Trials & Tribulations of Self-Generation

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We recently retired to a remote location in Nevada to enjoy the later years of our life. It is 85 miles (140 km) to the nearest town and 230 miles (370 km) to any city. One of the reasons Donna and I chose this location was the availability of wind, sun, water, and land.

I was a reactor operator in the Navy (submarines), a commercial power plant operator (coal, gas, nuclear), and was eventually a vice president in Silicon Valley integrated circuit manufacturing companies, with an education in physics. I thought I had a reasonable background to easily start building my own electric generation capability.

My primary motivation in building this system was the satisfaction of generating my own energy. This article will recount some of the lessons I learned. Some of these were because I was much more ignorant than I originally thought. Others were because of some improvements that are needed in the renewable energy industry.

In general, I have found the equipment in this industry to be well made, and the technical support to be excellent. Unfortunately, the equipment documentation for installation, operation, and troubleshooting varies from poor to terrible. As a first-time installer, my expectations were that the documentation would allow me to easily and quickly install and troubleshoot equipment. This was not the case.

Fortunately, our local general contractor (and all-around good person to do nearly anything) is quite ingenious when putting things together. But often we had to discuss various alternatives in order to choose what was the most practical.

System Description

We purchased a seventeen-acre property with seven existing buildings on it, and built two more buildings at some distance apart. Since the existing buildings were wired for AC already, it made sense to continue using AC distribution and equipment. For ease of operation and due to availability, we planned only to install new items that are AC powered. We would need 240 VAC, 60 Hz inverters to power critical loads like water pumps, electronics, active solar heating, and elevator, which I need because of my disability. (I have muscular dystrophy, a genetic, degenerative neuromuscular disorder for which there is no treatment or cure. But I have not let that stop me.)

We are tied to the grid, but had been told there would be frequent and lengthy blackouts. This meant that the battery bank should be large. Since we had both wind and sun, we set up the system to use both. Combined rated output of the solar and wind electric systems is about 15 KW, but actual usable output is less.

We built our first garage for our existing vehicles and to contain a power room, sized for the initial system setup. The initial garage became too small for our needs, so we added another garage. We also found that we needed more energy.

We decided to add a second system in the second garage, because the line runs were shorter, which meant less trenching and power loss. We built power rooms in each garage to house the batteries, power panels, and breaker boxes. Both the power rooms are insulated and heated to help with the cold. The battery boxes are insulated enclosures inside each power room.

The local electrical cooperative did not understand why we wanted to generate our own electricity, given the 5.9 cents per KWH price of electricity then. But they worked with us anyway. They had no experience with home generation, but followed the Public Utility Regulatory Policies Act (PURPA) and other regulations.

Nevada passed net metering legislation in 1997. But we could not convince the utility to use our original bidirectional meter. We had to purchase a two-channel meter that tracks both grid and RE generated electricity separately. The meter has proven very useful to us to track our energy usage. But the cooperative now wishes that they had stuck with the original meter, because of the additional paperwork to record and bill for both buy and sell.

Wind & Sun

The first system combines PVs with a World Power H4500 wind generator. The turbine has a rotor diameter of 15 feet (4.6 m) and was rated at 4,500 W at 25 mph (11 m/s). In a 10 mph (4.5 m/s) average wind regime, it should produce about 325 KWH per month. This turbine is no longer manufactured. The wind generator's output is 240 volt, 3-phase variable frequency that is transformed and rectified to 48 VDC using a Whisper EZ-Wire Center.

Thirty-two Kyocera 120 watt solar-electric panels complement the wind generator's energy production. PV output is regulated by two Trace C40 charge controllers. We opted for a Trace Power Panel containing two SW4048 inverters, two C40 charge controllers, and all DC breakers for overcurrent protection. The panel is prewired, which made installation simple. This system has a 48 VDC input. The two inverters are wired in series to produce 60 Hz, 120/240 VAC output.

After some initial difficulties, the modified World Power Whisper H4500 is a viable addition to the system.

The battery bank is made up of eight Concorde Sun XTender PVX-12105, 12 VDC batteries (210 AH total at 48 VDC). The batteries are wired in two series strings of four batteries each. The two series strings are then wired in parallel.

The second system is similar, except that the wind generator has been replaced with 32 additional Kyocera 120 watt solar-electric panels. This system uses Wattsun dual-axis PV trackers instead of fixed mounts, and one series string of batteries.

Thirty-two of the ninety-six PV panels are on stationary mounts.

Wind Generator Issues

Since we are in a windy area (class 5 or 6 on the map), a wind generator makes good sense. Traditional water-pumping windmills are still present in the valley. We purchased a World Power H4500 wind generator with a 70 foot (21 m) tower kit. The first problem was figuring out how to install the tower in our sandy soil.

Fortunately, a retired civil engineer lived nearby. He suggested that the guy wires should be attached to steel rods embedded in concrete. He specified a pyramid (tetrahedron) 6 feet by 6 feet (1.8 x 1.8 m) on bottom, 3 feet by 3 feet (0.9 x 0.9 m) at the top, and about 6 feet (1.8 m) deep. Each pyramid contains more than 5 cubic yards (3.8 m^3) of concrete for the four, guy wire pedestals and the center support pedestal.

The Whisper H4500 manual gave no instruction about the tower other than to consult a civil engineer. The manual should have contained more general information on approximately what support system is required for various tower heights and soil conditions. Why is this important? Putting the concrete in and getting the schedule 40 pipe cost nearly the same as the wind generator.

Using the tables from the *National Electric Code (NEC),* we calculated that #12 (3.3 mm^2) wire was required to run the 300 feet (91 m) from the wind generator to the power room. This seemed undersized to me, so I used #6 (13.3 mm^3) wire, just to be safe. Given the complexity of the *NEC* tables, the installation manual should have included a table for the specific wind generator, by power output, voltage, and amps per phase, listing what gauge wire should be used for the length of the run from the wind generator.

Various tests must be performed before installing the wind generator. These tests even had to be repeated after getting repairs on the generator at the factory. As noted previously, the H4500 had many design and material problems, and we experienced them all. World Power (later bought by Southwest Windpower) has been most cooperative in the repairs. After repairs, the wind generator is essentially derated to a 3000 watt wind machine (plus a little).

Photovoltaic Issues

Photovoltaic panels are much easier to install than a wind generator, although the cost per watt is still higher. The construction cost for schedule 40 pipe, concrete, etc. is still significant for a PV mount. Trackers can be a worthwhile investment, because over time, the increased output can more than recover the initial cost of the tracker.

Sandy soil necessitated large concrete footings for the 70 foot tall tilt-up tower.

The Whisper EZ-Wire Center, step-down transformer, and diversion load heater box in the power room.

Sweetman Load Estimates

Year Round Loads			
Load	*Watts*	*Hours/Week*	*KWH/Week*
Pool cleaning & circulation	2,000	35	70
Electric gate	2,000	10	20
Vehicle battery chargers	100	150	15
Entertainment (TV, stereo, radio)	500	20	10
Battery chargers (tools, shavers, etc.)	200	50	10
Computers	400	20	8
Communications (phones)	100	10	1
		Total Year Round	134
Summer Loads			
Well pumps (home & irrigation)	3,000	56	168
Cooling (fans, coolers)	3,000	49	147
Lights (mostly fluorescent)	1,000	100	100
Utility cart chargers	1,000	42	42
Power tools	2,000	20	40
Solar heating pumps	300	63	19
Elevator	1,500	10	15
Cooking (microwave, oven, cooktop)	1,500	10	15
Appliances (freezers, refrigerators, etc.)	1,000	10	10
Washing (washer, dryer, dishwasher)	1,000	10	10
		Total Summer Loads	566
		Total Summer Plus Year Round	700
Winter Loads			
Heating (fans, heat pump)	4,000	50	200
Lights (mostly fluorescent)	1,000	150	150
Well pumps (home & irrigation)	3,000	14	42
Cooking (microwave, oven, cooktop)	1,500	20	30
Solar heating pumps	500	42	21
Elevator	1,500	10	15
Power tools	2,000	5	10
Appliances (freezers, refrigerators, etc.)	1,000	5	5
Utility cart chargers	1,000	5	5
Washing (washer, dryer, dishwasher)	1,000	5	5
		Total Winter Loads	483
		Total Winter Plus Year Round	617

We used #1 (42 mm^2) copper wire to carry the approximately 30 amps per subarray of sixteen panels the 200 feet (61 m) to the power room. It would have greatly simplified the installation to have a chart in the documentation for wire sizing for the distance, voltage, and amps.

The combiner boxes had to be put together, but there were minimal instructions and recommendations for materials or components. Using the correct size of components for voltage and current requires numerous calculations and comparisons of specifications. There is also the difficulty of getting all the components to mechanically fit together.

Battery Issues

The batteries were the most frustrating and expensive component to work with. My first error was miscalculating the total battery backup that would be required. I seriously overestimated the amount. The reality is that the local grid is rarely down, and then only for short periods of time.

I originally used eight, large, 425 amp-hour, 465 pound (210 kg), lead-acid batteries in two, 48 volt banks. We eventually found out that these required frequent (quarterly or more) addition of distilled water and regular equalization. Since we were away from home a lot, we did not meet the necessary battery watering schedule. After a little over three years of operation, the batteries died and had to be replaced.

We now use maintenance free batteries. I also contacted the battery manufacturer to get detailed instructions on operation and maintenance. Using the correct bulk and float voltage set points is critical for long battery life.

Power Panel Issues

The Trace Power Panel consists of two SW4048 inverters and two C40 charge controllers. Also included is an inverter bypass switch and an enclosure with all the necessary DC overcurrent protection. The inverters and charge controllers come with separate operation manuals. However, the systems interact. Float voltage must be set for each, but there were no clear instructions about that.

These settings must also be compensated for the voltage bias between the two pieces of equipment. The SW series inverters' bulk and float battery charge set points are programmed using the inverter's LCD display. The C40 charge controllers use potentiometers to set these parameters. Since it's a little hard to tell exactly where the potentiometers are set, a digital voltmeter

Power panel #1 for 64 PV panels.

Power panel #2 for 32 PV panels and the wind generator.

should be used to double-check the set points. This way the inverters and charge controllers are regulating based on identical set points.

The inverters offer great flexibility in how they may be used, but examples of typical setups in the manual would greatly help. The manual contains virtually no troubleshooting instructions or test modes to verify correct operation.

Two additional C40 charge controllers were added to match the output current of the photovoltaic panels. Actually that is more controller capacity than is required. Two 60 amp controllers would have probably worked, but adding two more C40s was easier. In any case, the power panel should have had all components matched in capacity or clearly identified otherwise.

Tracker Issues

Although mechanical assembly of the panels and racks was relatively simple, putting the combiner boxes together required a great deal of figuring out. Also, the trackers require extensive grounding to work reliably. With our initial setup using "standard" grounding, some trackers would occasionally not track (especially with some clouds), or would not reset to the correct position.

The tracker manufacturer explained that we needed to add additional grounds (rods sunk into the earth and tying connected metal structures together with additional ground wires). Once this was done, the problems disappeared.

Lessons Learned

My expectations for the adequacy of documentation were not met. I had to rely on significant verbal communication with the manufacturers. In general, the installation and operation manuals were incomplete. At worst they were inaccurate and inconsistent. The manuals appear to be more a reference for experienced installers rather than what is needed for the first or only time installer.

All the manufacturers have excellent phone or e-mail technical support. But you must plan on several calls. I suggest that you keep a log of all calls and adjustments for review and clarification. Get the name of the technical support person and try to talk to that person each time, even for a new problem.

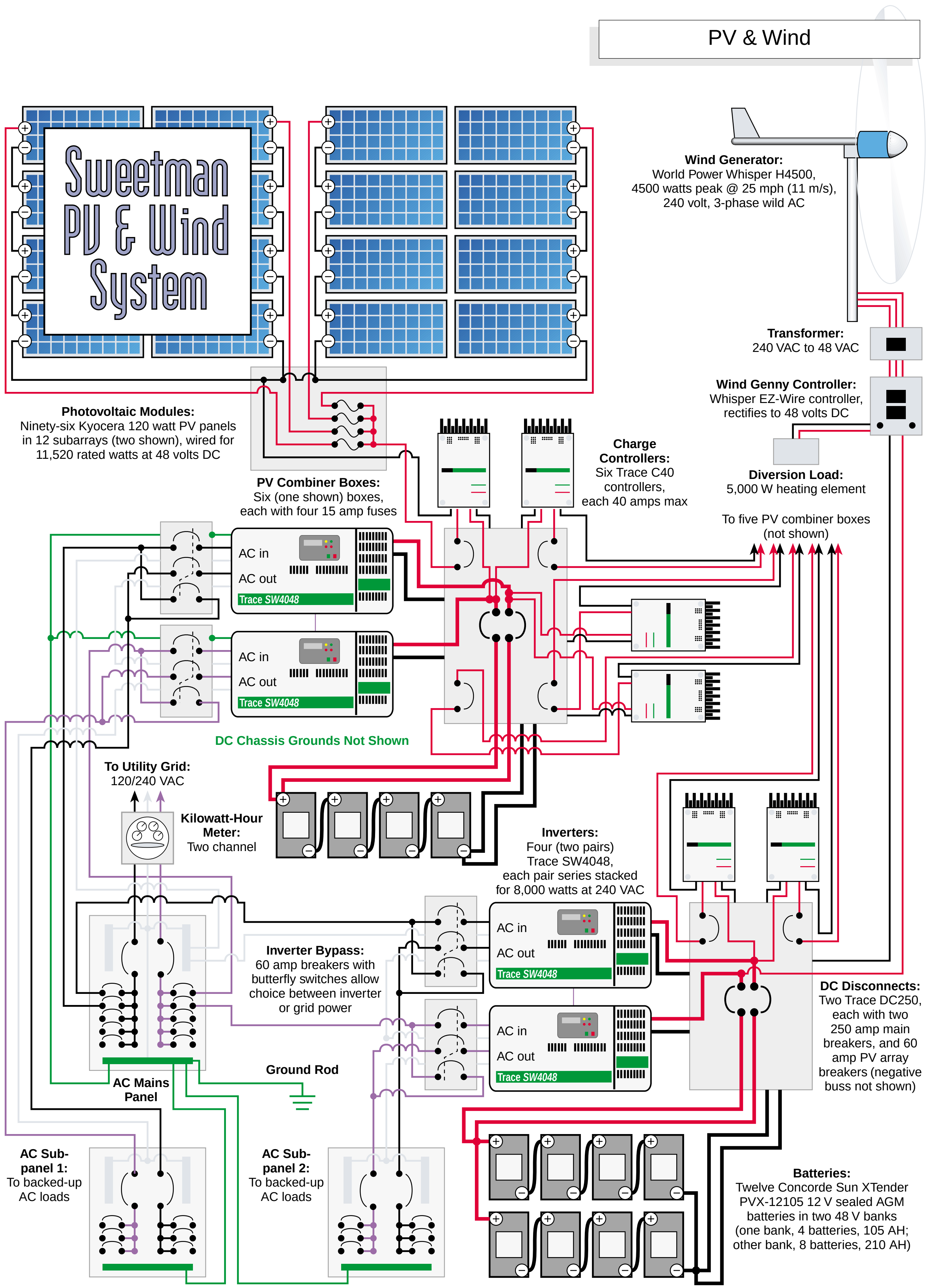
Little or no written information is readily available about how the various pieces of equipment can or should interface. So you must carefully think through how the complete system should operate and determine what interfaces are needed. Most interfaces are hardware—wire, breakers, nuts, and bolts. But others are software items—voltage and current settings.

Many of the manufacturers have recommendations on what should be used and at what values, which are only available if you call or e-mail. A system troubleshooting manual, including a flow chart, instruments required, and tools required would be a significant improvement.

Have plenty of the correct tools and troubleshooting instruments available. Minimum test instrumentation consists of a digital AC/DC multimeter capable of testing voltage, amperage (a clamp meter is handy), and frequency. The multimeter should be equipped with

Generation Capability

Source	*Watts*	*Hours/Week*	*KWH/Week*
Summer			
Photovoltaic	9,000	63	567
Wind generator	3,000	56	168
		Total Summer Generation	735
		Percent of Summer Requirements	105%
Winter			
Photovoltaic	9,000	42	378
Wind generator	3,000	63	189
		Total Winter Generation	567
		Percent of Winter Requirements	92%


Sweetman PV & Wind System
Wind Generator:
World Power Whisper H4500,
4500 watts peak @ 25 mph (11 m/s),
240 volt, 3-phase wild AC
Transformer:
240 VAC to 48 VAC
Wind Genny Controller:
Whisper EZ-Wire controller,
rectifies to 48 volts DC
Diversion Load:
5,000 W heating element
To five PV combiner boxes
(not shown)
Photovoltaic Modules:
Ninety-six Kyocera 120 watt PV panels
in 12 subarrays (two shown), wired for
11,520 rated watts at 48 volts DC
PV Combiner Boxes:
Six (one shown) boxes,
each with four 15 amp fuses
Charge
Controllers:
Six Trace C40
controllers,
each 40 amps max
AC in
AC out
Trace SW4048
DC Chassis Grounds Not Shown
To Utility Grid:
120/240 VAC
Kilowatt-Hour
Meter:
Two channel
Inverters:
Four (two pairs)
Trace SW4048,
each pair series stacked
for 8,000 watts at 240 VAC
Inverter Bypass:
60 amp breakers with
butterfly switches allow
choice between inverter
or grid power
DC Disconnects:
Two Trace DC250,
each with two
250 amp main
breakers, and 60
amp PV array
breakers (negative
buss not shown)
Ground Rod
AC Mains
Panel
AC Sub-
panel 1:
To backed-up
AC loads
AC Sub-
panel 2:
To backed-up
AC loads
Batteries:
Twelve Concorde Sun XTender
PVX-12105 12 V sealed AGM
batteries in two 48 V banks
(one bank, 4 batteries, 105 AH;
other bank, 8 batteries, 210 AH)

Sweetman Estimated Costs

Item	*Cost (US$)*
64 Kyocera PV modules & 8 Wattsun dual-axis trackers	$50,000
32 Kyocera PV modules & 4 fixed mounts	20,000
2 Trace Power Panels, with 4 inverters & 6 charge controllers	16,000
Wind generator tower pipe, tube, concrete, labor	8,000
World Power H4500 wind genny, tower kit, transformer, rectifier	7,500
PV array installation; pipe, concrete, labor	5,000
Wiring in conduit and trenching between facilities	5,000
Power rooms construction and materials	2,500
12 Concorde Sun XTender batteries	1,000
Total	$115,000

both test probes and alligator clips. A battery load tester may be useful. A good set of tools for connecting (and taking apart and reconnecting) the equipment is necessary. This should include a variety of screwdrivers, wrenches, socket sets, pliers, wire crimper/stripper, and Allen wrenches. Heavy lifting equipment is required for installation.

My load calculations for system sizing were not exact. I underestimated the load by not recognizing how much energy irrigation would use. Actual output of the system is only about 70 percent of rating. I had thought this would be closer to 90 percent, but module temperature, line loss, conversion inefficiencies, and availability of sun and wind reduce how much energy is actually produced. The system was designed for modular expansion, which has greatly facilitated the addition of more PV modules.

Whining, or Constructive Criticism?

As a former vice president of quality and reliability, I believe the quality management practices of the renewable energy manufacturers are inadequate. A start, at least for the smaller companies, would be to comply with ISO-9001 quality management standards. All companies need to perform a quality review of their documentation to improve usability, consistency, adequacy, and accuracy.

I am very satisfied with my system, which is now finally working as expected. My frustration was with the time necessary to get all items working together and working correctly. My primary complaint is the inadequacy of the manufacturer's documentation for the first-time installer.

I came from an industry where if I had one 35 cent part in a million fail, I had to travel to explain to the customer what we (as the manufacturer) and he (as the user) were going to do to prevent a reoccurrence of the failure. I also was expected to provide detailed application information on how to use (and not use) the part for a wide number of functions.

I had to make sure the company I worked for took all reasonable actions to prevent any problems, either in the device or the application of the device. I do not see anything like this in the RE industry. This is a failure of management, both in setting corporate direction, and in having or using quality management practices.

I would like to see this industry grow rapidly. For this to happen in a way that builds confidence in the equipment and industry, companies will have to implement some quality systems to prevent the sort of frustrations and irritations that I had.

The hardware is good, and the verbal technical support is good. But the documentation for installation, operation, and troubleshooting ranges from poor to nonexistent. I hope RE companies can improve customer satisfaction by having more user friendly products and documentation. Then even people like me will be able to get a system to work easily and quickly.

Access

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Whisper 4500 wind generator

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Trace Power Panel

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www.kyocerasolar.com • PV modules

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