Tuesday, September 14, 2021

Elmer Night Solar Primer

Overview

- System components
  - Panel(s)
  - Battery
  - Charge controller
- But first, some math!
  - Ohm's law
    - P = V x I
      - 100W panel is indeed about 20V x 5A in full sun!
      - Compare power, not amps…
        - 100Ah lead acid battery yields 630Wh (12.6V x 100A x 50%)
        - 100Ah LiFePO4 battery yields 1320Wh (13.2V x 100A x 100%)
    - V = I x R
      - Prefer 84% of the panel's power to the controller or 98%?
        - 50' of 18 AWG wire to panel results in 3.2V drop (5A x 50' x 2 x 0.006385Ω)
        - 50' of 10 AWG wire to panel results in 0.5V drop (5A x 50' x 2 x 0.000999Ω)

Panels

- Polycrystalline vs monocrystalline
  - Monocrystalline solar panels have solar cells made from a single crystal of silicon, while polycrystalline solar panels have solar cells made from many silicon fragments melted together.
  - Monocrystalline slightly more efficient.
  - Polycrystalline are slightly cheaper.

  - Monocrystalline are black, poly blue.
  - Polycrystalline handles shadows & clouds slightly better.
  - Polycrystalline more eco-friendly.
- Flex vs rigid
  - Heat is a solar cell killer: 2-4 year lifespan for flex vs basically infinite for rigid.
  - Flex isn't really flex - solar cells *are* glass, after all.
  - Flex do have their place - lightweight, aerodynamic.
- Chaining panels for mo powah!
  - Panels have built-in blocking diodes, allowing parallel or series wiring.
  - Parallel wiring
    - Doubles current, voltage stays constant.
    - Pre-made Y cables make wiring easy.
    - Relatively shade resistant.
    - Needs heavier gauge wire to avoid voltage drop.
  - Series wiring
    - Doubles voltage, current stays constant.
    - Wiring can be more complex, but cheaper due to lower current demands.
    - Shade brings the whole party down.
    - MPPT controllers only.
    - Beyond two panels gets into the "Ow that hurts!" range. Pay attention!
      - High-voltage DC requires specialized breakers and switches.

Battery

- The major players: Lead acid, Lithium Polymer, Lithium Iron Phosphate.
  - Lead acid
    - 2.1V per cell, 6 cells in series = 12.6V fully charged battery.

- Great temperature tolerance.
- Inexpensive, but heavy.
- Depletion beyond 50% results in internal damage including grid corrosion and sulfation which increase the batteries internal resistance. This leads to the battery being unable to accept charge.
- Pay attention to composition - it matters when it comes to charging parameters!
  - Flooded (car battery)
    - Liquid electrolyte can spill.
    - Vent hydrogen gas.
    - Longest life of the lead acids (if cared for.)
  - Absorbed Glass Mat (AGM)
    - Electrolyte captured in matting; no spill or outgas risk.
    - Can be mounted in any orientation.
    - More expensive than flooded but “maintenance free.”
    - Great tolerance for extreme cold.
  - Gel
    - Does not tolerate high discharge rates!
    - Supports much deeper discharge than flooded or AGM without damage.
    - Tolerates extreme heat really well.

- Lithium Polymer
  - 3.7V per cell. Various series & parallel geometries used.
  - Highest energy density.
  - Do not suffer fools well - rigorous charge & discharge requirements for voltage current, and temperature limits or things get explody. Normally, sophisticated charging circuitry in the device handles all this.
  - Relatively short life - typically 500 or so full discharge cycles.
  - Common Li-Po portable power stations: Jackery, Anker, Goal Zero.

    - By far highest cost per Wh, but sure convenient with built-in AC and solar charge controllers, USB, 12V and 120V outputs.
  - 4S RC battery packs offer extraordinary discharge capacity (20C) for very low cost but be aware - your equipment must tolerate 15V and they rarely have much for protection circuitry. Understand setup and charger requirements to avoid flaming excitement.
- Lithium Iron Phosphate
  - 3.3V per cell, 4 cells in series = 13.2V fully charged battery.
  - Extremely safe and durable - 6,000+ discharge cycles.
  - Huge discharge capacity - 40C not unusual.
  - Most expensive but costs coming down fast. Many DIY their own packs and come out with costs less than lead acid.
  - Must NEVER be charged below freezing (discharge is fine). Normally the battery management system (BMS) handles this, but not always!
  - 100% usable capacity. BMS handles specifics but if a LiFePO4 battery is rated 100Ah, that's 100Ah or more, fully usable.
  - Extraordinarily flat discharge voltage from 99% to under 5%. So flat in fact that it's impossible to gauge LiFePO4 battery capacity from voltage alone. Typically a shunt is used to measure current out / in.

Charge Controller

- Hard part's done with panel(s) and battery chosen. Just need to make sure the charge controller can handle the solar array output and that it supports the desired battery chemistry. As we've seen, LiPo and LiFePO4 are NOT the same! Pay attention to the specs.
- Pulse Width Modulation (PWM) vs Maximum Power Point Tracking (MPPT) controllers
  - PWM
    - Older tech, cheaper, less efficient.
    - Steps the panel voltage down to the desired charging voltage.

  - PWM cannot regulate current - current in is current out. This means the controller must be rated to handle the solar array output or magic smoke will emanate.
  - All that switching is RF noisy! Not a ham's friend.
  - Some solar panels have built-in PWM controllers for direct battery charging - Harbor Freight, Zamp, etc.
- MPPT
  - More expensive, more efficient.
  - Varies the load characteristics presented to the cells to get the most power out of the panel based on sunlight hitting it and temperature. Under ideal, full sun conditions, differences between PWM and MPPT are minimal. Under cloudy, sub-optimal conditions, MPPT gets significantly more output from the array.
  - MPPT can be designed to support hundreds of volts from large serial arrays. This isn't cost effective or practical for PWM.
  - Solar panels actually draw power after dark. MPPT controllers stop this, preventing the panels from running the battery down.
  - Less RF noise (but still some).
  - Popular MPPT controllers: Renogy, Victron, West Mountain Radio (hams).

- West Mountain Radio Epic PWRgate - the ideal ham MPPT charge controller solution?
  - Also brings shack AC power supply into the mix providing true uninterrupted power to gear. Other solar charge controllers can't do this alone.
  - AC supply will also charge battery when there's no sun.
  - 10A charge rate, plenty for 50-100Ah of battery storage.
  - Up to 30V solar input. So two 100W panels in serial won't work (~ 40V) but two panels in parallel would be fine and deliver 70-80Ah of charging capacity per sunny day.
  - Uses the Anderson Powerpoles we know and love.
  - Designed to be low noise and ham friendly. Even a battery charge suspend button to eliminate all RF noise for 30 minutes.

- Supports AGM, gel, and LiFePO4 chemistries via a simple jumper and all charging parameters are accessible via serial USB to support any battery type.
- Optional temperature probe available, if needed.
- 40A continuous output for even the thirstiest HF rigs.

More Info

- YouTube: DIY Solar Power with Will Prowse
- https://diysolarforum.com/
- DIY MPPT controller: https://www.instructables.com/DIY-1kW-MPPT-Solar-Charge-Controller/