Off-grid Lifestyle, Arizona Desert

Being responsible for your own electric generation adds a level of maintenance and conservation that one doesn’t have on-grid. Power conservation means limiting peak power and total kilowatt hours consumed at night.

Most people on-grid have 200 amp service, hence 200*220 = 44Kw of available power. One solution to the required conservation rules would be to expand your own power system to 2o Kw or approximately 100 amp service. But here we currently have 6kW which means only 27 amps at 220V, or only 13.5% of a normal on-grid service.

People mistakenly think that if you have solar power you essentially have free electricity. However, one must amortize the cost of all components of the system over their expected lifetimes.

Electric Conservation as a New Normal

With both limited peak power and limited stored power you need to practice some conservation measures in keeping with the performance parameters of your power system.

We have a simple policy. On significant power device at a time. But one could build a table of significant power consuming devices and which phase (which inverter) they load. Then one can plan their use accordingly. We adopted a fairly simple rule. Only run 1 major appliance at a time. Those major appliances include the well, the pool pump, A/C or heat pump, and microwave oven. Check the current draw for other devices to be considered in this restricted use. The 220 V devices divide the load between inverters. Many devices have variable current draw and others are constant. Pool pumps and well pumps generally draw steady amounts of power. But A/C, heat pumps, water pressure pumps can suddenly change. So one must power budget with this in mind.

One wants to minimize power use at night. Setting the thermostat higher in summer or using the evaporative cooler will reduce night time use. One should not run the heat pump at night as it can cause the generator to start even when the batteries actually have a significant charge. It is best to use the propane heater for winter nights and even winter days.

So there are 2 sets of rules. One set is followed to avoid equipment damage. The other set is to minimize cost of operation.

Damage Prevention

While the inverters can support short duration of 2x the rated current, and they have built-in cut-off breakers, one should not count on those being a safe way to prevent damage to the inverter. We had a shorted evaporative cooler motor draw excessive current and caused permanent failure of an inverter. We were slow to identify what was happening and failed to simply cut off power to that circuit. So the rule to follow is at any sign of abnormal power behavior, start switching off breakers (or other power switches) to isolate the failure.

The other area of damage prevention pertains to the batteries. The primary damage comes from doing things that can dramatically shorten the battery life. This includes over-charging and over-discharging.

The primary methods to prevent overcharging is to disconnect half of the solar field at least during peak sunlight hours or to run a power consuming device such as the pool pump during peak sunlight hours. When we had drained the pool and did not run the pool pump, we ran for weeks with only half the solar panels without running the generator. On cloudy days we would reconnect the full solar field.

Over-discharging is generally prevented by making sure the generator is enabled to start when battery voltage drops. If the generator fails, the inverter will shut down when voltage drops too far. One must not be running a 220V appliance when this happens or the appliance may suffer a failure from only one phase being supplied. We have never had a problem with this because the generator has always worked. The key to this was using the proper starter. We had used some cheap ones and they failed. Fortunately we never discharged the batteries as we never used much power at night when the discharge would occur. Once we used the John Deere recommended starter, it has never failed to start the generator in the past 2 years.

Power Cost Reduction

The average Tucson household pays about $0.17 per kWh. The average bill is about $280/mo (53% above national average). That translates to 1650 kWh or about 55 kWh per day. We used an average of 40kWh/day.

Cost is estimated by the lifespan of batteries and fuel consumed. 36 batteries * $350 cost per battery with 5 yrs battery life = $210/mo. Amortization of inverter and solar panels over their lives is about $40/mo. I don’t know what the generator amortization would be.

Fuel consumed by the generator is about 200 gal/yr @ $5/gal = $85/mo. That’s a total of $335/month for electric. This does not include the propane used for hot water and supplemental heating of about 400 gal/yr at $3 which is $100/mo.

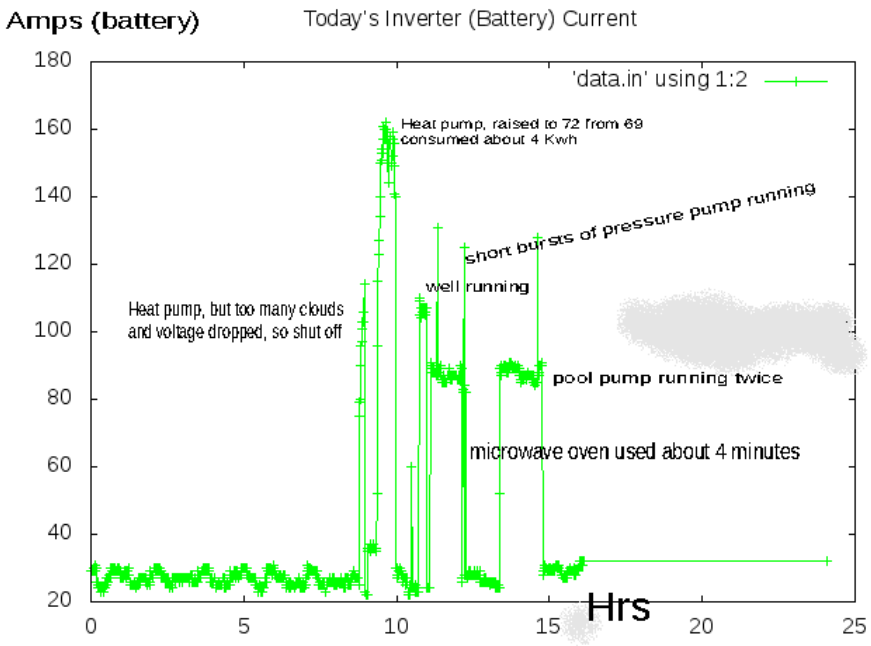
This cost figure could be double if lifestyle changes are not adopted. More aggressive conservation measures could reduce the total to $250/mo or less.

The life of the battery is primarily affected by the number of charge/discharge cycles, the depth of discharge, overcharging and the battery temperature. So one approach to reduce electricity cost is to put the batteries in a temperature controlled environment. One can employ charge controllers to prevent overcharging. Another is to reduce the number or depth of charge/discharge cycles.

Ways to decrease depth of discharge by reducing night time power consumption:

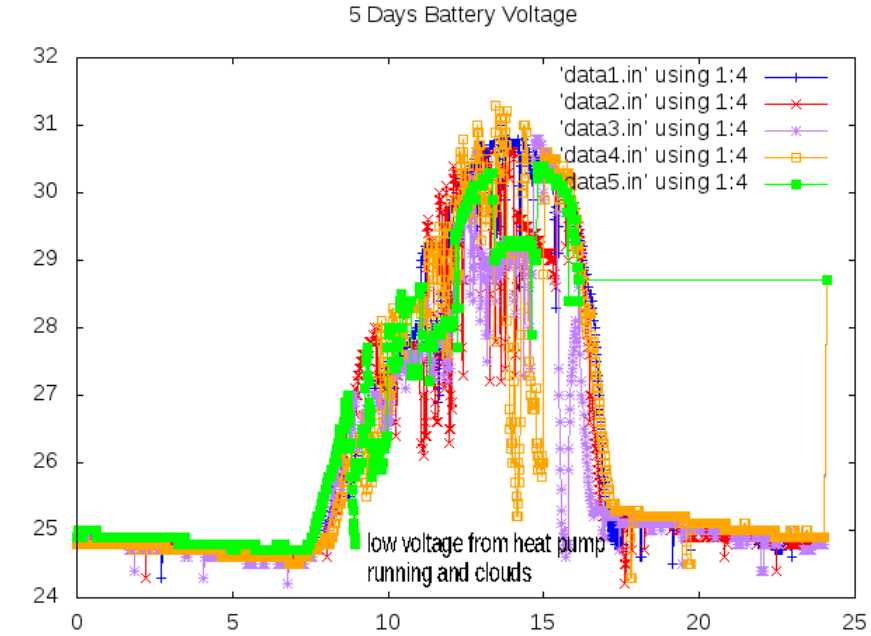
1. Set thermostat to higher temp at night in summer.
2. Use evaporative cooler instead of A/C when humidity is not too high.
3. Use the propane heater in the winter instead of the heat pump and set the fan to ‘on’ so the heat gets distributed throughout the house.

Snapshot of power system status taken at 4pm 11/28/2023

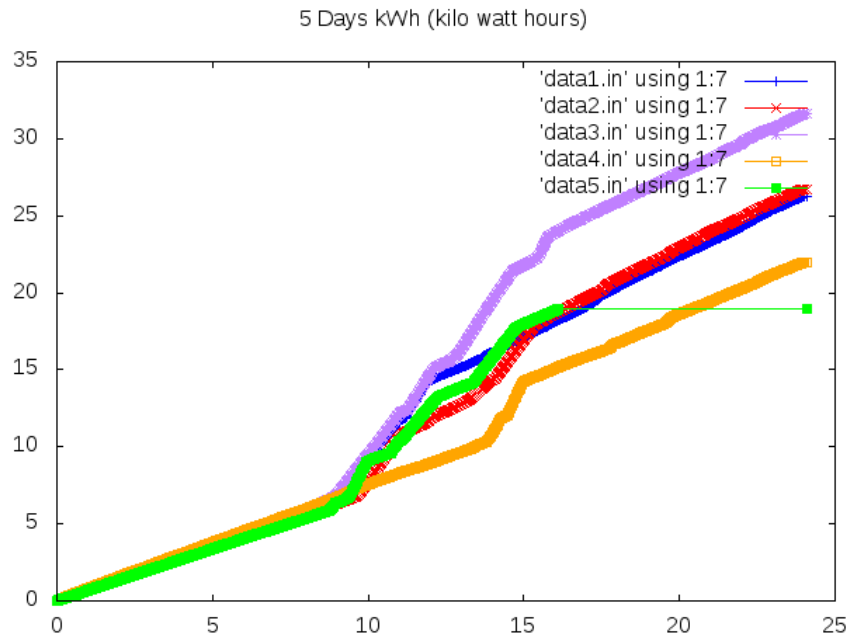


In this example, the heat pump was turned on about 9 am. It was a bit cloudy and the battery voltage dropped (figure below) So it was turned off until the clouds cleared. This shows about 3 Kwh of power used in about 1 hr drawing 130 Amps (24 volts) This raised the house temperature from 69 to 72 degrees while it was about 70 degrees outside.

The next pulse at 100 for 30 minutes was the well pump running. The following 2 pulses at about 90 were the swimming pool pump. The narrow spikes while the pool pump was running was from the water pressure pump running.



The heat pump high current draw pulled the battery voltage down. Had this occurred when the battery was around 25V it would have drawn it below the generator starting threshhold of 22.9 V. This is why it is not recommended to run the heat pump at night. This is why central air is not a good solution for off-grid. It may be possible that certain configuration settings can be found to avoid this. We found settings to prevent the air conditioning from doing this but were unable to find out how to make the heat pump operate on less power.



Power is stored in batteries in Kwh. Mathematically, 36 L16 batteries should offer 40Kwh but we generally don't see anywhere near that. The battery discharge from about 1 hr before sunset to 1 hr after sunrise shows about 10-20 Kwh are drained. The high end is when we run the evaporative cooler or A/C overnight in summer. We use propane heat in winter, usually just January and February.

Power System Enhancement Options

The best overall solution to the power system is to replace it with a more modern 48V system which would have lower operating costs. Lithium Iron Phosphate batteries last much longer and have more energy per pound than lead acid batteries and don't have to have water added or terminals cleaned. But they do need temperature control to preserve their advantages. We considered putting the power system in the pantry where it would be temperature controlled and a short distance to the house breaker panel.

But there are incremental improvements that can be applied to the existing system.

A higher power inverter can solve the maximum load constraints (one would likely still have some restrictions, but just being able to run 2 major appliances at a time makes things easier. We put a 10KW 220V inverter in the power shed that can be wired into the system. I would recommend keeping both in play with switches/breakers or other means so that if one fails there is a readily available back up system. Or one could use the original system to supply the well or pool or an RV site.

One could add charge controllers which could require rewiring the solar panels into higher voltage series connections as opposed to the current configuration where all solar panels are in parallel. But there are 7 pairs of wires coming from the solar field. One could

create a series string of 4 and another of 2 if one finds adequate 24V charge controllers. This solves the manual intervention of protecting overcharging by either disconnecting solar panels with the knife switches or by setting the pool timer to run the pool during peak power hours, say 1pm to 3pm.

Another improvement we considered was to create a separate power system for the pool with its own solar panels and inverter. This would use minimal battery support and simply turn the pool on when the solar panels had enough voltage and shut it off when the voltage fell too low. Then the pool power consumption would have no effect on the house power and could filter the water more hours in the day than the present arrangement. The one drawback is that the pool would no longer be available to help prevent overcharging of the batteries, so the charge controller upgrade should accompany a pool solar system. An alternative to using an inverter would be to use a DC pump and just drive it from the solar panels. This solution generally requires the use of a robotic pool sweeper and I am not sure if the DC pump would backwash the filter properly.

A better shade for the batteries could reduce their heating. A canopy or even just another hanging shade as we did on the south end of the power shed.

Another improvement would be to replace central air with mini-splits. These are usually DC motor based for very off-grid friendly performance. And without duct work they are more efficient. It would then be reasonable to use the heat pump mode to heat the bedrooms overnight.

Conclusion

While it may seem the conservation steps are a burden, they eventually just become routine. That is part of the reason we never got around to installing other upgrades. The routine just became normal to us.