Remote Solar Power on the Farm

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“Solar Panels”

- Thermal: designed to provide heat from the sun.
  - Almost always referring to heating water via copper pipes inside a glazed box
  - LWF has a great video on DIY solar water heating
  - Sometimes referring to DIY air heaters

- PV: photovoltaic. Electricity generated from sunlight.
  - Process where sunlight excites electrons on wafer thin sheets of silicone.
  - First solar cell was invented in 1873. Observed increased conductivity of Selenium when exposed to light.
  - Bell telephone and NASA drove the technology to commercial availability in 1960’s.
  - Modern day PV cell- 2 very thin sheets of Boron and Phosphorous doped Silicon crystal, with electrical contacts on each. One has electron surplus, the other deficit.
  - 1 cell is ½ Volt. 36 cell - 18V module

- Advantages of PV technology:
  - Very little maintenance = reliable
  - Quiet = no moving parts
  - Modularity = with some planning, system can be upsized at a later time
  - No fuel = no cost, no refueling, no emissions
  - Independent, decentralized, environmentally friendly

- Challenges:
  - Storage, management of variability
    - Can be coupled with conventional power sources in larger systems
    - Battery technology is improving
    - Other creative ways to store energy - water towers, compressed air
  - Upfront cost
    - upfront cost
    - Compare to running a power line
    - Compare to operating a conventional portable generator
    - PV module prices have dropped significantly in recent years
    - It’s an investment - because it offers payback
  - Education
    - thinking about efficiency: “Every dollar spent on energy efficiency is 4 dollars spent on solar”
  - Load management - Smaller systems may require planning ahead
    - only do the necessary work! as farmers you’re used to it!
  - Proper siting
    - As farmers you already have a deep connection to your property
Siting

- Solar PV works best when rays of sunlight are perpendicular to panels
- “Solar Window”
  - Refers to sun’s arc across the sky throughout the season.
  - Sun is high in the summer, rises a little north of east. Sets north of West.
  - Low in winter, rising and falling much closer to south.
  - As you go further to the poles, this changes.
    - Tropic lines - furthest point from the equator where the sun can be directly overhead.
    - So, north of the tropics - we orient our solar panels to the south.
- Quick rules of thumb:
  - Orient to true south for highest average daily gain
  - Fix panels at latitude angle for optimum annual production.
  - For seasonal adjustments: (36°, +/- 15)
- Do not underestimate environmental factors:
  - Water vapor, dust, leaves, anything that blocks sunlight
  - Amount of energy available is called solar insolation
  - Charts available, account for losses in our humid southern climate
- Do not underestimate shade:
  - You know your land - best to watch throughout the day
  - Take note of fast growing trees, etc
  - Rule of thumb: Ok if no shade between 9AM and 3PM. 6 “sun-hours”
  - Make a “solar chart”

Remote Power Applications

- Our mobile PV system: 400W solar, 40A charge controller, 12V 215 Amp/hr battery
  - Power source for automated farm tasks: Irrigation control, water storage, automatic feeders, livestock watering, environmental controls, etc
  - Field Data logging and Monitoring for research - environmental data, operate cameras
  - Provide electrical power in the field for our small DIY appliances: small heaters, blowers and pumps
  - Meet expectations as a small portable generator: operating power tools, emergency backup in greenhouses
  - Power source for greenhouse loads when not needed elsewhere

- Common applications:
  - Pumps
  - Power tools - intermittent 10A/120v
  - Block heater - 750, 1000 Watts for 1 hr?
  - Electric fences
  - Backup (AC or DC) power
When calculating loads need to know: Instantaneous load and Duration
  - **Volt** - measure of electrical potential
  - **Amp** - measure of electrical current
  - **Watt** - Volts x Amps. Measure of electrical **Power**.
  - **Watt/hr** - Electrical power over time.

Examples:
  - Block heater: 1000W for 1 hr = 1 kW/hr
  - Power tools - 7 amps, 120v = 840W. *Intermittent use.*
  - Greenhouse fan - 2 amp, 120V = 240W *cycling load* (humidistat controlled)
    - Irrigation pump - 5A, 12VDC, 4 hours/day. **240 w/hrs.**

**Modules**
- The “solar panel”, the power source
- Quality and price ranges dependent on a lot of factors.
  - Silicon crystal Mono, Poly, or Amorphous.
    - Recommended polycrystalline for most applications
  - Quality of frame, workmanship warranty
  - Power production warranty - usually something like 80% to 25 years
  - Financial standing of the company, ability to backup warranty claims
- Power output dependent on a lot of factors
  - Solar insolation: amount of available sunlight
  - Temperature: higher temperatures reduce efficiency
  - Load resistance: Module output must match load
    - 12V load requires more than 12V power supply.
    - There may be a more narrow window in which this is possible
- Our 240W/hr irrigation demand:
  - 60W instantaneous, for 4 hours. 4-6 hours sun/day available
  - Upsize module by 20% to accommodate less than ideal conditions. Actual module performance is typical 80-85% of **Standard Test Condition. (STC)**
  - When operating loads directly off a module, try to pick one that has a **MPP** close to the load demand.
    - **Voc** - Voltage at open circuit. (no load)
    - **Isc** - Current at short circuit (theoretical max load)
    - **Vmp, Imp**. - Voltage and current at power max.
    - **MPP** - intersection of voltage and amperage where module performs at peak efficiency.
  - Some loads will run at lower than rated voltage, generally not a good idea to do this for any significant amount of time. A **Linear Current Booster (LCB)** will condition power for extended working hours and prolongs life of motor by preventing low voltage stalls.
Batteries

● Batteries are typical means of electrical energy storage
  ○ Other creative ways to store potential energy… Electrical…not so much
● Think of this as the buffer, and as a means, for a limited time, to pull more power than modules generate.
● Sized by Voltage and Amp/hrs
  ○ Amp/Hrs - A measure of battery Capacity
    ■ Amps for hours. Ex. 200 amp/hr battery - 5 amps for 40 hrs.
    ■ Discharge rate. Recommendations from battery manufacturer.
      ● C/5 - capacity of batteries in 5 hrs. Would be a fast rate
      ● Battery capacity will diminish with faster discharge
      ● Depth of Discharge - max 80%.
      ● Recommended for longest battery lifespan - 50%.
      ● Rule of thumb - batteries should be sized so that capacity is twice the load.

For 12V, 5A system@ 4 hrs/day: 20AH
  Double for 50% discharge (40AH)
  Multiply for ‘days of autonomy’
  3 x 40ah - 120AH.

Series/Parallel Connections:
For both PV modules and Batteries: the way they’re connected can affect electrical characteristics. Series (in line) connections will affect Voltage. Parallel (manifolded) connections will affect Amperage, or Amp/Hrs.

○ Common battery types:
  ■ Flooded lead acid
    ● Pros - lower upfront costs, some comparatively long lifespans.
    ● Cons - maintenance, hydrogen gasses
  ■ SLA or VRLA - Valve regulated lead acid
  ■ AGM - a type of sealed lead acid battery
    ● Vibration tolerant
    ● Freeze tolerant
    ● Little maintenance
    ● More tolerant of higher charge/discharge rates
  ■ Many others: expect a big future in battery technology
○ MOST IMPORTANT when purchasing is selecting an actual true deep cycle battery.
○ Temperature compensation: High - discharges fast, lower capacity. Low - slow discharge, lower internal resistance. Maintain around 75F. Lower range OK.
Charge Controller
- Conditions power from PV modules to batteries.
- Prevents overcharge.
- Controls rate of charge for specific battery chemistry, essential for long battery life.
- Nominally sized on battery system voltage and Max input amps from PV array.
  - Our 100W module and 12V battery system
- Varying levels of sophistication.
- Efficiencies:
  - PWM - roughly 80% efficient
  - MPPT - roughly 92% efficient, generally worth the investment.

Wiring
- **Ampacity** - Maximum allowable current that a specific wire can carry
  - Based on size of conductor
  - Stranded v. solid
  - Less so, but still important: insulation type, number of wires in a conduit.
  - Very important part of the design process.
  - Wires catch on fire when they’re undersized!!!
- Overcurrent protection
  - Protects wires and components
  - Size fuses to less than ampacity
- Voltage Drop
  - Loss of power through wires, specifically in low voltage DC systems.
  - Wires must be oversized to accommodate voltage drop. (2-5%)
- Insulation type
  - USE type is typical for exposed PV wire
- MC4 connectors - Appears to be industry standard for connections between modules
  - Don’t get fooled into buying an MC tool! (I just saved you $6!)
  - Not necessary with one module systems

12V, 5A, 4 hrs/day system with 6 sun/hrs
VOC on all modules in series - **22.5V**
ISC on PV array - **5.75A**

Select a charge controller that operates in this window, upsize if future expansion is expected.

Fuse PV wires at 1.56% of Isc. **9A, (10A OK)**
Fuse between charge controller and battery at rated CC output.

Inverter
- Changes DC power generated from modules or stored in batteries into AC form.
- Varying levels of quality and expense.
  - Square Wave - clunky and inexpensive for clunky and inexpensive loads
  - Sine Wave - More expensive, higher quality AC waveform for electronics
- For these very small systems: Use DC loads when possible
  - Avoid additional expense, efficiency losses, and standby losses of AC conversion
Loads

- DC loads can pull directly off the battery, or in some cases, the charge controller.
- AC loads pull directly off the inverter.
- Multiple loads should go to load center, with breakers and fuses.

**Our PV system for a 240 w/hr load, with 3 days autonomy**

- 80W module (100W module nearly same price): $100-$150
- 120 Amp/hr deep cycle battery $150-250
- 10A mppt charge controller (92% efficient) $50
- Upsize to 20A CC for future expansion $75
- 10A fuses, #10 wire, misc electrical hardware $50-100
- 10A DC rated breaker for irrigation pump $20
- Mounting hardware $20-50

Expect $450-750 for a 100W PV with 3 days autonomy with DC load of 240 Wh/day.

**Resources**

A DIY technique using a compass for a detailed solar site analysis
http://www.builditsolar.com/SiteSurvey/site_survey.htm
https://www.youtube.com/watch?v=FG5KUlfswrc

Very cool custom sun chart builder program
http://solardat.uoregon.edu/SunChartProgram.html

Solar insolation data
http://rredc.nrel.gov/solar/pubs/redbook/

Wire sizing
A good online calculator, with metric units (need to convert to standard US AWG sizes)
Understanding code compliance for wiring PV installations
http://solarprofessional.com/articles/design-installation/code-compliant-conductor-sizing#
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