Energy & Power Management

Power available

- How much Power from the PV module?
  o At noon in Tucson in May. GHI ~ 700 Watts / m^2.
  o Module has 10% conversion rate
  o Module area is 2 m^2
  o 700 * 2 * .1 = 140 Watts.
  o 150 lb person climbing stairs at a rate of 1 ft every 1.5 seconds is generating ~150W
  o A Prius driving at 50 mph on a level road is using ~15,000 watts.

- How much Energy is stored in the batteries?
  o 4x 6 volt 4.5 Amp-Hour battery pack
  o 4.5 Amp-Hour = 16,200 Amp-Seconds
  o 4 * 6v * 16,200 amp seconds = 39,000 Watt seconds = 39 kJ
  o 39 kJ = energy in 1/2 liquid ounce of gasoline
  o 20 min race = 1200 seconds
  o 39,000 watt seconds / 1200 seconds = 320 watts average over race

- Best case ~400 watts available at output of power sources.

Electrical Losses

- Charge controller
  o 10% of PV power
- Motor controller
  o 10% of power to motor
- Wiring
  o 1-10%
- Motor
  o 50% – 85% efficiency
- Output of motor
  o ~250 W

Mechanical Losses

- Drivetrain
- Rolling resistance
- Wind resistance

Power Management

- How much energy is left in my battery pack?
- How much power am I using?
- How much power is the PV module making right now?
Wiring and Troubleshooting

Wiring

Equipment Layout and positioning
- Functionality
- Impacts on losses and serviceability

Means and Methods

- Wiring methods is a balance of
  - Installation expense (one-time expense)
    - Cost
    - Time
  - Electrical losses (ongoing expense)
    - Area and Length of wires
    - Connection resistance
  - Serviceability (avoiding potential future expense)
    - Labeling and Color
    - Accessibility
    - Visibility and Clarity

- Connections / Splices
  - Plug
  - Bolted
  - Wire nut
  - Twisted
  - Soldered

- Wire management techniques concern
  - Avoiding future damage
  - Aesthetics
  - Preserving serviceability

Measuring / Estimating Electrical losses

- In the absence of data our tendency is to either ignore problems or over-compensate for them. It is really tough to have a measured response.
- What can be done to either estimate or measure the various electrical losses?
- Are there any tweaks I can implement to mitigate or reduce some type of loss?
Troubleshooting

The most important thing you can do for effective troubleshooting is preparation.

Troubleshooting steps

1. Symptoms
   a. Why do I think something is wrong?
   b. How the observed behavior different than what I expect?
2. Diagnosis
   a. What underlying causes could manifest the observed symptoms?
      i. Wiring errors
      ii. Wiring faults (what is the difference between an error and a fault?)
      iii. Equipment faults
   b. What tests can I do to rule out or confirm proposed causes?
3. Correction

Troubleshooting Tips

- Label wires with numbers in drawing and match with numbered labels at each end of wiring in system
- Straight wires, clean turns, pairs together.
- A wire that is 20% longer in order to make a clean install is better than the shortest possible route. Risk / Benefit consideration.
  o Benefit of shorter wire:
    - reduction in losses
    - reduction in cost
  o Harms of shorter wire
    - Reduced tolerance / capacity for movement
    - Increased difficulty in identifying errors / faults