Handyman's Special!

Mick Sagrillo

Lou Ann and Kelvin's wind/PV island in the sky.

In January of 1998, Lou Ann and Kelvin Washington were in the market for a new home, away from their hectic jobs in Denver. They found their piece of heaven high on a hilltop in South Park, Colorado. But their new dream home came with some problems, including a power system that was not the best introduction to renewable energy.

The house is 2,600 square feet (242 m^2), passive solar, and super-insulated, with a gorgeous view of the surrounding valley. They were told that the house had an "off-grid" electrical system. Being from the city, they had no idea what that meant. Nor could anyone vouch for its reliability.

Eric Westerhoff of Innovative Energy, the PV dealer from nearby Breckenridge, was contacted by the realtor to inspect the electrical system. What Eric found was that nightmare known as "the handyman's special!"

A Bit of History

The power system for the house was initially installed back in the mid-1980s, but evolved through the years. When we arrived on the scene, it consisted of twenty Kyocera 50 watt PV panels mounted on the roof. The PVs were series-paralleled, configured in five arrays with four panels in each array. Three of the arrays were regulated by one Trace C-30 charge controller, and the other two arrays passed through a second C-30. Maximum output of the 24 volt PV system was 35 amps.

The batteries and some of the controls were replaced in 1988. The new 24 volt battery bank consisted of twelve Trojan L-16s, series-paralleled for 1,400 amp-hours of capacity. Backup power was originally supplied by an 8.5 KW Onan LP (propane) generator through two Todd 75 amp battery chargers. Three 2,500 watt Heart Interface inverters supplied AC power to the house.

When the property changed hands in 1992, the new owners ran a small jewelry shop out of the house. It was during this time that the system fell into disarray. In order to meet production, the owners had to max out the system on numerous occasions, which eventually damaged the battery bank. The system was well used, but obviously with little preventive maintenance. Entropy set in, and system output declined. The owners depended on the Onan genset more and more.

Upon inspection, Eric found that the L-16s were more or less dead after only five years of service. During the day when the sun was shining, battery voltage climbed to 28 volts. When the sun set, however, the system voltage quickly fell to 19 volts. As a result, the inverters

shut down due to low battery voltage at night, and power had to be supplied to the house by the LP generator. Eric characterized the installation as "basically a direct drive system. You've got solar lights during the day, but LP lights when you most need them." Just prior to our arrival, the worn out Onan was replaced with a Generac 5,500 watt gasoline generator.

Superfund Site?

Eric remembers first approaching the battery/inverter/controller room and being overpowered by the smell of battery fumes. There was obviously something wrong. Among other things, Eric discovered that the Trace C-30s were operating continuously in the equalize mode. This resulted in the batteries merrily boiling away on bright sunny days.

Needless to say, the battery room was a toxic waste site. Battery acid had boiled over onto the concrete floor, etching canyons into the cement. Battery acid wicked up one wall of the room, dissolving the drywall in the process. The battery box hardware had begun to vaporize from the acid fumes. The previous owner had covered the spills with various layers of indoor-outdoor carpeting. As the carpeting decayed in the acid, bits of rubber and tuft were tracked away by visitors. Fortunately, most of the acid had been neutralized by the dissolving concrete.

Eric's inspection report to the realtor indicated that not only did the batteries need replacing, but the battery room also needed a complete overhaul. Once they closed on the house, Lou Ann and Kelvin bought new batteries from Eric. They also requested a general tune-up of the RE system.

Adding Wind

Eric had noticed that it was rather windy up on the hill, and suggested to the proud new owners that they might want to consider installing a wind turbine. He pointed out that the siding on the west side of the house had been caulked to reduce wind infiltration. Eric explained that adding wind to the PV system would increase the system's reliability. It would also reduce the amount of propane and generator time required to keep the batteries charged up. This sparked an interest in Lou Ann, and she asked Eric for a quote.

At this point, Eric knew he was getting in pretty deep. Since he'd never installed a wind turbine before, he contacted Johnny Weiss at Solar Energy International, in Carbondale. SEI teaches an excellent series of RE workshops, some of which culminate in a system installation. Johnny immediately called me about the possibility of doing this installation during SEI's wind power workshop, which I teach.

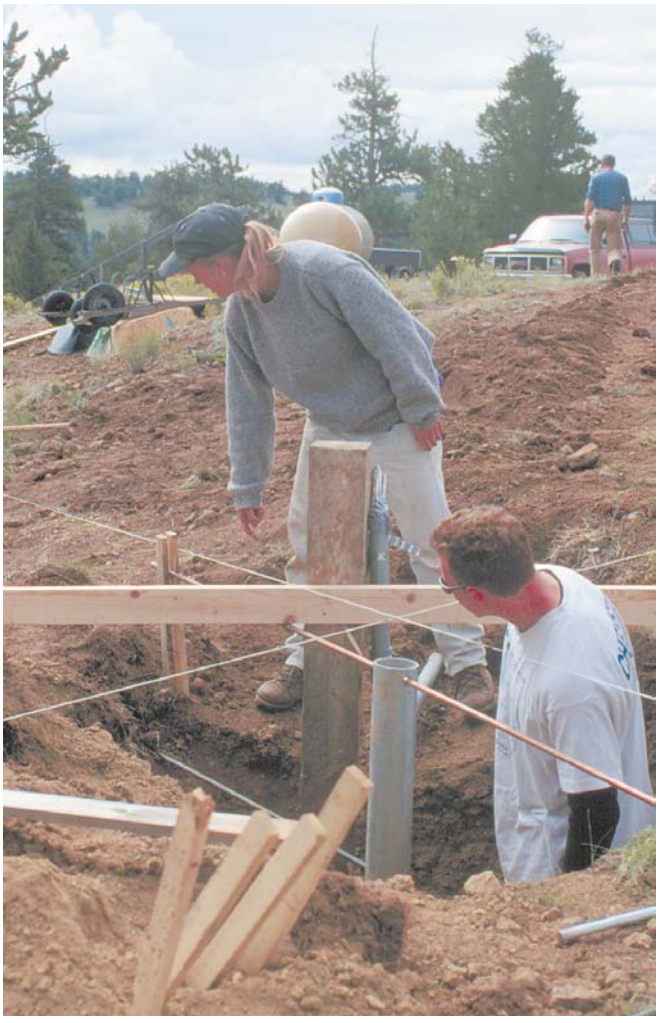
Eric is an accomplished and very professional PV installer. He's also smart, and knows the limitations of one-resource-only RE installations. Eric's offer actually resulted in everyone winning. Lou Ann and Kelvin got a top of the line system installed for a very reasonable price. SEI secured a wind installation for its students. The students received a great lesson in system rehabilitation and a difficult tower installation. And Eric acquired the experience he knew he needed with wind generators and towers.

First Impressions

Based on the pictures and information he supplied about the site, battery bank, and the house loads, Eric and I settled on a Whisper 1500 wind generator mounted on a 60 foot (18 m) tilt-up tower. We decided that the location for the tower would be determined when I arrived in Colorado. I flew in a few days before SEI's wind power workshop began so I could make a site visit with Johnny and Eric.

The first thing that I discovered during our initial site visit was that the Washingtons' house was indeed perched "on top of a hill." In fact, the hill dropped off rather precipitously in all directions. And it certainly was windy! This was going to make for a very interesting tilt-up tower installation.

Johnny Weiss holds a makeshift surveyor's staff while the crew checks anchor heights with a transit.



Setting the anchor orientation amidst a cat's cradle of leveling strings.

The second thing I discovered was that Eric's characterization of the battery room as a "toxic waste site" was no exaggeration. There would be some serious work ahead of us to get the battery room back into a user friendly condition. All in all, this was going to be a challenging installation that neither students nor instructors would soon forget. Johnny, Eric, and I left the site excited with the possibilities.

Work Begins

SEI's Wind Power workshop is a two week program. The first week is spent in the classroom in Carbondale, with forays outside for various demonstrations. Students assemble about nine wind turbines to familiarize themselves with various models and their components. After a week of intense instruction, the students and the instructor are ready to get their hands dirty. Once on site, Johnny, Eric, and I oriented the students and explained the week's work. Even though we had a lot of work ahead of us, we were all anxious to get started.

The first task at hand was to pour concrete for the tower anchors. We had laid out the anchor locations during our pre-workshop site visit. This allowed time for Eric to jackhammer holes in the granite bedrock that hid about a foot below the surface. (Another great lesson! How many PV dealers get to use a jack hammer?) With a group of students in tow, Johnny set up a transit and explained how to use it to determine the tower anchor heights. The rest of us laid out a maze of strings so that we could accurately place the tower anchors in relation to each other.

Setting the anchors for a tilt-up tower is somewhat forgiving on flat level ground. On the side of a hill, anchor location is critical if the tower is to be safely raised and lowered without binding. Binding guy cables can buckle a tilt-up tower in a heartbeat, endangering anyone or anything near it.

Strings and elevations were checked and readjusted numerous times before we were satisfied with their positions. All of this was necessary because once concrete sets, there is no going back for readjustments. Late in the afternoon, the concrete truck labored up to the top of the hill and carefully dumped its load into our holes. We rechecked and readjusted the anchors one last time before quitting for the evening.

Teamwork

The next day, we split into various work groups. One group laid out the underground conduit and wiring from the tower base to the house, then worked on getting the wiring through the concrete wall and into the battery room. We were privileged to have two licensed electricians as students. This helped assure that all wiring, inside the house as well as outside, would be done up to code.

A second group tackled the battery room clean-up and rebuild. After a complete tear-down of the battery room, all acid laden cement, drywall, and lumber were safely landfilled. Needless to say, so were some acid-eaten

Pouring concrete for the tower anchors.

Drilling the battery room walls for tower wiring access. Note the original location of the inverters over the battery box.

clothes. The team then began to rebuild the battery room correctly.

The third group worked on laying out the tower components and assembling the tower. The tilt-up tower was a kit supplied by Lake Michigan Wind & Sun. The tower kit components were all nicely galvanized. However, the four inch (10 cm) tower tube itself, purchased in Denver, needed priming and painting. Since South Park is essentially a desert at a 10,000 foot (3048 m) elevation, the paint was dry after a mere coffee break!

Assembling the tilt-up tower.

Tilt-up Basics

Tilt-up towers are pipe or tube towers, held upright with a system of guy cables. The tower tubes, cables, and connecting hardware are assembled on the ground, then raised into an upright position with a lifting device, such as a tractor, truck, or winch.

A raised tilt-up tower is shaped like the capital letter "L." The long vertical part of the "L" represents the tower, and the short horizontal part represents what we call a "gin pole." The gin pole is the lever used to raise the entire tower into the upright position. When assembling a tilt-up tower on the ground, both parts are horizontal. First, the short part of the "L"—the gin pole—is hoisted into place, making the tower look like an "L" lying on its back.

A lifting cable attached to the gin pole by way of a pulley system is attached to the lifting device—Eric's 4x4 pick-up truck in our case. As the vehicle backs away from the tower with lifting cable attached, it pulls the gin pole into the horizontal position, and the tower into the vertical position. In effect, the gin pole levers the tower into its upright position.

Electronics

The entire house is on AC, powered by three Heart Interface 2,500 watt inverters. The inverters are "cascaded" together, and feed the AC circuit breaker box for the house. Two of the inverters feed up to 5,000 watts at 110 VAC into one side of the 220 VAC breaker box, while the third inverter feeds 2,500 watts at 110 VAC into the other side of the breaker box. Our journeyman electrician from New York City commented that he had never seen anything like this before, but he was unaware of any reason why it couldn't be configured this way.

The inverters were originally located on a shelf about a foot above the battery box. This is not a good situation in any case, but especially not when the batteries are venting acid fumes on an almost daily basis. Ideally, batteries should never be placed in the same room as the inverters, controllers, and other electrical system components.

Unfortunately, it was not possible to totally separate batteries from electronics in this installation. Instead, the team decided to move the inverters and other electronic equipment to the adjacent wall, rather than reinstall them over the battery box. Since this would involve the house being without power for a time, planning and choreography to minimize shut-down time became a consideration. It's real-life challenges like this that make these classes and installations so great!

Untangling the maze of tower guy cables.

While troubleshooting, the students discovered that one of the Trace C-30 charge controllers was not

“Heave-ho”ing the tower gin pole into place.

operating. That meant that only three of the five PV arrays were actually online charging the batteries. The previous owners had limped along, not only on bad batteries, but also with only 600 watts of a 1 KW PV system online! Fortunately, Eric had a spare C-30 that was then plugged into the system, restoring full PV power to the batteries.

The crew built a new battery box complete with a 1 inch (2.5 cm) PVC pipe vent that passed through the concrete block wall. The battery box was constructed very tightly and sealed to eliminate fuming in the battery room. The L-16s were gently placed in the battery box, with anti-corrosion grease coating all battery terminals and interconnects.

Leveling the tower and tensioning guy cables with a come-along.

Whisper Controller

When the batteries are fully charged, many PV charge controllers simply interrupt the PV to battery circuit, effectively disconnecting the PVs from their load, the batteries. Unlike PVs, most wind generators must have a constant load connected to them. Breaking the circuit between the wind generator and its load results in a freewheeling wind generator rotor. This can sometimes lead to thrown blades.

The Whisper controller is a “shunt” regulator. As the batteries charge up, a resistive load is progressively added to the wind generator/battery circuit. Excess power that the batteries can’t take from the wind turbine is shunted to this resistive load. This accomplishes two important things. First, it taper charges the batteries as they reach full charge. Second, it maintains the load on the wind generator, preventing the rotor from freewheeling and possibly self-destructing. A bonus is that the waste heat can be used to heat hot water, or warm your battery room in the dead of winter.

Since wind generator dump loads can get extremely hot, it is critical to install them on a fireproof surface. While this point is stressed in the Whisper installation manual, many folks still install dump loads on plywood instead. With safety in mind, the team mounted both the Whisper controller and dump load on the concrete block wall of the battery room.

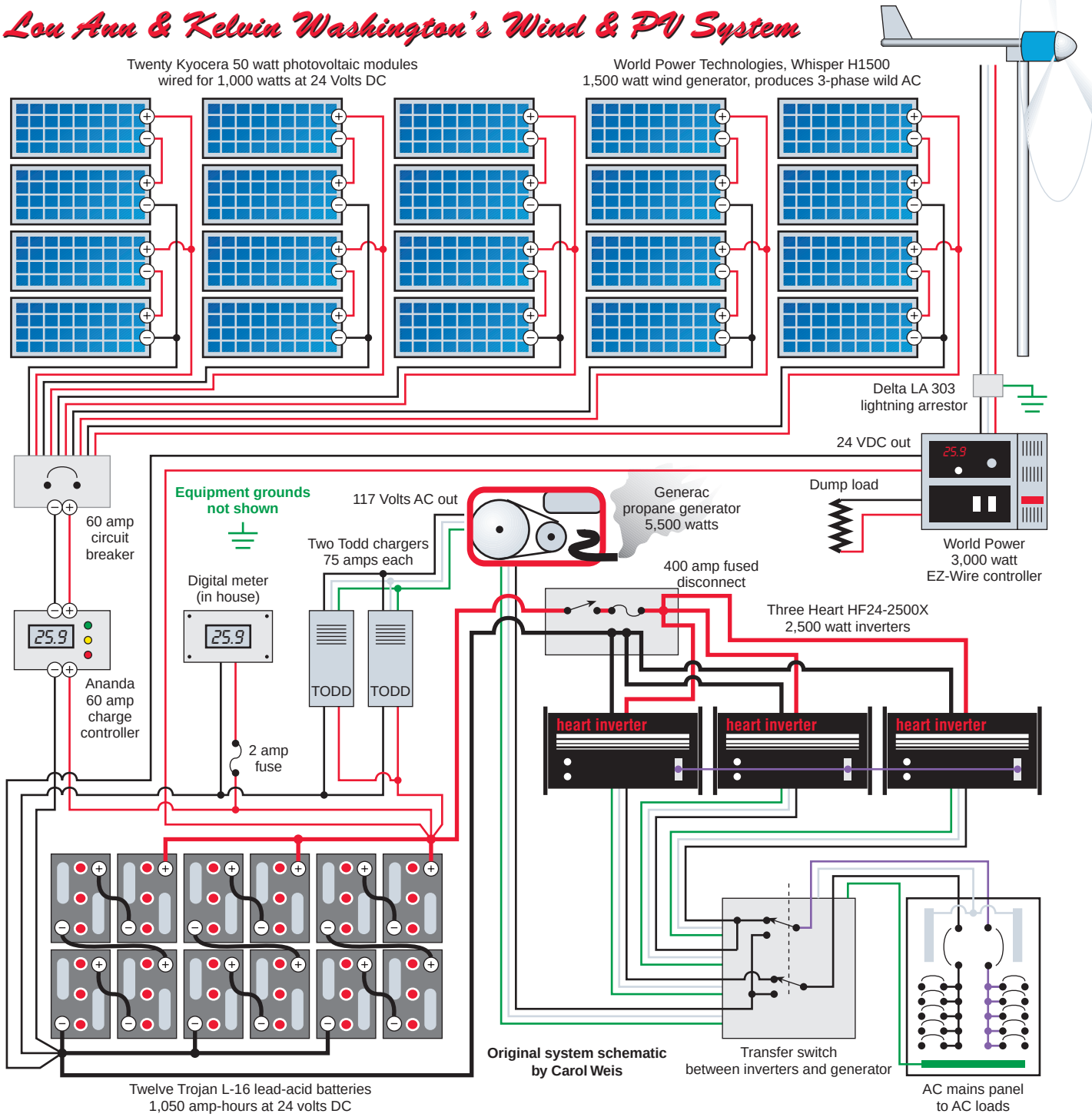
One last feature of the Whisper controller is the wind generator brake switch. Most of today’s wind generators are three phase AC permanent magnet alternators. The AC is rectified to DC in the controller for storage in the batteries. By shorting out the three AC phases coming from the wind generator before it is rectified to DC, a very large electrical load is placed on the wind generator. The electrical load is so large, in fact, that the wind turbine’s spinning blades are stalled. This action is similar to stepping on the brake pedal in your car, which “loads” the car, so to speak, reducing its speed until the car comes to a stop.

The brake switch is a nice addition to a wind system. It allows the owner to stop the wind machine from the comfort of the control room for any number of reasons: when inspecting or servicing the wind turbine or controller, when the batteries are fully charged, when a storm is approaching, or when leaving the system unattended or unused for long periods of time.

Back Outside...

Meanwhile, the team working on the tower assembly had finished their task. The tower was ready for its initial raising. Since we didn’t have a winch, we hitched Eric’s 4x4 pick-up truck to the lifting cable, and began slowly raising the tower. Halfway up, we discovered yet another problem—a tree was in the way of some of the guy cables. This was not evident when we laid out the anchors, tower, and guy cables. Fortunately, with a bit of limb

Lou Ann & Kelvin Washington's Wind & PV System



trimming (by *Home Power* staffer and tree monkey Ian Woofenden), we were able to make the guy cables clear the tree. Another valuable lesson while doing a real life installation!

Next came the rather tedious business of plumbing the tower by tensioning the many guy cables. The lower guy cables are always tensioned first. Then the other guys are done, moving progressively to the top. This assures that the tower will stand straight without buckling. Once the tower was plumbed and all cables properly tensioned, it was lowered. It was time to install the Whisper 1500, the culmination of the installation.

TGIF

With the tower back down on the ground, we prepped the Whisper 1500 for mounting atop the tower. We connected the wind generator wires to the tower wires with inline butt-type cable connectors. We wrapped the connectors individually with rubber splice tape, the type

Final nuts and bolts check on the Whisper H1500 before we raise the tower.

used on submersible well pumps. The electrical wires coming down the tower are held in place with a wire basket type of strain relief, known as a Kellums grip. This device acts like a "Chinese finger trap," in that the more the wires pull, the stronger it grips. The Kellums grip supports the wires at the top of the tower, preventing their weight from pulling the wires out of the wind generator.

Once the Whisper generator was wired up and bolted to the tower, we installed the blades and tail. We did final inspections on all of the tower cables and fasteners. We checked all wire connections, both at the wind generator and in the battery room. Then we rechecked wind generator fasteners, making sure they were tight. The wind was blowing, and Lou Ann was anxious. Everything was finally ready!

With Eric's 4x4 in position, once again we slowly raised the tower. This time, we had the wind generator on it. Once the tower was upright, several students secured the gin pole to the front anchor, then disconnected the lifting cable. With the Whisper facing the wind, Lou Ann did the honors and turned off the brake switch. The wind genny started spinning and within seconds, the 35 amps from the PVs was accompanied by an additional 35 amps from the Whisper. Wind and sun, as it should be!

Best of all, we finished the entire project by Friday afternoon—concrete, complete tower and wind generator installation, all wiring, plus a total battery room makeover. Quite an accomplishment. But then, it was quite a group of students!

Original System Costs

Components	*Cost*
Twenty Kyocera 50 W PV panels	$7,000
Three 2,500 W Heart HF24-2500X inverters	$3,780
Twelve Trojan L-16 batteries with interconnects	$2,304
Generac 5,500 W gasoline backup generator	$915
Two Todd 75 amp battery chargers	$590
Roof mounts	$525
2/0 and 4/0 cables	$412
Transfer switch	$344
APT 60 PV charge controller	$249
Wiring	$187
Misc wire, lumber, & hardware for battery box	$180
Miscellaneous hardware	$142
400 amp fuse	$125
Total	$16,753

** All costs are presented in present dollar value.*

Wind Upgrade System Costs

Components	*Cost*
Labor	$400*
Whisper H1500 w/ controller & dump load	$3,210
60 foot (18 m) tilt-up tower kit & tubing	$1,995
SEI overhead fee	$500
Concrete	$345
Wiring & conduit (500 feet of #4 AWG)	$307
Excavation	$225
Colorado state sales tax (3%)	$170
Shipping	$128
Misc. electrical parts (lightning arrestor, etc.)	$87
Misc. hardware (Kellums grip, bolts, etc.)	$77
Whisper controller EZ-Wire Center upgrade	N/C
Total	$7,444

** This was Eric's first real wind installation, so he was learning with the rest of the class. He only billed the Washingtons 25 percent of his normal labor rate.*

Cost tables by Eric Westerhoff

Experience Solar Energy International

I have always been impressed by the caliber of student that the SEI wind workshop draws, as well as the diversity of their backgrounds. Most folks are PV dealers and homeowners interested in learning how to integrate wind into their energy mix. But a number of students have other professional interests in the wind workshop. Students have included folks with PhDs in physics, mechanical and civil engineers, licensed electricians, accountants and financial policy analysts, home contractors, and even an oil company executive.

Check out the diverse perspectives of Carol Weiss and Eric Glatstein, students in the 1998 wind workshop.

Carol Weis: Apprentice Electrician

I am approaching the solar world by apprenticing as an electrician. I worked for eight months doing commercial work in Minneapolis before moving to Carbondale, Colorado, in pursuit of hands-on practice in the renewable energy field. I also wanted an electrical job so I could work towards my license. Once in Colorado, I struggled to find an employer in this traditionally male field who would hire a woman electrician. I finally found Patrick Kiernan from Eco Electric in Basalt, who does a combination of solar and regular electrical work.

My goal as an electrician has always been to work in renewables. I've learned to work with tools and wires in the AC world, but I had never worked in the DC world, or with solar panels or wind generators. I have always been a hands-on learner, so taking SEI workshops seemed like the logical choice.

The wind class was my favorite workshop offered by SEI. I loved taking apart the wind generators in class, and it has inspired me to take a motor and generator class here in town. The material covered at SEI was in-depth, current, and easy to grasp. Above all, I enjoyed the blend of personalities which we entertained in the group and the triumphant event of raising the tower and hearing the blades flutter in the wind for the first time.

Eric Glatstein: EPA Engineer

I am an engineer with the United States Environmental Protection Agency's regional office in Chicago, where for the past seven years I have worked on a variety of projects. The subject of radioactive waste is closest to my heart—cleaning up abandoned radium paint from the 1920s, and trying to figure out ways of disposing radioactive material.

Practicing engineers are deluged with notices for continuing education on such topics as limited difference modeling of reinforced concrete under minor earthquake loads, offered in the ballroom of a Holiday Inn just off the expressway. SEI is different. Students learn something, then they get to try it and see the results. After a week in the classroom and several days installing the turbine, I became hypnotized by the blades as they finally began spinning and free power began trickling into the battery. I never would have thought this would be so fascinating to watch.

One reason other engineers may want to try an SEI course—besides spending a few weeks in the Rockies—is to inspire thoughts about innovation. A prediction among people who know far more about the electricity business than I is that the U.S. will not be building any more large generating stations. If this is at all true, the technologies SEI teaches will become increasingly significant.

Since Then...

On Christmas day, Kelvin came home to the smell of smoke in the battery room. The Whisper controller had overheated and self destructed. Thank goodness for cement block walls. Yet another lesson—electricity can cause fires! The decision to mount the Whisper controller and dump load on the cement block wall was a good precaution. As Eric said, "I don't want to be responsible for someone's house burning down."

Whisper wind generators have a reputation for producing more than their rated power. Lou Ann reported that she has seen the Whisper's peak output hit 79 amps. With a 24 VDC nominal system voltage, charging often reaches 30 VDC. That's more than 2,300 watts going through the 1,500 watt controller and into the dump load. Eric wisely replaced the 1,500 watt controller with a 3,000 watt controller.

Eric also replaced the two Trace C-30 PV controllers with an Ananda 60 amp charge controller. In addition, he added a PV circuit breaker switch between the PVs and the Ananda, something the original PV system lacked.

Satisfied Customers

Lou Ann is thrilled with their wind/PV hybrid system. With the exception of the down time they experienced

Class photo of the crew with an almost complete installation.

when the Whisper controller fried, the Washingtons have never run their backup generator.

Besides the normal AC electric loads like a deep well pump, the household appliances include a dishwasher, washing machine, and a high efficiency 22 cubic foot (0.62 m^3) Amana frost-free refrigerator. Most of their heating loads (furnace, water heater, clothes dryer) run on propane. Even so, Lou Ann reports that they have "more electricity than they know what to do with." She says that when the wind really blows, she runs around the house turning on lights rather than shutting down the wind generator. With no sun or wind, the Washingtons have four days of battery storage.

An enthusiastic Lou Ann throws the final switch, starting up the wind generator.

When he first met them, Eric said that neither Lou Ann nor Kelvin knew an inverter from a PV module. Now, Lou Ann calls him to discuss charge controller regulating voltage versus inverter shut-off voltage. Notes Eric, "You couldn't ask for better customers. They want answers, and they're involved with their system."

The system has come a long way from the days when the 8.5 KW generator had to be run just to turn on a light at night. And according to Eric, so have Lou Ann and Kelvin. With a smile in her voice, Lou Ann said, "I've learned a lot. I'm in charge of my own electric system. I can't imagine ever living on the grid again."

Access

Author: Mick Sagrillo, Sagrillo Power & Light, E3971 Bluebird Rd., Forestville, WI 54213 • 920-837-7523

Eric Westerhoff, Innovative Energy, PO Box 6538, Breckenridge, CO 80424 • 970-453-5384
Fax: 970-547-0220 • innovate@colorado.net
www.renewablepower.com

Johnny Weiss, Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855
Fax: 970-963-8866 • sei@solarenergy.org
www.solarenergy.org

Equipment suppliers:

Lake Michigan Wind & Sun, 1015 County Rd. U, Sturgeon Bay, WI 54235-8435 • 920-743-0456
Fax: 920-743-0466 • lmwands@itol.com

Sunsense, PO Box 301, Carbondale, CO 81623
970-928-9272 • Fax: 970-928-9696
sunsense@sopris.net