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 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
            - c/20 - capacity in 20 hrs. A nice gentle rate. Usual 'Nameplate' rating.
            - 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=FG5KUIfswrc

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)
http://www.ecoonline.com.au/sizing-calculators/solar-pv-wire-sizing-calculator
Understanding code compliance for wiring PV installations
http://solarprofessional.com/articles/design-installation/code-compliant-conductor-sizing#.WWYLpumQw2w

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