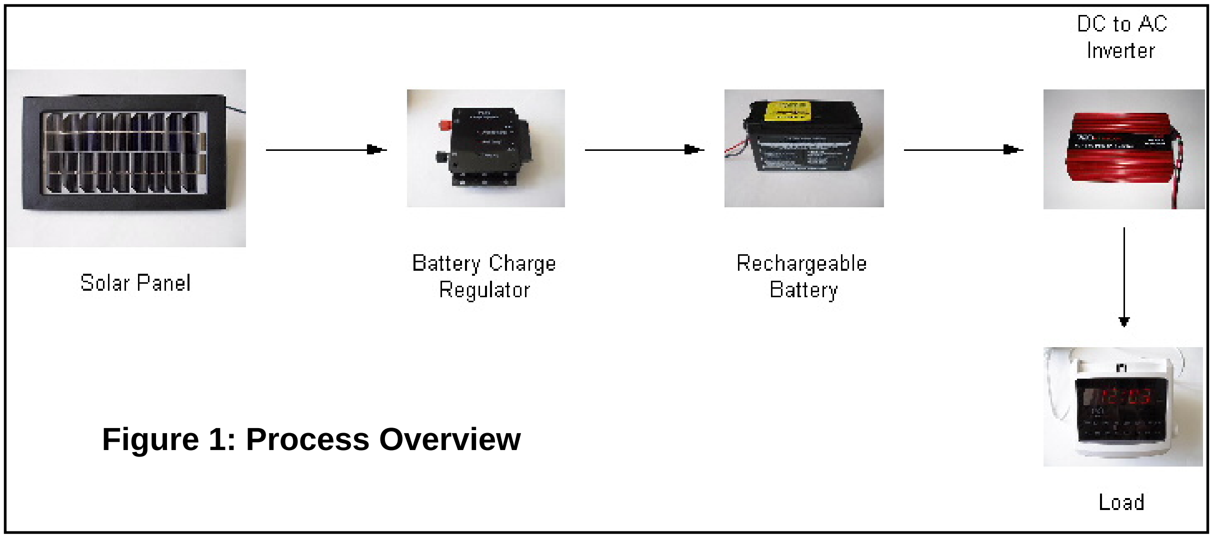


Figure 1: Process Overview

- The lab results should be submitted to the instructor upon completion.

Time Needed

Lab Performance:
It should take you approximately 2 hours to work through the entire lab, in groups of two students.

Lab Deliverables:
You should provide the results to your instructor.

Equipment & Supplies

Item	Quantity
Solar panel (12 volt) 5 watt thru 50 watt	1
Battery charge regulator for 12 volt systems	1
SLA (Sealed Lead Acid) battery (approximately 9AH)	1
DC-to-AC inverter (approximately 300 watts)	1
AC load: clock radio (can substitute a soldering iron or 40 watt bulb)	1
Multimeter	1

Special Safety Requirements

Please note that the Inverter does convert DC voltage into AC voltage. The AC voltage produced is typical of 110VAC house voltage. A person could receive an electrical shock if not careful.

Also SLA batteries do contain Sulfuric Acid. Care should be taken so as not to drop the battery causing the casing to “crack” open.

Lab Preparation

1. View the video on solar energy from the US Department of Energy at www1.eere.energy.gov/solar/animations.html.
2. Read Chapter 4 of the Solar Thermal &Photovoltaic Systems guide provided by the U.S Department of Energy found at www.eere.energy.gov/buildings/building_america/pdfs/41085.pdf.

Introduction

In this lab, a solar energy system will be measured and analyzed. A solar panel will convert sunlight into a DC voltage. The DC voltage will then be sent to a battery charge regulator, which will keep a SLA battery charged. The battery in turn will supply power to the DC-to-AC inverter. The inverter then supplies AC voltage to a common household appliance such as a clock radio or a light bulb.

Task

In performing this lab, the student will be responsible for measuring and calculating voltages, currents, power supplied, and efficiencies. Technicians regularly use measurement equipment to determine if a system is operating as it was designed to do. This lab reinforces basic measurement skills.

Performance

1. Solar panels generate an electric current and voltage when photons from sunlight strike the solar cells. Each solar cell has a voltage potential of about .5 Volts. The amount of current that each cell generates is directly proportional to the surface area of the cell. The larger the surface area of the cell, the greater the amount of amperage the cell can produce. Since each solar cell by itself has a small voltage, solar panels are an arrangement of a large number of solar cells so as to produce a larger voltage and current amount. Solar cells may be arranged in series, parallel, or series-parallel in order to achieve a specific voltage and current amount.

   The solar panel provides approximately 9 Volts, shown in figure 2 on the right.

   Take a close look at the solar panel. Are you able to see the series arrangement of the cells?

   This solar panel has eighteen cells in series, each cell is .5 Volts, giving the panel a voltage of 9 Volts.

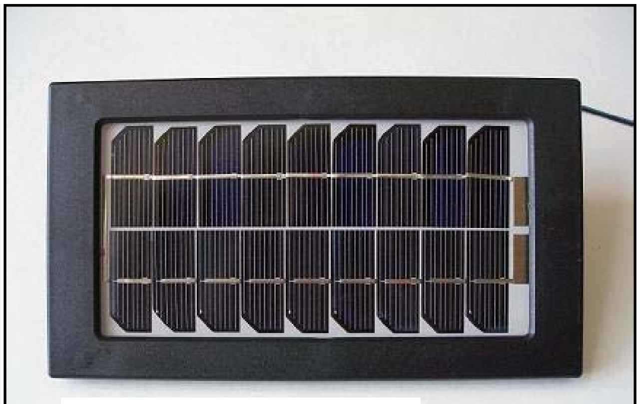


Figure 2: Solar Panel

Take a look at the solar panel you have. What is the arrangement of the cells? Draw the arrangement of the cells in this space.

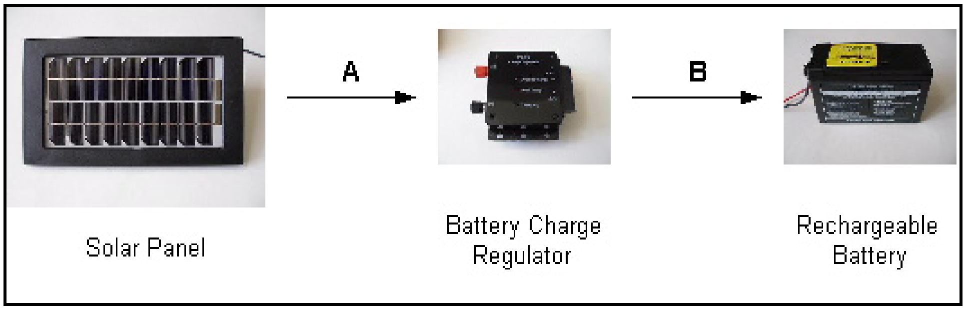
What voltage output does your solar panel have based on the arrangement of the solar cells? The anticipated voltage output based on the arrangement of cells is ________________ Volts.

2. Take your solar panel outside and place it so that the front of the panel faces the sun. The entire front of the panel should be in the sunlight. Measure the voltage of the panel. This is the open-circuit voltage. It is also referred to as the no-load voltage. For this lab, remember that the panel needs to be of the 12 Volt type. Most 12 Volt type solar panels will have a no-load voltage around 18 Volts. Remember that the solar panel provides DC voltage, so set the multimeter accordingly. The no-load voltage is ______________ Volts.

3. The following component sequence shows a solar panel system arrangement, which allows the solar panel to keep a SLA battery charged. The purpose of the battery charge regulator is to charge the battery when needed with the appropriate voltage and current. The battery charge regulator also prevents over-charging of the battery, which would decrease battery life.

   Connect the solar panel, battery charge regulator, and rechargeable battery in the connection sequence, shown in figure 3 below.

Figure 3: Connection Sequence for a Battery



Connect the solar panel to the battery charge regulator, shown in figure 4 below. Remember that the solar panel has polarity and that the positive lead of the solar panel goes to the positive input of the battery charge regulator, and the negative lead of the solar panel goes to the negative input of the battery charge regulator.

Figure 4: Solar Panel Connection to the Charge Regulator

Connect the battery to the battery charge regulator, shown figure 5 below. Please observe the polarity of the connections.

Figure 5: Battery Connection to the Charge Regulator

4. Using the arrangement of Step 3, place the solar panel in bright sunlight. Using the multimeter, measure the voltage and current draw at Point A when the battery charge regulator indicates that the battery is being charged.
   The voltage at Point A is _______________ Volts.

   The current flowing through Point A is _______________ Amperes.

5. Immediately after completing Step 4, measure the voltage and current draw at Point B when the battery charge regulator indicates that the battery is being charged.

   The voltage at Point B is ______________ Volts

   The current flowing through Point B is ______________ Amperes.

6. Using the measured values from Step 4, calculate the power supplied by the solar panel to the battery charge regulator. Power supplied is ______________ Watts.

7. Using the measured values from Step 5, calculate the power supplied by the battery charge regulator to the battery. Power supplied is ______________ Watts.

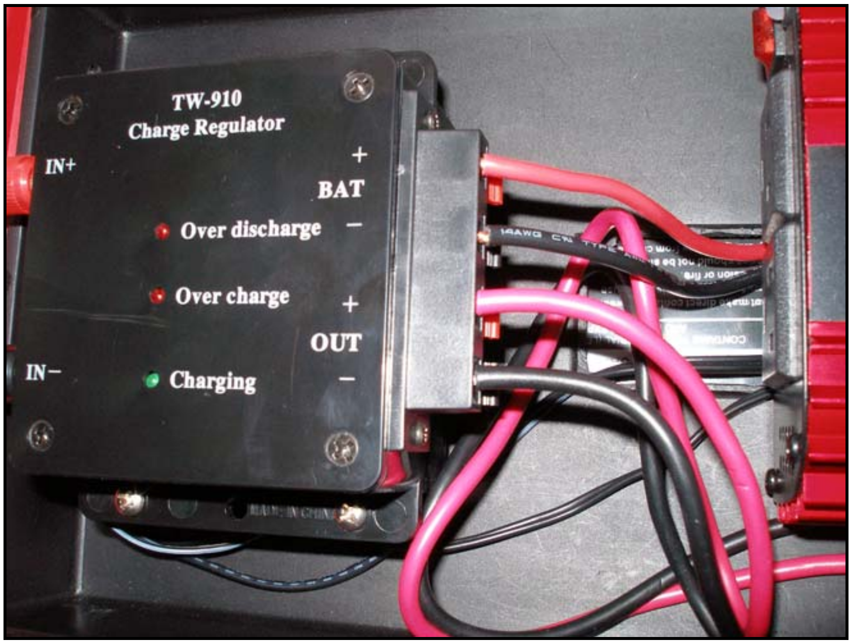
8. How efficient is the battery charge regulator given the current charge state of the battery. The battery charge regulator is designed to pass as much energy as possible when charging the battery. When the battery has reached a charged state, the battery charge regulator then only supplies a very small amount of energy to keep the battery "topped-off." The rest of the energy is usually converted to heat. This is necessary so as not to over-charge the battery. Efficiency can be calculated by the following equation:

$$\text{Efficiency \%} = \frac{\text{Power}_{out} \text{ (in Watts)}}{\text{Power}_{in} \text{ (in Watts)}} \times 100\%$$

   The efficiency (in percent) is ______________ when the battery was charging. Please note that the efficiency of the battery charge regulator will be at its highest when the battery is charging.

9. Connect the DC-to-AC inverter to the battery charge regulator, shown figure 6 below. Remember that the red lead is considered "+" and the black lead is considered "-". The DC-to-AC inverter is connected to the terminals labeled "OUT".

Figure 6: DC-to-AC Inverter Connection to the Charge Regulator



Next, connect a 110VAC load to the output of the DC-to-AC inverter. Figure 7 shows the 110VAC receptacles to which the load can be "plugged" into, below.

Figure 7: 110VAC Receptacles

An overview of the component flow is shown in Figure 8 below.

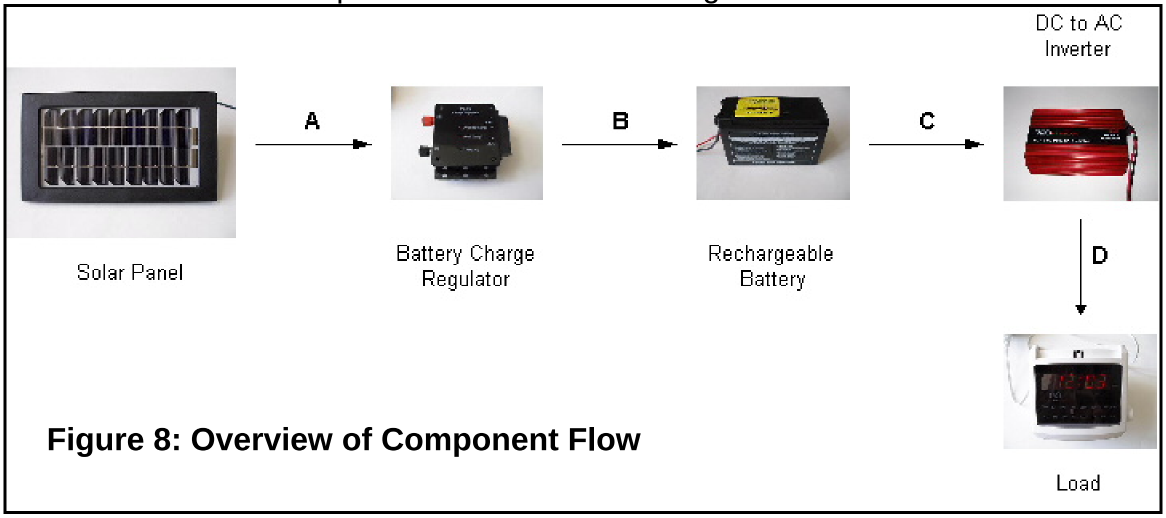


Figure 8: Overview of Component Flow

10. With the inverter's power switch on the "ON" position and the load also "turned on," measure the voltage and current draw at Point C. These measured values will give us a calculated power value that indicates the amount of power the inverter is using to run itself and also supply to the load. The inverter does require some power to run because it has internal electronics and most likely has a cooling fan.

    The measured voltage at Point C is _______________ Volts.

    The measured current flowing through Point C is _______________ Amperes.

    The calculated power that the inverter is taking in is _______________ Watts.

11. **This next step involves measuring 110 VAC. Remember to exercise safety.** Setting the multimeter to measure AC Voltage, measure the voltage across the load (Point D). Then set the multimeter to measure AC Current and measure the current supplied to the load.

    The measured voltage at Point D is _______________ Volts.

    The measured current flowing through Point D is _______________ Amperes.

    The calculated power that the inverter is supplying is _______________ Watts.

    Watts is still Voltage multiplied by Amperage.

12. Calculate the efficiency of the inverter by using the equation from Step 8.

    The efficiency (in percent) of the inverter is _______________ %.

13. Change the load on the inverter and repeat Steps 10 through 12.

    The measured voltage at Point C is _______________ Volts.

    The measured current flowing through Point C is _______________ Amperes.

    The calculated power that the inverter is taking in is _______________ Watts.

    The measured voltage at Point D is _______________ Volts.

    The measured current flowing through Point D is _______________ Amperes.

    The calculated power that the inverter is supplying is _______________ Watts.

    The efficiency (in percent) of the inverter is _______________ %.

14. Compare the efficiency of the inverter for the second load against the efficiency for the first load. Are they similar or different? Express your thoughts as to why.

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15. Make sure to put everything you used back, in the same condition and location where you found it.

Grading

Your instructor will let you know how this lab will be graded.