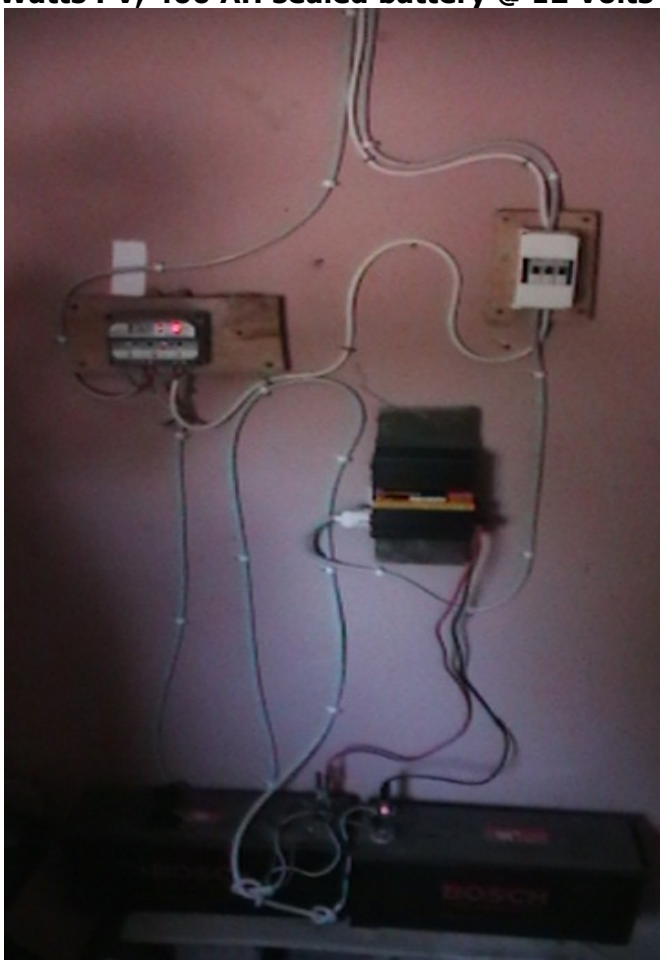
"Spaghetti Solar"
A photographic survey of African off grid PV systems

Eric Youngren
Solar Nexus International
March 2009

One of the goals of my recent trip to Africa was to assess the current state of off-grid electric technology use in Africa, with an eye towards developing new markets for Solar Nexus International. During my travels through Guinea Bissau, Tanzania and Uganda I tried to seek out and document as many existing PV systems as possible. I was hoping to make it an informal 'survey' of the currently operating systems. Whenever I saw PV panels on a roof or a rack I'd ask to see the batteries and the rest of the system. It was by no means comprehensive nor scientific (rating #'s are approximate) , but I did get to see a bunch of systems and developed a general impression on the state of the residential PV industry in Africa. I took some pictures and tried to document what I saw in terms of the quality of systems that are currently being installed and utilized in the countries I visited.

System #1 - ~300 Watts PV, 400 AH sealed battery @ 12 Volts



12V PV system in Canchungo, Guinea Bissau

This system is powering a small office that is used by Christian groups working to translate the New Testament into local tribal languages. They are running a few laptops for 5 to 8 hours per day and 3-4 lights for several hours in the evening. They had around 300 Watts

of various types of PVs on the roof. This is the first system that I got to see and it had several of the shortcomings that I saw in almost all of the systems that I saw in Africa.

Specifically:

- No fuses or circuit breakers on any battery-connected circuits (charge controller or inverter)
- Undersized PV array wire (approx #12AWG on 30 ft. run with over 20 Amps of current)
- Battery connection with inappropriate materials (no lugs or proper terminals)
- Sloppy, unsecured and unprotected wiring
- The PV array is too small to fully supply the desired electric load
- Inadequate supporting documentation or educational materials – system operators don't understand operations/maintenance requirements

System #2 – ~1200 Watts PV, ~800 AH flooded battery @ 24 Volts
System #3 – ~500 Watts PV, ~600AH flooded battery @ 24 Volts

24V systems at a national park office in Guinea Bissau

This system is an a national park office in Guinea Bissau. Actually there are two systems operating in parallel. Together they run lighting, a computer, cellphone charging and substantial water pumping. It was 'professionally installed' and one of only two 24 Volt systems that I saw in Africa. The park rangers had a basic understanding of the system and had established a good procedure for re-filling the flooded batteries with distilled water (though it was not clear if was really distilled water, or just the same bottle reused and refilled with well water). It did have a main battery fuse and the array wire looked adequately sized, but as you can see the wiring is still a mess.

System #4 - ~500 Watts PV, 600 AH sealed battery @ 12 Volts

Another 'professionally installed' system in a national park, this one in Uganda. This system seems adequately sized for the application and the main components are good, they have around 500 Watts of PV on the roof, 600 Amp-Hours of sealed '8D' style deep-cycle batteries and good quality PV charge controllers and inverter/charger. But once again the problem is with the 'balance of systems', how the components are connected together: no circuit protection (fuses or circuit breakers), undersized PV array wires, wiring on the wall was reasonably well secured but not tidy and the wires at the batteries are a mess. These 12V batteries were at 10.5V at 9:00 am. The rangers told me that the lights would work in the afternoon and then go off after a few hours in the evening. The lighting is 12 VDC running off the ProStar 30M charge/load controllers. The system was in a state of

'low voltage disconnect' (LVD) when I saw it. What probably happens is that during the day the PVs charge the batteries up to a high enough voltage to turn on the load controller, but not fully recharge them. Then the lights are used until the LVD turns them off. The inverter has a lower LVD setting and remains on 24/7, running a power strip with several cellphone chargers always plugged in. This has resulted in a chronic undercharging situation where the batteries are never fully recharged and regularly hover around the LVD setting. This is a recipe for disaster and explains why these 2 year old batteries are already wasted.
The rangers had very little understanding of what they should be looking for nor how to best use the system. I suggested they leave the lights off and connect a generator to the inverter/charger to try to rehabilitate the batteries as much as possible. There was no generator input wiring connected to the inverter/charger so they had no easy way to connect a portable generator to top off the batteries. All they need is some extension cord wire and a male plug to hook up a generator once a week to give those batteries a good full topping charge, that would really help those poor batteries.

System #5 - ~300 Watts PV, ~900 AH flooded battery @ 12 Volts

Tourist lodge lighting system

This system is running a tourist lodge inside Kibale National Park in Uganda, primarily lighting loads, but all the cabins and tents have AC receptacles so tourists are probably also using battery chargers and small electronics. The biggest problem I see here is that these flooded batteries are not accessible for maintenance, there is no way to check the water level nor add water to the bottom row of batteries. Additionally, the battery cables don't have proper lugs or terminals, the inverter is not fused, the wiring is a mess and the whole package is cramped in the too-small space.
This system is also drawn down to its LVD settings almost daily. There is no external metering or battery health indicators for the lodge employees to monitor and they have little understanding of how to operate or maintain the system.

Additionally, the guests at the lodge are given complete access to 240VAC power without any special instructions about the limited nature of their electricity supply. Many people (Westerners especially) are so clueless about energy conservation that I could see people leaving their bathroom or outside lights on all day and night without realizing the consequences.

System #6 - ~400 Watts PV, ~200 AH sealed battery @ 12 Volts

This battery helps to run a 12V deep-freezer at the same lodge as above. This is a load that is well matched to its dedicated PV array and I don't see any real performance problems with the system, the battery is being well cared for. As long as no new loads are added it should run the freezer for many years. Personally I think the buffalo skull is a nice touch, and the VRLA sealed battery does not need maintenance so it does no harm sitting there. Still, not exactly 'professional grade' looking installation, some fuses and a meter would be good improvements.

System #7 – ~650 Watts PV, ~400 AH sealed battery @ 12 Volts

Satellite internet cafe system

PV array, rainwater catchment, VSAT dish

Nicest quality system I saw in Africa. But I'm not sure why the controller wires are twisted and dangling like that. It looks like a phone handset cord, or as if the controller was going to bungee jump off the wall. Runs an satellite internet cafe at Queen Elizabeth National Park, Uganda. It was the fastest internet connection I found during the whole trip. We watched some of my YouTube videos.

System #8 - ~200W PV, ~600 AH sealed battery @ 12 Volts

Tourist lodge near Queen Elizabeth N.P. Same problems: no fuses, no meters, no battery lugs, undersized PV array wire, regular LVD load control and little O&M understanding by system users. This system is chronically undercharged, they need to reduce their load with better conservation and efficiency measures and also increase the PV array. I suggested a timer or remote switch for all the loads, so they only provide power for a few set hours per day. That could help elminate the problem of lights being left on all day and night. Another PV module or two would be really good too, especially with the ongoing expansion of the lodge and increasing lighting requirements.

These next four pictures are all from a rural office in Tanzania run by a large international development aid organization, they have 3 systems of different ages operating in parallel.

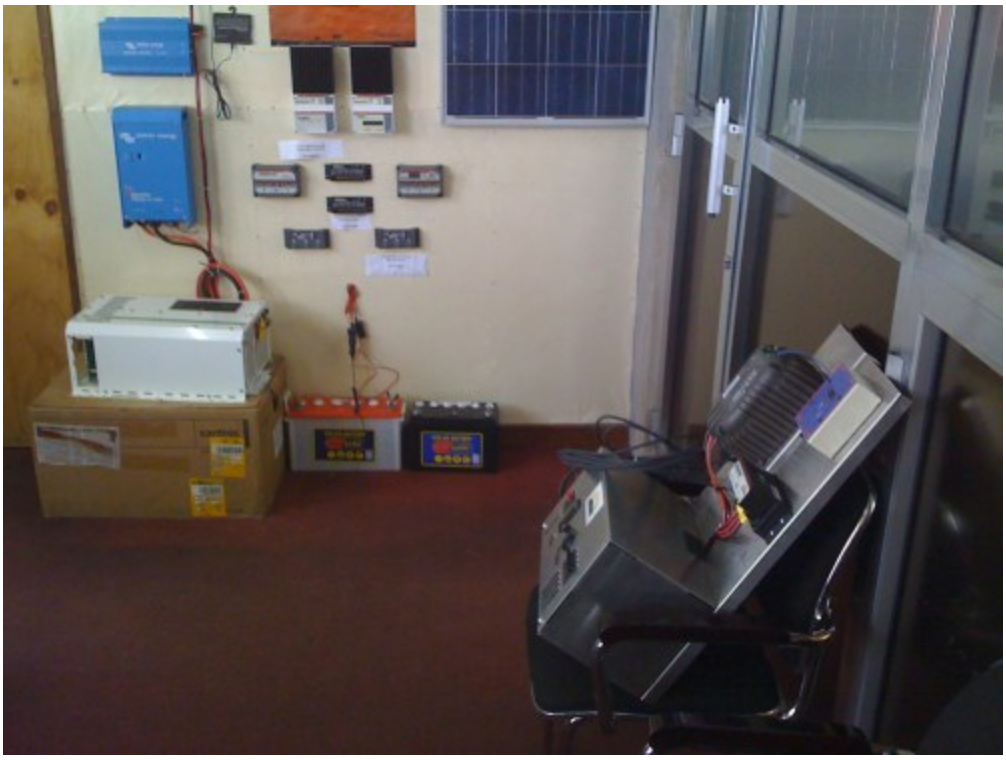
System #9 - ~480 Watts PV, ~400 AH sealed battery @ 24 Volts
System #10 - ~160 Watts PV, ~200 AH sealed battery @ 12 Volts
System #11 - ~100 Watts PV, ~150 AH sealed battery @ 12 Volts

Rural office in Tanzania

This 'professionally installed' system in a remote Tanzanian village runs a medium sized office including 3 desktop computers with LCD monitors, occasional additional laptops, two printers, a VSAT satellite internet system and 6 to 10 lights for several hours each night. They are running at a regular energy deficit, with the average baseload of the office exceeding the charging capacity of the PV array.

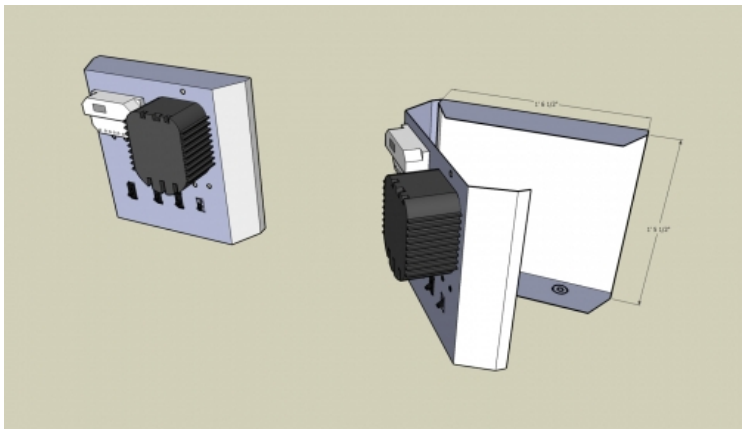
There are actually 3 different systems running here in parallel. The have the same problems as the others: no fuses, no meters, undersized wires, inappropriate terminals and generally sloppy looking wiring. Most of the loads were on the biggest system, with about 500 Watts of PV on a 400 AH battery @ 24 Volts. The 24V system was at 23 Volts in the middle of a bright sunny African afternoon. The PV array was producing about 18 amps and the loads were consuming around 26 amps. While the office is occupied this load is fairly constant. It was a little cloudy when I was there so they might see a bit over 20 amps with better sun, but that is just not enough to keep up with the load. The office is

closed on the weekend, and it seems that is the only time the batteries get close to a full charge. They need more PVs and some metering so they can take better care of the batteries. There was no way for them to read the battery voltage at all. That is bare minimum essential equipment in my opinion.
Also, the 24V system has a good DR inverter/charger that could really help those batteries with an occasional recharge from a portable generator but there was no AC input wiring connected to it. Just like in Uganda, all they need is an extension cord and a plug and they would be able fully recharge the batteries occasionally until they can get more PVs installed. As it currently is running I don't think the batteries will last more than a year.
The last picture showing the modules on the roof is a really extreme example of something I saw pretty often. The installers are reluctant to cut wires and cables to the proper length! They often leave huge loops or coils of excess wire. In a 12V PV charging circuit, this practice, along with undersized wires, results in unfortunate and avoidable power loss through voltage drop. Wire is cheap compared to PV modules and batteries. Don't choke out your array with wires too small and too long!



SolarNexus v1.0 prototype at Ensol Ltd office in Dar Es Salaam, Tanzania

Okay, have I convinced you that the solar electric industry in Africa could use improvement? How do I propose we do it, you ask? Well, one solution will hopefully be the SolarNexus, the new off-grid electric system product from Solar Nexus International. I took a prototype version of the Nexus over to Tanzania and showed it around to solar dealers and prospective end-users. People liked it. They see the obvious value of an integrated package that includes pre-wired circuit protection, high quality electronics and metering. On the plane ride home I came up with the next design iteration:



SketchUp model of SolarNexus v2.0

Sunrise over Guinea Bissau

The sun rising over the Atlantic Ocean in Guinea Bissau is a great image to sum up the potential of solar electricity in Africa. They have the resource – there is plenty of sunshine. They have the need – over 500 million people without access to electricity. They have the desire, and solar electricity could bring many significant improvements to the quality of life, education and health care across the continent. What they need is improved, simplified systems and education on how to care for them. Solar Nexus International is committed to solar empowerment for the planet. Our goal is to supply products and services for high quality off-grid PV system installations to people around the world.

About the author:
Eric Youngren is a NABCEP certified Solar PV Installer and off-grid system specialist based on Orcas Island, Washington State, USA. He is president and founder of Solar Nexus International, a value adding distributor of battery based solar electric systems and equipment for markets worldwide. He can be reached at:
eric@solarnexusinternational.com

This article was originally published on Eric's blog at:
www.islandenergysystems.wordpress.com