Photovoltaic and Battery Primer

An Introduction
Putting Photovoltaic Technology to Practical Use

• Some key vocab to discuss first:
  – Voltage (volts) (V)
  – Current (amperage) (I)
  – Power (Watts) (P)
    • $P = IV$
    • more info:
      http://www.youtube.com/watch?v=ZSviOnud7uY
Increasing Voltage

**Series Wiring:**
- Connecting individual cells together (+ to -) into a string.
- The **voltage** of each individual cell accumulates as they are connected in this way.

![Diagram of series wiring with 36 cells connected in series.](image)
Increasing Current

• **Parallel Wiring**
  – Connecting PV series together ("+ to +" and "- to-") into parallel
  – The current *(amperage)* of each individual series accumulates when wired in this way.
Power (Watts)

• The power output is a function of both voltage and amperage and is calculated by multiplying the values together.

  – If you are not measuring one complete circuit, you will be calculated theoretical max power output.

  \[
  12V \times 3A = 36 \text{ W}
  \]

  Theoretical Max Power

Notice that 12 volts are achieved by a series of two 6V modules

Notice that 3 amps are achieved by two 1.5A series in parallel
Complete the Following

• You have 20 PV cells each rated at 2.0 volts and 1.0 amps.

1. What is the maximum voltage that can be achieved and how would you wire them together to achieve this?
2. What is the maximum amperage that can be achieved and how would you wire them together to achieve this?
3. What is the maximum theoretical wattage that can be achieved through parallel wiring?
4. What is the maximum theoretical wattage that can be achieved through series wiring?
5. What is the maximum theoretical wattage that can be achieved by a combination of series and parallel wiring?
Solar Cells vs. Modules

• A solar module is a PV device with multiple PV cells connected electrically (either in series or series and parallel).
Modules vs. Arrays

• A PV array consists of multiple modules connected electrically (either in series or series and parallel)
DC to AC Inverters

- PV cells, modules, and arrays produce DC (direct current) electricity
- In the US, the electrical grid and most household appliances are equipped to handle AC (alternating current) electricity.  
  – ([http://www.youtube.com/watch?v=xyQfrzBfnDU](http://www.youtube.com/watch?v=xyQfrzBfnDU) for more info.)
- To solve this problem, inverters are installed to convert from DC to AC.
Power vs. Energy

• In this context, **power** refers to the instantaneous output of a solar module or array. (W or kW)

• **Energy** is the ability to supply power over time. (Wh or kWh).
  
  – Calculated by multiplying the power by the time for which the power is supplied
Power vs. Energy

• Power:
  – Determines whether the source of energy is strong enough to “power” certain devices or homes

• Energy:
  – The ability to sustain certain amounts of power over time
Power vs. Energy in Solar Arrays

• A typical solar panel is rated at 200W
  – Is this power or energy?
• In W WA, we average 5 hours of peak sunlight each day (more in summer, less in winter)
  – How could you determine the average daily energy value provided by a single panel?
• Solar panels can easily be scaled-up to provide both the power and energy needed to replace fossil fuels
  – Why do they still pose a problem for us though?
Batteries

• Batteries use chemical potential energy to produce DC power.
• Rechargeable batteries use DC power to “re-supply” the chemical potential energy
The power rating of a battery is a function of:
- Voltage (combined voltage of each cell)
- Storage (Amp hours (Ah))

A fancy new Li ion drill is typically 18 V with a storage of 3 Ah. This would result in about 54 Watt hours of energy.
Battery charging for dummies

• In order to charge a battery the following must be true:
  – The incoming voltage must be greater than the total voltage of the battery being charged.
  
  • To charge an 18 V Li⁺ battery, you must supply more than 18 V.
  – A typical household outlet supplies 120 V and up to 15 Amps of AC electricity (way more power than is needed for this battery)
Battery charging for dummies

• The charger for these batteries controls the amount of power going into the battery to optimize charge-time without overheating.

• The typical 120 V/15 A outlet can supply up to 1800 Watts. This “could” charge my 54 Watt-hour battery in 1.8 minutes. The down-side is that so much heat would be generated that my battery would “fry” in pretty short order.

• My charger takes the available power and keeps the voltage and amperage at levels that will charge my battery, but not so fast that it overheats.
  – Usually requiring about 1 hour for a full charge.
  – Power input is reduced to just over the 18 V and about 3 Amps.
Messing with V and A

• A 200W solar panel provides about 37 V and up to 5.4 A of power.
  – How many 18V Li+ batteries could I charge at a time?
• The answer isn’t so simple
  – The voltage and amperage can be adjusted up or down through conversion
  – I could cut the voltage to 19 V, and boost the amperage to 10.5 A (buck converter)
  – I could boost the voltage to 74 V and cut the amperage to 2.7 A (boost converter)
Best Practice

• Cut the voltage to “just above” the battery rating and convert the rest of the power to amps to speed-up the charging time