Experiment A7
Solar Panels II
Procedure

Deliverables: checked lab notebook, **Full Lab Report** (due the week after break)

Overview

This week, you will create your own "Solar Microgrid". The microgrid consists of the solar panel, a 12V lead acid battery, and a charge controller, as shown below in Figure 1. Solar panels obviously do not produce energy at night, so the 12V battery is used to store energy produced during the day. Directly connecting ~20V DC output of the solar panel to charge the 12V battery would damage it, so the charge controller is used to step down the 20V DC to 12V DC. Additionally, the charge controller contains two 5V USB outputs for charging and powering various consumer electronics.

Then, you will independently design a system for harvesting and storing solar energy.

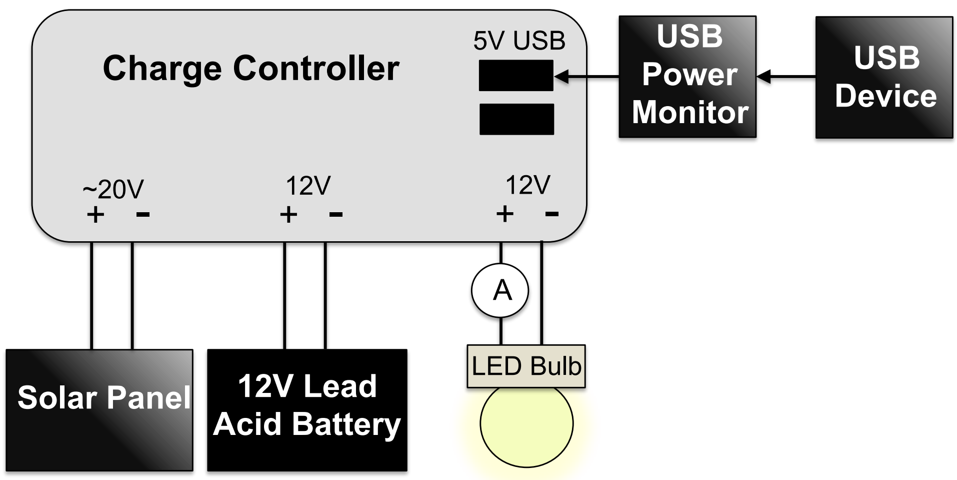

Figure 1: A schematic of the Solar Microgrid.

Part I – Constructing a Microgrid

Procedure

1. Sketch the schematic shown in Figure 1 in your lab notebook.
2. Connect the solar panel to the input terminals on the far left of the charge controller:
    a. Loosen the two terminal screws on the top of the charge controller.
    b. Use the female banana cables with stripped wire on the end.
    c. Twist the stripped end of wire to tidy it up, insert it into the side of the charge controller, and tighten the screw to lock it in place.

3. Place the solar panel directly under the lamp, and set the variac to 120 V.
4. Connect the battery to the charge controller:
   a. Loosen the two terminal screws on the top of the charge controller.
   b. Use the "spade connectors" with stripped wire on the end. Insert the stripped end of wire on the side of the charge controller and tighten the screw to lock it in place.
   c. Place the spade connectors on the battery.

Caution: This is a powerful battery. It is NOT a toy. It can cause painful shocks, burns, and even cause fires.

5. Check that the battery is securely connected to the screw terminals of the charge controller.
6. Look at the screen on the charge controller. What do you see? Flip the panel upside-down. Does the screen on the charge controller change? Sketch the screen in your lab notebook.
7. Flip the panel right-side up again.
8. Connect the LED light bulb to the 12V DC output terminal of the charge controller:
   a. Insert a length of wire into the 12V output positive screw terminal.
   b. Locate the handheld DMM with mini-grabber. Make sure the red cable is in the 10A socket. Connect one of the DMM cables to the wire in the charge controller and the other DMM cable to the red light bulb wire, such that the DMM **in series** with the LED bulb, as shown in Figure 1. Switch the DMM knob to the 10A current setting.
   c. Connect the other light bulb wire to the negative screw terminal on the charge controller.
   d. Turn on the LED bulb, and you should see a value for the current on the multimeter.

   Caution: You must use the 10A setting, or you will burn out the DMM!

9. Place the LED bulb upside down in the metal Bunsen burner stand. Measure the **voltage** across the screw terminals on the bottom of the LED bulbs using the other handheld DMM with the needle-shaped probes. **The red probe should NOT be in the 10A socket.** Turn off the LED bulb.
10. Plug the USB power monitor stick into one of the USB charging ports. Choose a device and plug it into the other end of the USB power monitor. (Possible devices include your cell phone or tablet or the rechargeable flashlight or fan provided by Prof. Ott.)
11. Use the USB power monitor to measure the voltage and current of the USB device.
12. Copy Table 1 into your notebook. Fill it out by recording the current for the LED bulb and current and voltage for two different USB devices. (Be sure to write down the actual names of the USB devices you used, not just "USB Device 1".) Put the solar panel directly under the lamp to simulate day and turn it upside down to simulate night. Demonstrate this to the lab instructor or TA.
13. When you are all finished, **turn the variac dial back to zero and turn off the variac.** Turn off the LED bulb and disconnect the handheld DMMs. Disassemble everything. Return everything to the plastic case, except for the battery.

Table 1: Energy usage of various electronic devices.

	USB Device 1		USB Device 2		LED Bulb	
	Voltage	Current	Voltage	Current	Voltage	Current
Day						
Night						

Part II – Independent Case Study

In your lab report, you will present a preliminary design for a solar microgrid. Each student will be randomly assigned a location and several devices that need to be powered by the solar system. You will have to choose the number of solar panels based on their efficiency and the average solar irradiance of the given location. Then, you will need to select a charge controller and batteries with the capacity to store half a day's worth energy produced by the panels.

Procedure

1. Do a bit of online research. Be sure to bookmark your sources, as you will need to reference them in your report.
    a. What are the typical voltage requirements for each of the devices (i.e. 5V DC, 120V AC, etc.)?
    b. What are the typical current requirements for each of the devices (i.e. 10 Amps, etc.)?
    c. What is the typical instantaneous power in kiloWatts needed to power each of the devices?
    d. How many hours/day do you estimate that each device will be used? Multiply the device power in kiloWatts times the estimated daily usage in hours/day to give you the average power consumption of the device in kWhrs/day.
    e. What is the average solar irradiance in kWhrs/day/m^2 at the given location?
2. Choose a solar panel from one of the preferred vendors. Write down its cost, efficiency, and surface area. (You might have to do a bit of digging to get the technical specifications, but that's just part of the job!)
    a. Use the average irradiance of your given location, the area of the solar panel, and its efficiency to calculate the average amount of energy a single solar panel would output in kWhrs/day.
    b. How many of these solar panels would you need to power all the devices?
3. Choose a battery from the same vendor as the solar panel. Write down its cost, voltage, and charge capacity in Amp-hrs.
    a. What is the total amount of energy it can store in kWhrs?
    b. How many of these batteries would you need to store half a day's worth of energy output by the solar panels?

4. Choose a charge controller from the same vendor capable of handling the power output by the number of solar panels you will need to power the devices. Be sure to write down its cost.
5. If your appliances run off of AC power, you will also need to select a "power inverter" to convert the DC voltage from the batteries to AC. Make sure it can handle the power requirements of your AC appliances.

Preferred Vendors:

Northern Arizona Wind & Sun - http://www.solar-electric.com/

Solar Electric Supply, INC. - http://www.solarelectricsupply.com/

Wholesale Solar - http://www.wholesalesolar.com/

Week II Deliverables – Download the LaTeX or MS Word template from the course website and use it to write a brief lab report, no longer than **8 pages**. You are required to include the following items in your lab report **along with the deliverables from the previous week**. (See the score sheet for points.)

1. A table containing the following parameters for your devices. (Be sure to include references.)
   a. The typical voltage requirements for each of the devices. (i.e. 5V DC, 120V AC, etc.)
   b. The typical current requirements for each of the devices. (i.e. 10 Amps, etc.)
   c. The typical instantaneous power in kW for each device.
   d. The estimated daily usage of each device in hours/day.
   e. The estimated average power in kWhrs/day needed to power each of the devices.
2. A table summarizing the calculations for the size and number of solar panels and batteries you will need.
   a. The average irradiance in kWhrs/day/m^2 at the given location.
   b. The percent efficiency of the solar panels you chose.
   c. The approximate size (area) of the solar panels you chose in m^2.
   d. The number of solar panels you will need to power all the devices.
   e. The total average power in kWhrs/day you expect all the solar panels to output at your given location.
   f. The energy storage capacity of the battery you chose.
   g. The number of batteries needed to store half a day's worth of energy from the panels.

3. A table containing a bill of materials (BOM) for the parts you chose from one of the preferred vendors.
    a. Solar panels, their part number, and total cost in USD.
    b. Batteries, their part number, and total cost in USD.
    c. Charge controller, its part number, and cost in USD.
    d. Power inverter to convert the DC voltage from the batteries to an AC voltage for the appliances (if necessary), its part number, and cost in USD.
    e. The total cost of the system.

Suggested Talking Points – This lab is to test your ability to work *independently*, so these are merely *suggestions*. Feel free to be as creative as possible in your analysis.

- Write a few paragraphs describing the microgrid, its location, what devices it powers, the vendor, its components, how much power it produces, etc.
- Discuss the economic feasibility of the microgrid. Look up the cost of electricity in USD/kWhr at the given location. Based on the average power output by the solar panels, how many years would it take the microgrid to pay for itself? Compared to the average lifetime of the components, does it make sense to build the microgrid in the given location?

Appendix A

Extra Equipment Available for Independent Experiment

- Solar Panel w/ 24” wire leads ending in male banana connector
- Multi-meter w/ 24” wire leads ending in male banana connector
- BK Precision AC Power Supply
- Halogen lamp Fixture w/ GE Lamp: GE 90w 1900lm M/N 66286 PAR 38
- Extech handheld digital multimeters with minigrabber cables
- Extech handheld digital multimeters with probe cables
- 2 BNC to banana adapters
- Set of banana cables (1 black, 1 red)
- Black plastic case containing Micro-grid
  - Mohoo 20A Charge Controller Solar Charge Regulator Intelligent USB Port Display 12V-24V
  - Eversame USB Digital Power Meter Tester Multimeter Current and Voltage Monitor, DC 5.1A, 30V
  - ExpertPower EXP1272 12V 7.2 Amp-hour Rechargeable Battery
  - ChiChinLighting 12v LED Bulb Daylight AC DC Compatible 7 Watts 6000k Low Voltage
  - Porcelain Medium-Base Light Bulb Socket with Pull Switch, 250 Maximum Watts, 250 Maximum Volts
  - Bunsen burner stand
  - USB device (fan or flash light)
  - Small flathead screw driver
  - Female banana cables with stripped wire end (1 black, 1 red)
  - Black battery wire with spade connection
  - Red battery wire with spade connection and 2A fuse
  - 18 AWG wires with stripped ends (black and red)