Water Pumping with PV

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Tuesday, January 19, 2016
San Diego, CA
PV-Direct Water Pumping

- PV-direct water pumps don’t need batteries or separate inverters
  - Batteries can be used to extend pumping times beyond the solar day

- 12 VDC nominal to 300 VDC PV Array
  - Varies by pump model, volume pumped per day, and other factors

- Pumps available for most water sources and applications
  - Drilled or dug wells, ponds and lakes, streams and rivers, irrigation ditches, spring catchment boxes, storage tanks or cisterns
  - Household water, irrigation, livestock, water transfer (tank-to-tank), fountains, aerators, swimming pools, and many other uses

- Some pumps require filtering, others work with turbid (dirty) water

- Use PV-direct pumps to fill storage tanks or cisterns during the day
  - The water can then be used for homes, businesses, or farms
PV-Direct Water Pumping

• Generally used to fill non-pressurized storage tanks or cisterns

• Variable flow rate depending on the time of day and available sunlight
  – Water is only pumped during the daytime

• Performance is measured in average gallons per day (gpd)
  – Average total volume delivered per day

• Storage tank typically holds several days’ worth of water
  – To carry through periods of cloudy weather

• PV-direct pumps can be used for direct irrigation
  – Assuming variable water flow is acceptable
Storage Tanks

• Store pumped water to provide for times of low sunlight, night, or higher flow rates

• Cheaper, easier, and more reliable to store water in a tank than energy in a battery
Information you need to collect:

- **Site location**
  - Latitude, climate and solar insolation data

- **What the water will be used for**
  - Drinking, irrigation, livestock, etc.

- **Seasonal water usage pattern**

- **Type of water source**
  - Well, open channel, catchment, etc.

- **Water volume provided by the source**
  - Gallons draw-able per minute and day

- **Water quality**
  - Potable/non-potable, clean/turbid, etc.

- **Total pumping head or lift**
  - Well depth or elevation difference between source and tank
What is “Head”

• **Static Head:**

  Total elevation difference between the water source and the top of the storage tank.
  
  – This is the amount of feet or meters that the pump has to lift the water
  – This is the net elevation change, **not** the pipe length to the tank
  – Static head can be measured using an altimeter, GPS device, or USGS maps

• **Dynamic Head:**

  Static head plus friction losses in the pipes
  
  – Pipe friction can be calculated using pipe loss charts, or an on-line calculator
    
    • [http://www.calculatoredge.com/mech/pipe%20friction.htm](http://www.calculatoredge.com/mech/pipe%20friction.htm)
Calculate head from the standing water level, no matter how deep the pump or water inlet is submerged in the water.
Calculating Pipe Friction Losses

- Water flowing along the inside surface of the pipe, generating friction
  - This represents a power loss that must be overcome by the pump
  - Friction loss increases with flow rate and length but decreases with pipe diameter

- Given total pipe length and flow rate, trade off pipe diameter vs. pump size

\[
\text{Pipe head loss} + \text{total static head} = \text{total dynamic head}
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Head and Pressure

- Head (feet) ÷ 2.31 = Pressure (psi)
  - Ensure that selected pipe can sustain pressure
  - Some pumps have pulse pressures up to 4X the total head in psi

- Pressure (in psi) x 2.31 = Head (in feet)
  - Static head can be measured directly by filling the pipe with water and reading pressure at the bottom of the pipeline

- Be sure to use the same units when adding static and dynamic pressure components.
Pumps Can Only Suck so Far

• “Pushing” water uphill is simply a function of pumping power

• “Pulling” water from downhill relies on atmospheric pressure (<15 psi) to “suck” water up to the pump
  - The theoretical limit is 33.9 feet (10.3 meters) at sea level
  - Any vacuum leak reduces that limit, as will higher altitudes
    • Most pumps limited to no more than 20 feet above water surface

• Any well more than a few feet deep requires a submersible pump

• Surface pumps should be as vertically close to water surface as possible
Types of PV-Direct Water Pumps

• **Surface Pumps**
  - Pump located no more than 20 feet above the water surface
    - subtract one foot for each 1,000 feet above sea level
  - Used with very shallow wells, ponds, streams, spring boxes, or storage tanks and cisterns

• **Submersible Pumps**
  - Installed below the water level, usually in a well with an output pipe that extends to the surface
  - Can pump surface water with some special design considerations

• **Jack Pumps**
  - Used for very deep wells

• **Circulation Pumps**
  - Used to move water around in a closed system
  - Solar water heating systems, hydronic heating, swimming pools, etc.
Centrifugal Pumps

- Move water by spinning it through an impeller
- Water enters in the middle and is pushed to the outside of the impeller by centrifugal force
- High volume output, but relatively low pressure (< 50 psi)
  - Multiple impellers are used in series to gain pressure
- Require high RPMs
- Many models require a linear current booster (LCB) pump controller
Diaphragm Pumps

- Uses a pulsating flexible diaphragm to pump water
- Can pump moderately dirty water
- Can run dry without damage
- Positive displacement
- Can pump water at slow speeds
- Linear current booster (LCB) required
Rotary Vane Pumps

- Moves water with a rotor similar to a paddle-wheel
- Positive-displacement
- Can pump water at slow speeds
- Heads up to 440 ft
- Linear current booster (LCB) required
- Requires very clean water or fine filtration
Piston pumps

- Moves water using a reciprocating piston
  - Similar to a piston engine

- Positive displacement

- Very rugged and reliable

- Can pump water even at slow speeds

- Linear current booster (LCB) required
Helical-Rotor pumps

- Moves water through the progressive-cavity action of a fluted rotor in a flexible stator
- Positive displacement
- High heads – up to 800 feet
- Able to handle somewhat dirty water
High Lifter pump

- Uses pressure created by gravity from descending pipeline to power mechanism
- Pumps a portion of available water further uphill to a storage tank above the water source
- Runs 24-hours a day without additional power source
- See page 231 in the 2016 AEE Solar Design Guide and catalog for further details
PV Well Pump System Design Considerations

• Total head
  – Static Head = Depth of standing water level in the well + Height from well surface to top of tank
  – Dynamic Head = Linear distance between pump and storage tank X pipe friction

• Required production (gpd)
  – Gallons used per day? Do requirements change seasonally?
  – Size storage tank to hold 3 to 4 times daily requirement
  – Requirement must be within “Recovery rate” or “yield” of the well

• Water Quality
  – Potable? Filtration or treatment required?

• Location
  – Distance from well to other potential power source
  – Solar insolation and weather conditions (cloudy, freezing?)
  – Shading issues for the PV array, if any

• Well casing diameter
  – Will selected pump fit?
Measuring Static Water Level

- Use a fishing line, weight and float with a measuring tape
- Use a two-conductor cable or coaxial cable and an ohmmeter
- Use a commercially available measuring tool
Grundfos SQFlex System

1) Grundfos SQFlex pump
2) Submersible pump cable
3) Cable ties
4) Pump support rope or cable
5) Well seal
6) PV array
7) PV array mounting structure
12) IO-50 SQFlex on/off switch box
Drawing from Ponds or Lakes
System Design Considerations

• **Total Head**
  - Vertical distance from water surface to top of storage tank
  - Linear pipe distance x friction losses

• **Required Production**
  - Area and water depth in pond or lake
  - Does the water level change seasonally?
  - How is water replenished? At what rate?
  - Lowest water level vs. pump location

• **Water quality**
  - Potable, filtration/treatment required?

• **Location**
  - Solar insolation and weather conditions (cloudy, freezing?)
  - Shading issues for the PV array, if any

• **Control Scheme**
  - Float switch, float valve with pressure switch, or directed overflow
Drawing from Streams or Rivers
System Design Considerations

• **Total Head**
  - Vertical distance from water surface to top of storage tank
  - Linear pipe distance x friction losses

• **Required Production**
  - Stream width, depth and flow rate
  - Does the water level change seasonally?
  - Can water be diverted from its course to a special pumping point?

• **Water Quality**
  - Potable? Filtration or treatment required?
  - Turbidity, sand and silt
  - Debris - Intake clogging issues

• **Location**
  - Solar insolation and weather conditions (cloudy, freezing?)
  - Shading issues for the PV array, if any

• **Control Scheme**
  - Float switch, float valve with pressure switch or directed overflow
Drawing from Tanks or Cisterns
System Design Considerations

• Total Head
  – Vertical distance from bottom of source tank/cistern to top of secondary storage tank
  – Linear pipe distance between tanks
  – Is secondary tank pressurized?

• Required Production
  – Source tank capacity (gallons)
  – Method and rate of water replenishment

• Water Quality
  – Potable? Filtration or treatment required?
  – Is source pre-filtered or settled?

• Location
  – Solar insolation and weather conditions (cloudy, freezing?)
  – Shading issues for the PV array, if any

• Control Scheme
  – “Pump-down” switch in source tank to prevent dry running
  – “Pump-up” switch in secondary storage tank to turn pump off to prevent overflow
PV-Direct Pump Systems
Array Sizing

- Nameplate array size should be at least 20% greater than rated power draw of pump
  - Oversizing the PV array increases daily production (gpd)
    - A 1.2 kW array will run a 1 kW pump at full speed from ~10 AM to 2 PM
    - A 2 kW array will run a 1 kW pump at full speed almost the entire day
  - The pump will only draw the power that it needs, regardless of how much power is available from the PV array
    - Be careful to keep array voltage within prescribed limits!

- Consider seasonal variation
  - Reduced solar resource at winter solstice
  - Greater water requirements are common in Summer

- Size pump controller or linear current booster (LCB) to rated current draw of pump, not the total array current
Sun-Tracking PV mounts can increase total daily pumping volume by up to 50% in the summer.
Example #1:
PV-Direct well pumping system

Residential water system with gravity flow from storage tank to house

- 200 ft deep well with 6” casing
- Static water level at 100 ft below ground
- Well produces about 20 gpm
- Storage tank located 100 ft above wellhead
- Total static head equals 200 ft
- Minimum daily water requirement in the winter is 1500 gpd
- Minimum daily water requirement in the summer is 3000 gpd
- Domestic and irrigation usage
- Storage tank located uphill providing enough water pressure
- Clean water
- Site receives about 3 kWh/m² in the winter and 6 kWh/m² in the summer
# Grundfos SQFlex Submersible Pump Selection Chart

## Module watts

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<td>750 W</td>
<td>1,000 W</td>
<td>1,250 W</td>
<td>1,500 W</td>
<td>1,750 W</td>
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### Notes

- [Grundfos SQFlex pump chart](http://www.grundfos-pumps.com)
Example #1: PV-Direct well pumping system

Correct chart gpd amounts to reflect the site’s insolation

• Chart shows 11 SQF-2 pump delivers ~4237 gpd with 7.8 peak sun-hours
  - To convert to the 6 peak sun-hour summer figure:
    • 4,237 gpd ÷ 7.8 = 543 gallons per peak sun hour
    • 543 gallons x 6 peak sun-hours = 3,259 gpd average in summer

• Chart shows 11 SQF-2 pump delivers ~3015 gpd with 4.7 peak sun-hours
  - To convert to the 3 peak sun-hour winter figure:
    • 3015 gpd ÷ 4.7 = 641 gallons per peak sun hour
    • 641 gallons x 3 peak sun-hours = 1923 gpd average in winter

• Conclusion: 11 SQF-2 with four 250 W PV modules provides minimum summer requirement of 3,000 gpd and winter requirement of 1500 gpd
Example #1: PV-Direct well pumping system

- A 4-module PV array should provide sufficient water delivery
  - 5 or 6 modules would provide more reliable performance

- Top-of-pole PV mounts are a good choice for pumping systems, but other mounts can be used

- Place pump 15-20 ft above well bottom
  - Provide settling space for sediment
  - Pump should be set at 170-180 ft level in the well

- Use 12 AWG pump cable for lengths up to 200 ft and with PV arrays of 4 or more modules in series
  - Use 10 AWG pump cable for deeper wells or systems with fewer modules in series (lower voltage)

- Use Grundfos CU200 control with a float switch in the storage tank for overflow prevention
Example #1: PV-Direct well pumping system

Equipment:

- Grundfos 11 SQF-2 pump 075-01018
- Grundfos CU200 controller 075-01033
- Grundfos Float Switch 075-01042
- 180 ft of #12/2 with ground 050-01635
- Underwater splice kit 075-00130
- Heat shrink tubing – 1” x 6” piece 051-01137-B
- Two-conductor wire for float switch 050-01151
  - Long enough to reach from well to storage tank. Shielded cable is recommended to reduce the chance of lightning surges
- 4 to 6 standard 60-cell PV modules
- Module mounting hardware
- PV output cable long enough to connect PV array to CU200 control
- Grounding system
- Optional: Add IO-101 control if a generator is to be used as an AC backup power source
Example #1: PV-Direct well pumping system

**Additional materials**

- Pump safety rope
  - Stainless steel cable or polypropylene rope (not nylon or polyethylene)

- Pipe and plumbing fittings

- Well seal

- Perimeter fencing
  - To protect children, wildlife, or livestock

- Foundation or structure for PV mount

- Hoist or crane to lower pump, piping and cable into well

- UV-hardened Plastic zip-ties to attach drop cable to drop pipe
Example #2: Livestock Watering System

Filling a stock tank for cattle or horses

- Water requirement – 300 gpd in summer; less in winter
- 120 ft deep well with static water level at 70 ft
- Open pasture with excellent sunlight access
- Stock tank at same elevation as wellhead

- Aquatec SWP-4000 submersible diaphragm pump will easily supply enough water delivery with a single 250-270 W PV module
Example #2: Livestock Watering System

Equipment BOM

- Aquatec SWP pump 075-04850
- Aquatec APC-30-250 075-04895  
  - LCB and Pump controller
- 100 ft of Pump cable 050-01639  
  - 10 AWG 2-conductor without ground
- Underwater splice kit 075-00130
- Float switch 075-05270
- Wire for float switch 050-01151  
  - Long enough to connect pump controller to float switch in stock tank
- Single 250-270 W PV module
- Module mounting system
- PV output cable  
  - Long enough to connect PV module to pump controller
- Pump safety rope
- UV-hardened Zip-ties
- Pipe and plumbing fittings
Thank you for attending!

Questions?