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

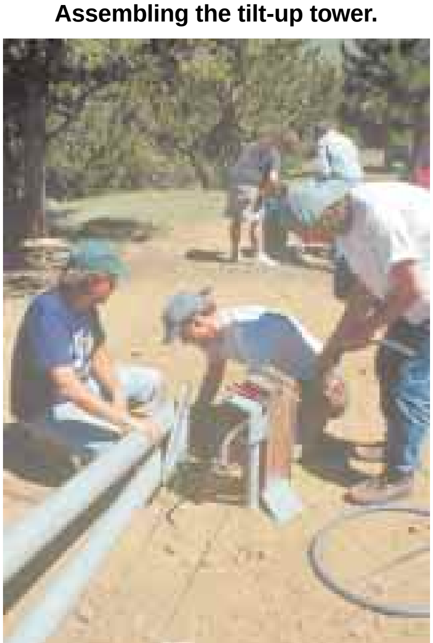
Pouring concrete for the tower anchors.

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.

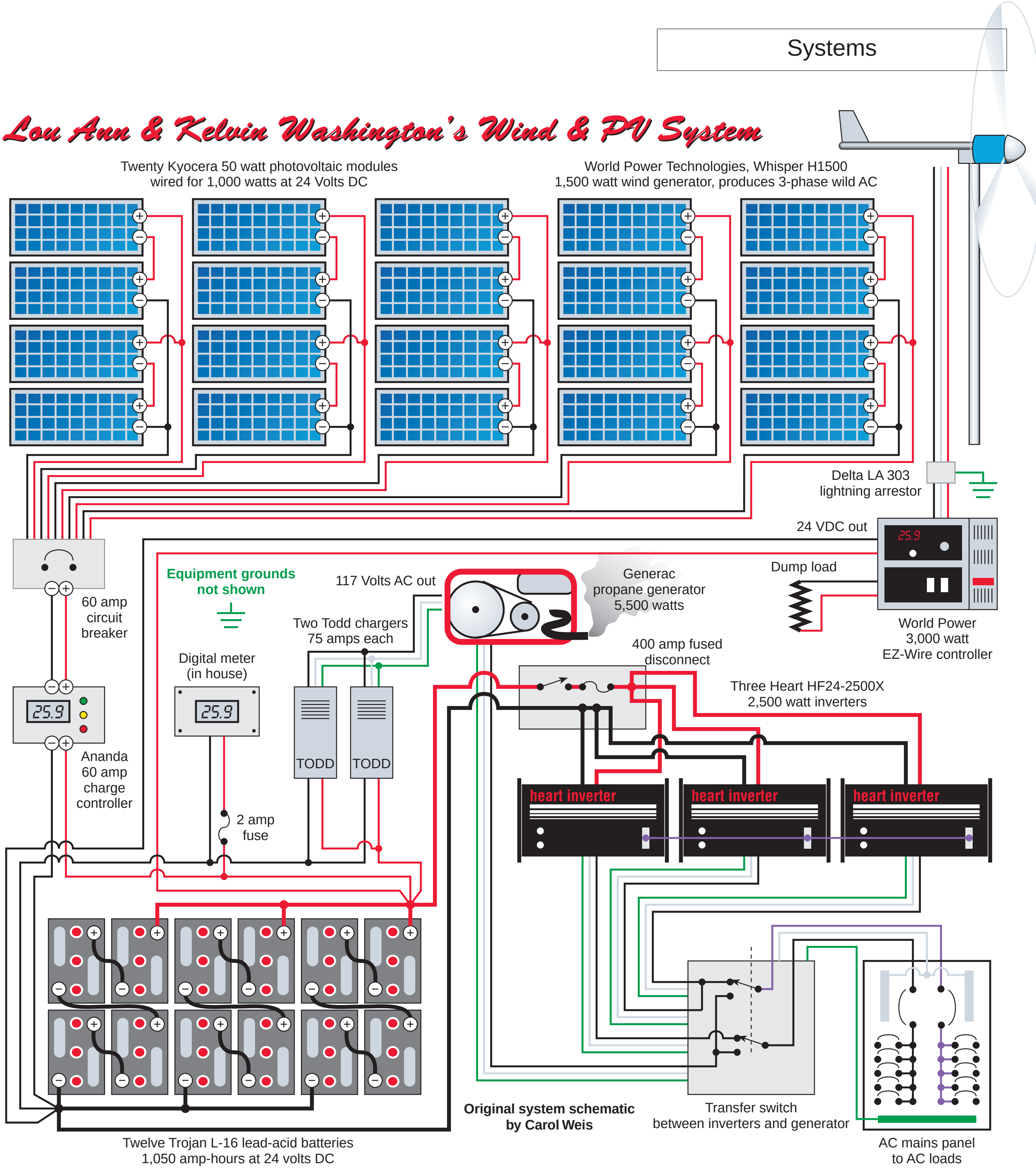
One last feature of the Whisper controller is the wind generator brake switch. Most of today's wind generators are three phase AC permanent magnet alternators. The AC is rectified to DC in the controller for storage in the batteries. By shorting out the three AC phases coming from the wind generator 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



Original system schematic
by Carol Weis

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.

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."

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

Access

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Equipment suppliers:

Lake Michigan Wind & Sun, 1015 County Rd. U, Sturgeon Bay, WI 54235-8435 • 920-743-0456
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Sunsense, PO Box 301, Carbondale, CO 81623
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In just one year, these Solarex Millennia modules will have generated an amount of electricity equal to the energy used in their production. Note: Actual photograph of Millennia modules with patented Integra™ frame.

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It could take five to ten years for comparably rated monocrystalline modules to generate the electricity equal to that used in their production. Note: Computer simulation showing comparably rated monocrystalline system and its frame.

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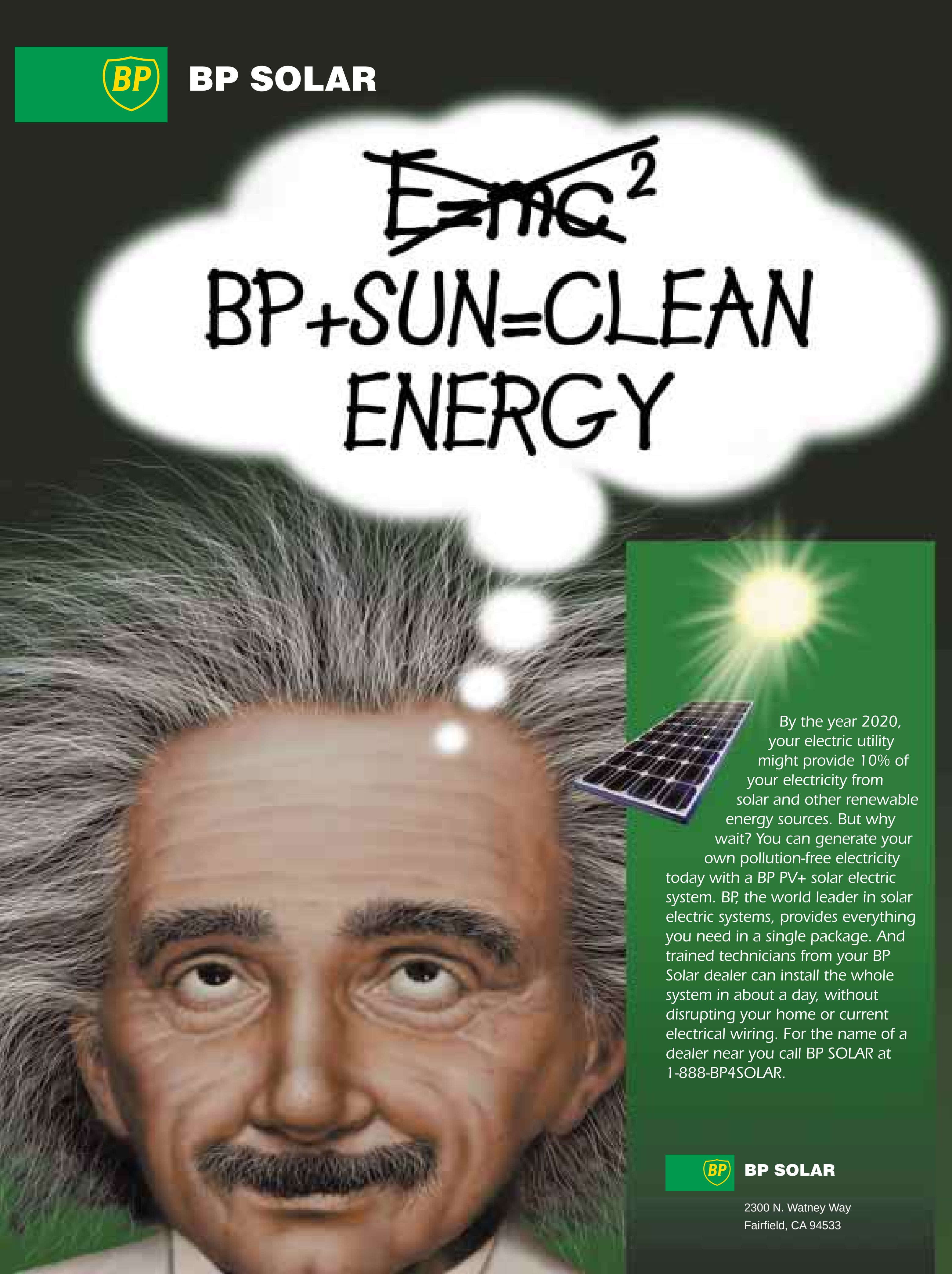
SOUTHWEST WINDPOWER

full page
four color on negatives

this is page 34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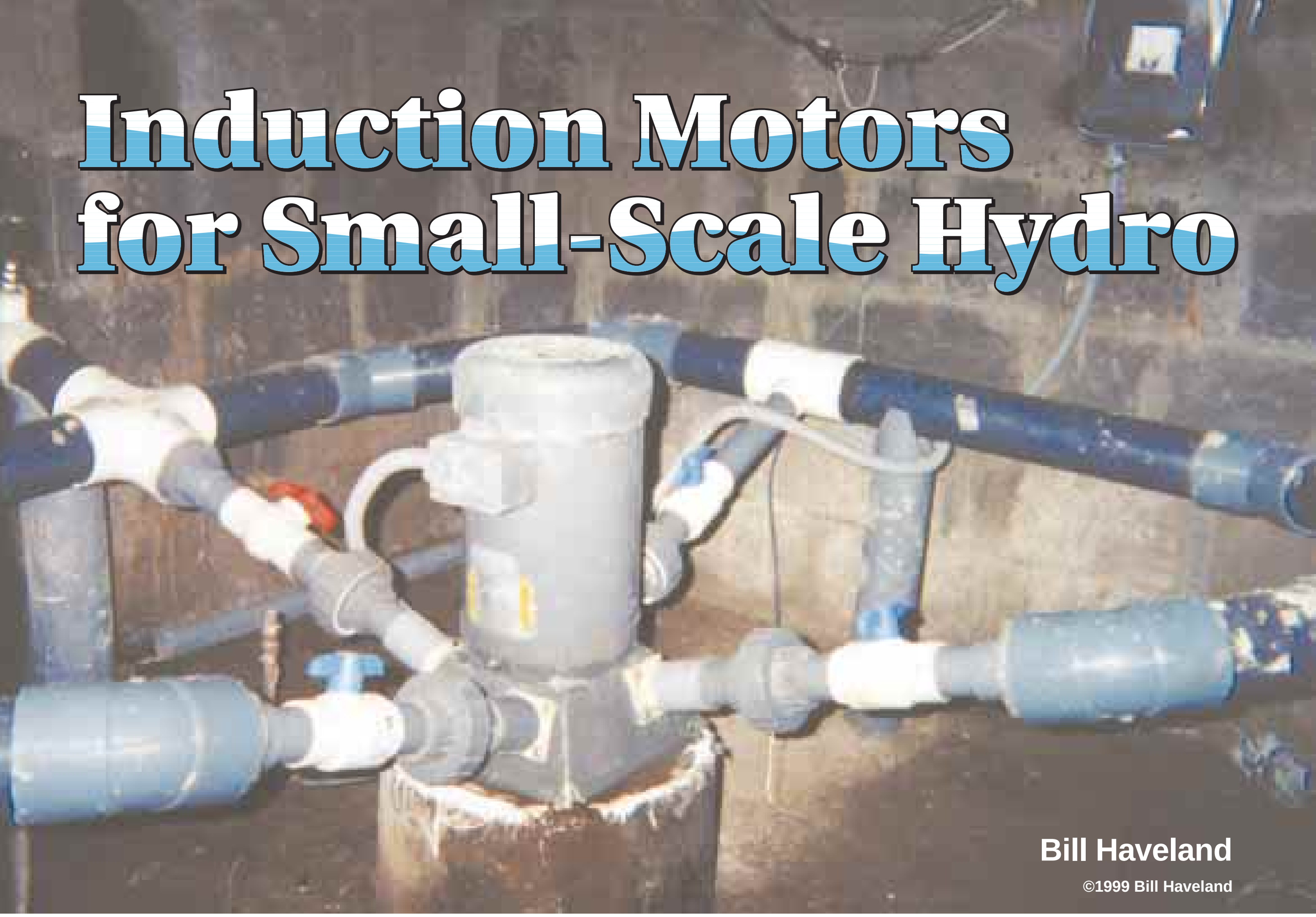
Induction Motors for Small-Scale Hydro

Bill Haveland



Richard & Nancy Lebo's 2 HP induction motor making juice in Costa Rica.

The standard three-phase induction motor is very well suited for hydroelectric generation. These motors, functioning as generators, can be used for both battery charging and stand-alone applications.

Induction motors are especially useful on streams and springs situated a long distance from where the power will be used. Excessive wire loss in these situations makes transmitting low voltage functionally impractical. The generation voltage of induction generators is typically from 120 to 480 volts, compared to the 12 to 48 volts of the small turbines commonly available on the market. This technology opens up many potential generation sites that were not previously usable with existing turbines.

Economical & Low Impact

A 1 1/2 horsepower (HP) induction motor, generating at 500 watts, produces about 12 KWH per day, which is equivalent to fifty 75 watt PV panels installed in Phoenix, Arizona. The PV panels would cost nearly $18,000; the hydro turbine generator would only cost about $2,000. Where the water resource exists, and local legal and social structures allow its use, battery charging hydro is almost always the most economical source of off-grid power.

With careful site development, small hydro installations, which generally do not use large impoundment structures, have a very low environmental impact. Where there are other creatures using the same water, consideration for their well-being should be practiced in all stages of development and operation.

Richard & Nancy in front of their hydro-powered home.

This article presents an overview of the technology with its advantages and disadvantages. For more on induction generator theory, see *HP3,* page 17, and sources at the end of this article. I've listed some of the pitfalls that I've learned from experience, and included a simplified development procedure to help you put your own hydro to work. Sources, suppliers, and references are listed at the end of the article.

Advantages of Induction Generators

1. Readily Available

Three-phase induction motors are readily available nearly everywhere in the world—new, used, or reconditioned. These motors are manufactured in a wide variety of voltages, efficiencies, case types, service applications, and rpm configurations. This makes it possible to locate a motor to fit nearly any site, except those with very low head.

All motors used as generators in hydro applications should be of the totally enclosed fan-cooled (TEFC) type, with severe duty motors preferred. C-face motor mounting is usually used for direct coupling the motor to the runner. Harris Pelton or four inch (10 cm) Turgo runners are the products generally selected for most home-scale battery charging applications. The C-face mount limits the selection of suitable motors somewhat. High-power turbines or motors with standard mounting can be belt coupled, through a jack shaft, to the turbine runner.

The C-face motor is designed for bolting the turbine housing directly to the shaft end of the motor. Adapting the Harris or Turgo turbine runners to the selected C-face motor will require one of three things: making a coupling adapter, ordering the turbine runner with a keyway the same diameter as the motor shaft, or machining the motor shaft to match that of a Ford alternator. Ford and Delco are the most commonly used high output automobile alternator models in microhydro applications, and most runners are built with shaft sizes to fit them.

2. Inexpensive

A new, premium-efficiency, severe duty, 1 1/2 HP, 1,800 rpm, 230 V/460 V, 56C-face, TEFC, three-phase motor will cost US$200 to $450. These motors are also available reconditioned at a significant discount. This initial cost is similar to the DC Ford and Delco alternators now used on small hydros, but these alternators require frequent rebuilds and have a limited life expectancy.

The complete hardware package of an assembled turbine for a 1 1/2 HP motor—induction generator, capacitors, capacitor enclosure, fuses, transformer, and rectifiers—will cost about US$2,000 to $2,500. Where the turbine is closer than 500 feet (152 m) to the batteries, the less expensive (US $900–1,400) and more efficient low voltage DC alternator should be used. The additional cost of the induction machine can be attributed to components that are unneccesary with the low voltage DC machine. These include capacitors, transformer, protection devices, wiring, and rectifiers with their enclosures. Though induction generators are somewhat more expensive up front, they can outlast conventional alternators many times over.

A typical filter tank at the top of the Lebos' penstock.

3. Very Robust

These generators will last decades, with bearing replacement every three to five years of continuous service, if they are set up properly to begin with. The

At the DC end, 258 V is stepped down to 24 V.

The Bosque del Cabo system utilizes a 1 1/2 HP motor (left) to produce 180 watts from 21 gpm at 190 feet of head. 2,300 feet from the hydro unit, the rest of the system (right) steps down from 415 VAC to 12 VDC.

motor design is meant to withstand many years of industrial use and abuse. There are no brushes, slip rings, diodes, or wire windings on the rotor to fail.

Not having windings on the rotor allows the generator to tolerate significant sustained overspeed without damage. The sealed machine housing provides excellent protection against dust and liquids. Induction generators will survive serious mechanical and electrical abuse that would kill automotive alternators.

4. Inherently Overload Protected

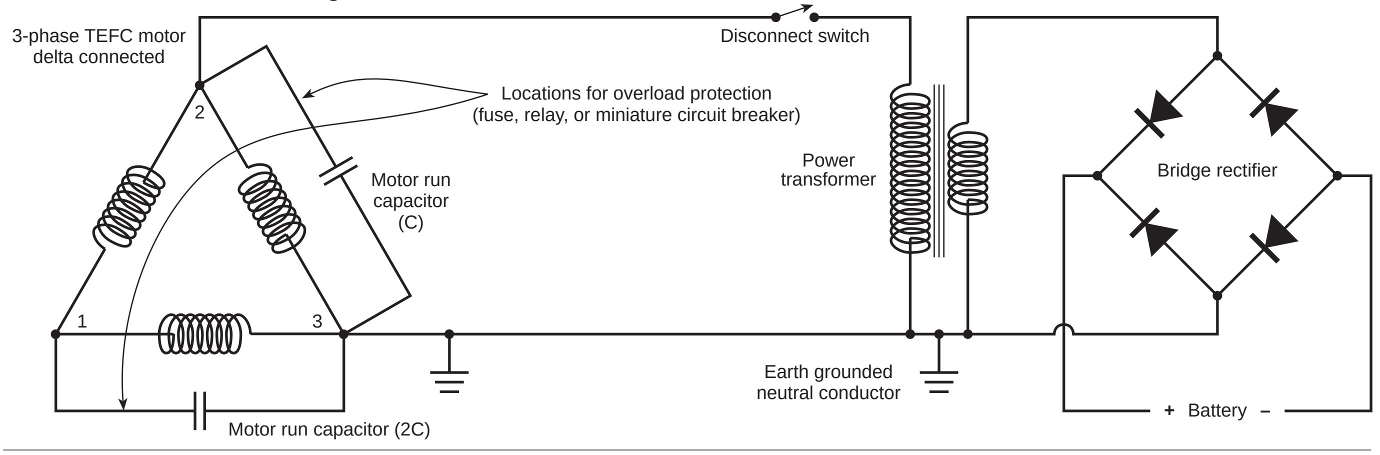
Sooner or later, a short circuit will be applied to the generator output. This might be caused by shorted wires in the transmission line or defective components in the battery charging system. With this type of failure, the generator will lose excitation and spin freely without suffering damage. If an overload occurs in the distribution of a stand-alone system, it will also cause the generator to lose excitation and begin to freewheel.

In contrast, a turbine using a Ford or Delco alternator subjected to a short on the output will cause the alternator to burn up. The induction generator will not restart until the overload is corrected. Although induction motors are inherently overload protected, runaway overload protection is necessary to protect against a disconnected load. This scenario is dealt with under *Disadvantages of Induction Generators.*

5. Can Generate at a High Voltage

Because induction motors generate at high voltages, long distance transmission is possible using light gauge, inexpensive wire. For example, a 575 volt motor generating at 480 volts can transmit 750 watts with 5 percent voltage loss for one mile (1.6 km) on two strands of #12 (3.3 mm^2) wire. This high voltage generation, transmitted over inexpensive wire, makes it possible to harness streams previously deemed too far away for battery charging hydro.

Induction Generator Wiring



Induction Hydro System Comparison

Owner	*Bosque Del Cabo Lodge*	*Buena Vista Lodge*	*Casa Corcovado Lodge*	*Richard & Nancy Lebo*	*Joel Stewart & Belen Momene*	*German Llano*
Motor manufacturer	Brooke Hansen	Brooke Hansen	Brooke Hansen	Baldor	Baldor	ESD (3 Phase Alternator)*
Motor rpm	3,600	1,800	1,800	1,200	1,200	N/A
Motor HP	1.5	1.5	1.5	2	2	N/A
Motor volts	575	575	575	480	480	N/A
Generation volts	415 VAC	415 VAC	386 VAC	258 VAC	334 VAC	28 VDC
Generation hertz	66	65	71	85	70	N/A
Test flow	21 gpm	55 gpm	60 gpm	300 gpm	185 gpm	73 gpm
Test net head	190 ft	81 ft	148 ft	55 ft	65 ft	55 ft
Net water potential	750 watts	840 watts	1,670 watts	3,100 watts	2,250 watts	760 watts
Turbine manufacturer	Harris / Pelton	Harris / Pelton	Harris / Pelton	ESD / Turgo	ESD / Turgo	Harris / Pelton
Turbine / generator efficiency	28.0%	50.0%	26.9%	17.1%	32.9%	60.5%
Transmission line efficiency	90.5%	97.6%	95.6%	90.6%	94.6%	97.8%
Transmission line length	2,300 ft	2,500 ft	1,600 ft	1,300 ft	1,100 ft	300 ft
Transmission line gauge	#12	#12	#12	#12	#10	#2
Transformer efficiency	97.4%	96.3%	97.7%	89.6%	95.7%	N/A
Rectifier efficiency	98.9%	93.7%	97.6%	88.8%	94.0%	N/A
System voltage	12 VDC	24 VDC	24 VDC	24 VDC	24 VDC	24 VDC
Overall efficiency	24.4%	44.0% **	24.6%	12.3% ***	28.0%	59.2%

* *For reference only, this is not an induction generator.*
** *Without retesting, no explanation can be found for this abnormally high efficiency.*
*** *Poor efficiency likely caused by an old installation using two equal size capacitors connected instead of C-2C configuration, or a locally made transformer.*

Disadvantages of Induction Generators

1. High Voltage!
Danger! Great care should be taken working with the 240 to 800 volts AC that these units generate. It can be lethal at worst, and at the least, it's memorable.

2. Initial Setup
With this system, capacitors must be connected to the motor to supply excitation current, allowing the motor to become a generator. *Danger!* To prevent electrical shock, the excitation capacitors need to have a 1 megaohm, 2 watt discharge resistor connected terminal to terminal.

The connection method calls for "C" amount of capacitance across the phase where the output is taken and "2C" across the other phase (see diagram). As an initial value of capacitance, use 3 µF per motor HP for "C" and 6 µF per HP on the "2C" phase.

To maximize efficiency, capacitor sizing needs to be done on a trial and error basis. The machine should be installed in its permanent site or with site conditions duplicated in a test situation. A clip-on ammeter, with a low scale such as 0-6 amps, is ideal for the procedure detailed below. If a clip-on meter is not available, the 10 amp range found in most multimeters will work, but the user will need a lot of patience and care. Each measurement will require shutting down the turbine and opening the circuit to allow connection of the meter for amp measurement.

When the three phases are combined into a single phase wire pair, then the electrical direction of motor rotation must be determined. The capacitors need to be connected between the correct phases for the rotational direction. First connect the motor as shown in the diagram. Carefully measure the current in the ungrounded output wire and note the result of the measurement. Change the 2C capacitor connection point from 3 to 2, leaving 1 connected. Again measure the current in the output wire. If the current is higher than in your first measurement, leave the capacitor in

The Buena Vista Lodge uses a 1.5 HP motor to generate 370 watts from a three-nozzle pelton wheel.

415 VAC becomes 24 VDC at Buena Vista's power center, 2,500 feet from the Harris hydro unit.

this position. If the current is lower than in your first measurement, return the connection to point 3.

The current in each motor lead should be checked for balance. Each leg needs to be within 30 percent of the others. Do not, under any circumstances, let the current exceed the motor nameplate rating for the selected wiring configuration. Most three-phase motors have dual voltage connections. For example, a nameplate rating list may show 2 amps for the 480 volt configuration and 4 amps when connected for 240 volts. So if the motor is wired for 480 volts, the 2 amp plate rating is the maximum allowed per phase even if the generation voltage is only 240 volts.

Capacitor substitution for the initial values will correct phase imbalances if they exist. It is very helpful to have industrial electrical experience for this process, but handy people with a good knowledge of electricity can usually muddle through it. A selection of motor run

Casa Corcovado Lodge gets 410 watts from 60 gallons per minute at 148 feet of head.

capacitors is necessary for maximizing machine output. This is a fairly significant cost outlay—about US$200—and you will end up with some extra capacitors when you're done.

3. Low Generating Efficiency
Thomson and Howe is a company in British Columbia, Canada that did much of the early work on induction hydro generation. They reported efficiencies between 86 and 95 percent for three-phase induction motors used as generators. My experience does not confirm these efficiencies. The highest efficiency I've seen was achieved with a stand-alone system using a 10 HP motor, and that was about 70 percent efficient. It is tempting to assume that the larger HP motors produce higher efficiencies, but additional experimentation is needed. Most motor catalogues will list the efficiency of the product. Generally, the higher efficiency models will also produce an increased efficiency when used as a generator.

The 1-2 HP motors generally used for battery charging systems have produced efficiencies in the 25-35 percent range. This is significantly below the 50-60 percent that a properly installed Ford or ESD generator will produce. But the more efficient low voltage DC units are not practical for transmission distances over 800 feet (244 m) in 48 volt systems. For lower voltages, maximum transmission distance is considerably less. For sites with long distances, the practicality of the high voltage induction generators outweighs the lower efficiency.

4. Load Disconnection Runaway Overload Protection
Overload protection should be used on generators run near their output limit. When runaway occurs because of load disconnection, if the capacitors remain connected to the generator, both the voltage and

current will rise. The motor has an information plate that indicates its maximum current per phase. If any of the individual phase currents exceed the nameplate maximum current at runaway, then controls need to be installed. The controls disconnect the capacitors from the motor, allowing it to freewheel.

Joel Stewart and Belan Momene are building a hydro-powered lodge. Currently, their system provides 15 KWH per day.

When the capacitors are disconnected, the generator voltage will collapse. This control circuitry can take several forms. The simplest is a 600 V fuse in series with each of the two capacitors in the C and 2C format (see diagram). This fuse should be no larger than the rating of maximum current on the motor plate. Miniature magnetic circuit breakers can be used in place of the fuses if loss of load is a common occurrence. With an additional level of control circuitry, the capacitors can be disconnected from the motor if either a high or low voltage occurs on the output. This same circuitry can actuate water valves that can shut off water flow to the turbine.

AC motor run capacitors with a voltage rating that exceeds the runaway voltage should be used. Newark Electronics has 660 VAC motor run capacitors that will withstand the peak runaway voltage on all but the 575 V induction generators.

When capacitors are not available with the correct voltage rating, lower voltage units can be used in series. With this configuration, the voltage rating of the capacitors will be additive. The capacitance is calculated with the formula 1/C total = 1/C1 + 1/C2 + 1/C3. Example: Two 440 V, 10 µF capacitors in series would then be 880 V, 5 µF.

5. Large Inductive Loads Need Power Factor Correction

Stand-alone induction generators have difficulty running inductive loads such as motors. A stand-alone induction generator directly runs the loads and does not use batteries or an inverter. These systems require more sophisticated electronics to operate, in the form of a load controller with ballast resistors, which hold the voltage and frequency near 60 Hz 120/240 volts. The motor load inductance reacts with the generator's excitation capacitors, causing the voltage to fall and the frequency of generation to rise. If too large an inductive load is connected, it will cause the generator to lose excitation. To correct this problem, motors run directly on stand-alone induction generators should be power factor corrected with both start and run capacitance.

6. Generator May Lose Residual Magnetism

Loss of residual magnetism occurs when the generator is rapidly shut down with a load connected, loses excitation because of an overload, or more often from running down (blocked intake water filter) with a load on. Residual magnetism is present in the iron core of the rotor. This allows the motor and capacitors to begin generation, which subsequently builds up to its normal voltage level.

If this magnetism is lost, it can be restored by connecting a simple 9 V radio battery between any two of the motor leads for a couple of seconds. The iron core material used in high efficiency motors holds less residual magnetism, so these motors are more susceptible to this minor problem.

Joel and Belan's turbine receives 185 gpm with 65 feet of head. The 2 HP generator delivers 630 W at 334 VAC.

Experience Is The Best Teacher

Sistemas de Energia Eficientes is the company I operated in Costa Rica for eight years. We installed six induction generating systems there in the last five years, and maintained an additional unit. See the system comparison table for details on these systems.

Experience is the name we give to our mistakes. The good news is that all of the systems are still working and the clients are very happy with them. The bad news is that it took making some mistakes to gain lots of experience. These are some of the lessons we've learned through the school of hard knocks:

• The jungles of the third world are not the place for product experimentation. The same applies, to a lesser degree, to field conditions in developed countries.

• Standard transformers and water valve solenoids work best at 60 Hz or above. The net head, turbine type, wheel diameter, and motor nameplate rpm need to be selected to allow the generator frequency to be within 55-75 Hz.

• Keep it simple—Murphy's Law is always enforced eventually. Use the simplest protection controls that will do the job, which usually means 600 volt fuses on the two capacitors. The operator of the plant must understand what occurs at runaway and why the fuses blow, and needs to have spares on site. If the phase current exceeds the nameplate value during loss of load or runaway, the motor is at risk of burning up. This is when the controls need to be used, a smaller turbine jet installed, or a larger motor selected.

• The motor generation voltage is determined by a chain of system components. The links in this chain are battery voltage, rectifier type and configuration, the main step-down transformer, and to a lesser extent, the resistance losses in the transmission line from the generator to the transformer. These must be carefully selected or system frequency and voltage may be drastically different than the design value. Low generation voltage and frequency will cause problems. If this happens, transformers will not operate as efficiently and water valve solenoids may not fully actuate, resulting in control transformer failure.

• Don't skimp on the penstock size; larger is always better. Black poly pipe, at least the pipe manufactured in Central America, has very high frictional losses. For this reason, I do not recommend it for hydro installations. PVC works very well but contains vinyl chloride, which is not at all good environmentally. Does anyone out there have experience with ABS and a knowledge of its toxicity?

• Shottky rectifiers should not be used with these systems. They cannot withstand the runaway voltage present if someone removes a battery cable while the turbine is generating.

Step-Down Transformers

High voltage from the generator needs to be lowered to the nominal battery voltage. A single-phase transformer is used, but it must be carefully selected for efficiency and proper voltage rating. Custom made high efficiency transformers are usually used on these systems. GE does make a production model with 480/240 primary and 48/24 secondary. They come in 0.75 and 1 KVA sizes retailing for US$294 and $370. These would function for 1 1/2 and 2 HP motors of 575 and 480 volts. The downside of production models is that they do not have multiple taps on the primary, which assist in maximizing output efficiency.

Generally, a motor can be used as a generator at voltages from 50 to 85 percent of the motor nameplate rating. For example, a 1 1/2 HP, 240/480 V, 1200 rpm motor is selected and connected as 480 volts. A custom transformer that would match this motor could be specified as 0.75 KVA, with primary voltages of 240, 280, 320, 360, and 400, and secondary voltages of 24 or 48 (depending on battery bank voltage), center tapped. If the GE production model is used, the 240 volt primary must be used. But custom wound, high quality transformers can be obtained at a cost very similar to the GE production models.

Site Evaluation

A thorough and accurate site evaluation should be the first step to any hydroelectric project. Everything you find on the subject will basically get you two numbers: *net head* and *flow.* It is very important that the analysis is accurately done, since the whole hydro project is designed around these numbers.

Step by Step Procedures

1. Determine whether or not there are legal or social obstacles to using the stream water. Get the permits or understand the risk.

2. Accurately determine the gross and net head available, and the water flow. An average yearly flow and minimum flow will be sufficient in most cases.

3. Calculate net stream potential using this formula:

$$P = H \times F \times E \div 100$$

Where P is power in watts (stream watts net), H is gross head in meters, F is flow in cubic meters per second, and E is overall efficiency.

Overall efficiency is expressed as a decimal, and includes penstock, turbine, generator, wire, transformer, and rectifier losses. A number that can be used for the efficiency of small stand-alone induction systems of less than 5 KW is 0.4 (40%). For battery charging configurations, 0.3 (30%) is appropriate.

4. Determine load in both KWH per day and peak KW. If the potential of the stream is equal to or greater than the peak KW needed, consider a stand-alone installation. A battery charging system is generally less than half the cost of a stand-alone system for the same peak KW. A properly installed stand-alone system is more reliable because it does not use batteries or inverters. It will also produce considerable excess power that can be used for water heating, etc.

5. If the turbine end of the penstock (pipe from water intake to turbine) is located farther than 500 feet (152 m) from the area where the power needs to be used, then an induction generator should be considered. If an induction machine is applicable, select the motor rpm and HP that is appropriate for the hydro resource available and the load needed.

See the rpm selection chart for induction motors used in battery charging systems. It assumes that the turbine runner diameter is four inches (10 cm). Try to stay as near as possible to the “ideal” shown in the chart. These ranges need to be experimentally verified under laboratory conditions, especially the minimums and maximums. Is any reader out there looking for a university thesis project?

German Llano’s filter tank, at the top of 55 feet of head, provides a clean 73 gallons per minute.

Motor RPM Selection Table

Motor rpm	*Head in Meters*		
	Minimum	*Ideal*	*Maximum*
3500	60	80	150
1800	20	40	80
1200	12	20	40
900	6	10	20

6. To select the horsepower of the motor using the average stream flow, determine the potential of the stream in watts. Next, divide this number by 745 watts, which will give you theoretical motor HP. But the motor will not produce as a generator what it consumes as a motor. To derate a small motor under 3 HP used as a generator, divide the resultant motor HP rating by 0.75. This will give you the actual motor HP needed. Here it is in one formula:

$$HP = P \div 745 \div 0.75$$

Where HP is the necessary rating of the motor in horsepower, and P is stream watts net.

Additional Technology Development In Process
I am now experimenting with the excitation and synchronization of the induction generator to the output of Trace sine wave and modified sine wave inverters. This has the potential to decrease the number of components required and the associated costs, while at the same time increasing the efficiency of the generation process.

Resources
Technical information on selection, purchase, setup, installation, and maintenance of induction generators is difficult to obtain. Very few publications exist describing this useful technology. The exception is one excellent book, still in print, from IT Publications in England,

Llano’s ES&D 28 volt DC alternator acted as the control group in the comparison of AC induction generators.

Motors as Generators for Micro-Hydro Power. In the Access section, you'll also find information on one company in Canada and two in the U.S. which offer assistance and sell equipment.

There are many books available on the subject of hydro site analysis. I highly recommend *Micro-Hydropower Sourcebook* and *Micro-Hydro Design Manual.* Both of these books are references on most facets of a hydro project and are well worth the expenditure. Also, see articles that deal with this topic in *HP42,* page 34, and *HP44,* page 24.

An excellent and accurate shareware computer program that is very easy to use is available for hydro site analysis. Preferred Energy Resources can supply this program for $10, which covers copying and mailing costs.

Care and Attention

I would like to advise care and attention to detail in all aspects of the design of microhydro installations, especially the civil works. A properly designed and built project will last a lifetime. Unfortunately, there are many installations abandoned shortly after they are built because of improper engineering or construction. So do it right, and if you have questions, seek professional help.

If the site parameters and budget lend themselves to a battery charging hydro but the water source is too far away for a DC turbine, then a high voltage induction generator should be able to satisfy the need. If properly engineered and installed, it will provide many years of clean reliable electricity at a fraction of the cost of other renewable energy options.

Access

Induction motors, turbines, transformers, rectifiers, and technical assistance:

Bill Haveland, Preferred Energy Resources L.L.C. (formerly Sistemas de Energia Eficientes SEESA), 3032 County Road 7, Grand Marais, MN 55604
218-387-2160 • Fax: 218-387-2173
bhaveland@boreal.org

Alternative Energy Engineering, PO Box 339, Redway, CA 95560 • 800-777-6609 or 707-923-2277
Fax: 800-777-6648 or 707-923-3009
jay@alt-energy.com • www.alt-energy.com

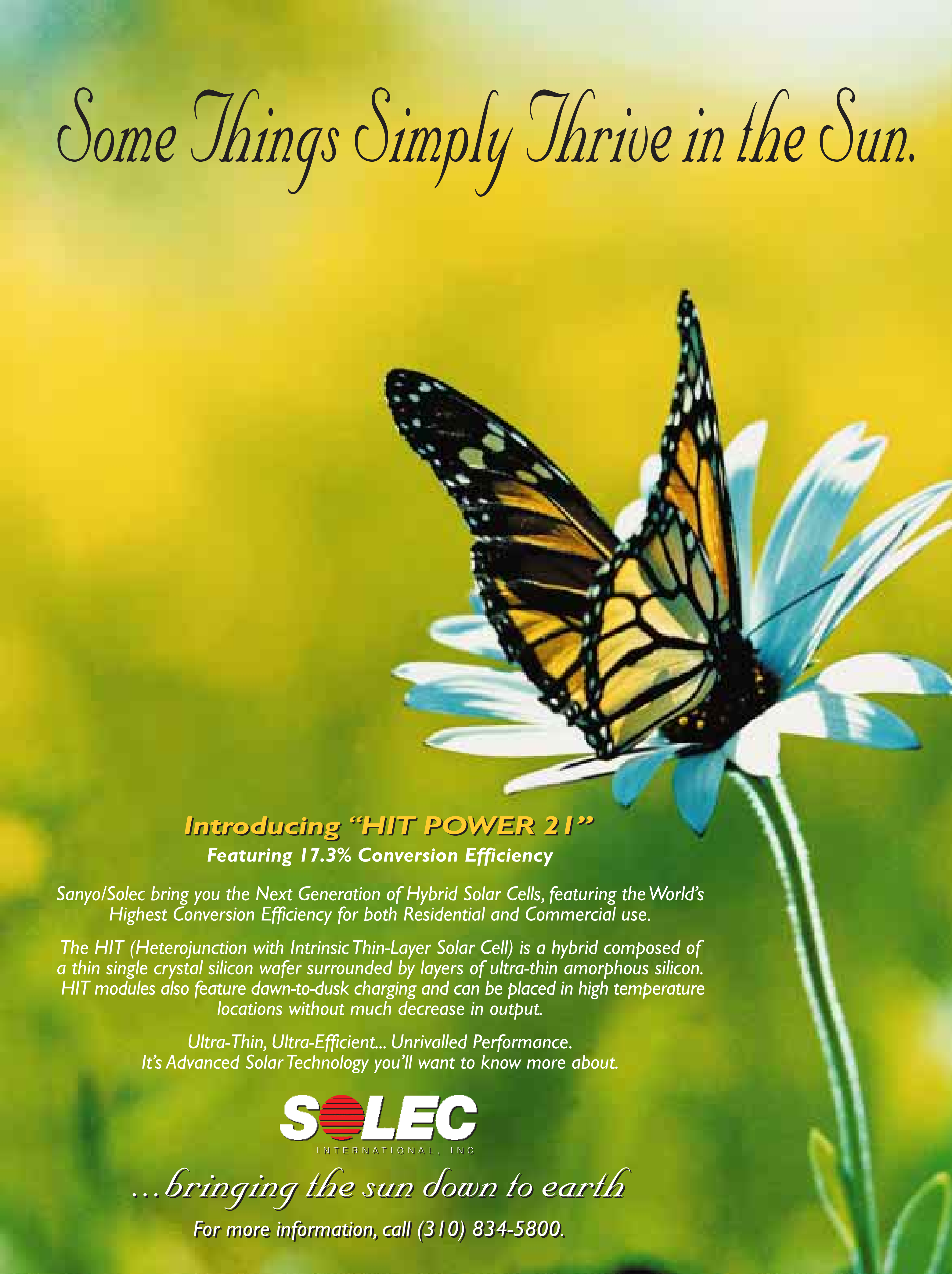
Stand-alone turbine manufacturer, using synchronous generators: Canyon Industries, 5346 Mosquito Lake Rd., Deming, WA 98244 • 360-592-5552
Fax: 360-592-2235 • CITurbine@aol.com
www.canyonindustriesinc.com

Stand-alone induction experts with the most experience in North America: Thomson and Howe, Site 17, Box 2, S.S. 1, Kimberley, BC, Canada V1A 2Y3
250-427-4326 • Fax: 250-427-3577
thes@cyberlink.bc.ca • www.smallhydropower.com

Micro-Hydropower Sourcebook, 1999. Allen Inversin, NRECA. US$26 postpaid from NRECA International Foundation, Mail Code IPD9-202, 4301 Wilson Boulevard, Arlington, VA 22203-1860
703-907-5637 • Fax: 703-907-5532
allen.inversin@nreca.org • www.nreca.org

Micro-Hydro Design Manual, 1993. Adam Harvey, IT Publications. $55 from Stylus Publishing L.L.C., PO Box 605, Herndon, VA 20172 • 703-661-1581
Fax: 703-661-1501 • styluspub@aol.com

Motors as Generators For Micro-Hydro Power, Nigel Smith, IT Publications. $12 from Stylus Publishing L.L.C. (see above).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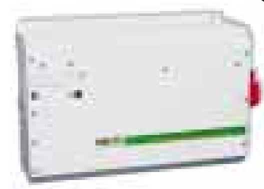
Without the need for flashy product pictures and fancy marketing ploys, we would like for you to decide which inverter will be trusted in your home. These laboratory test results intend to clear up misconceptions and illustrate an accurate comparison between Trace Engineering's SW2512 and the Statpower PROsine 2.5. Knowledge is power and so is a highly efficient inverter with low idle power consumption!



SW III

	TRACE SW2512	Statpower PROsine 2.5
✔ **Idle Power Consumption**	13 watts typical	60 watts typical
Efficiency		
100 watts AC load	88%	62%
200 watts AC load	91%	71%
500 watts AC load	93%	84%
1500 watts AC load	88%	88%
Peak efficiency	93%	88%
AC output waveform distortion	Less than 5% / typical 2%	Less than 5% / typical 2%
Number of 50 Watt PV modules to meet inverter's idle power Draw without use of search mode	1.3 PV modules in summer 3.1 PV modules in winter	5.8 PV modules in summer 14.4 PV modules in winter
Search Mode Power Consumption	Less than 1 watt	3 watts typical
Response time to AC loads coming out of search mode	Less than one second	Up to three seconds
Search mode adjustability	0 to 256 watts, via LCD control panel	0, 12, 25 or 50 via micro-switches on side
Ability to override search mode without changing control settings	Yes	No
Battery charger rating	150 amps DC	100 amps DC
Battery type compatibility	Fully adjustable bulk, float & equalize voltage. Adjustable absorption & equalize timers	Micro switch for sealed or vented battery type. Fixed absorption and equalization settings.
Battery Temperature Sensor	Standard	Optional
Synchronous AC operation	With utility grid or generator AC sources	Not available
AC transfer switch capacity	60 amps AC	30 amps AC
AC Inputs	Two - separate generator and utility grid inputs	One
Maximum AC pass-through with full battery charger operation	35 amps AC	9 amps AC
Maximum generator input power	7.2 kW	3.6 kW
AC input amps adjustment	1 to 60 amps AC in 1 amp increments	10, 15, 20 and 30 amps AC current settings
AC lower voltage limit	Adjustable	Fixed at 90 VAC
Standard display / Control panel	Advanced - full control & setpoint adjustment	Basic - limited control, no setpoint adjustment
Display type	Two line 32 character LCD with backlight Two 8 system status LED indicators Includes 9 meters - AC/DC volts/amps/freq Provides access to all settings	LED bar graph displays 10 system status LED indicators All settings via micro-switches on side of inverter
Optional Displays	Second advanced remote control panel PC / serial communication adapter	Advanced LCD control panel - $249 additional
Maximum control panels allowed	Two - one built-in / one remote	One only - no on/off switch on unit itself
Generator Management system	Standard - manual and automatic control	Not available
Series stacking option for 120/240 VAC	Yes	No
Parallel stacking Option for higher power	Yes	No
Suggested retail price	$2585.00 USD	$2,599.95 USD

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TOP SECRET

GUERRILLA SOLAR PROFILE: 0004

DATE: June, 1999

LOCATION: Somewhere in the USA

INSTALLER NAME: Classified

OWNER NAME: Classified

INTERTIED UTILITY: Classified

SYSTEM SIZE: 100 watts of photovoltaics; 1,500 watt wind generator.

PERCENT OF ANNUAL LOAD: 50%

TIME IN SERVICE: 2 years

NOTES: My system consists of a 100 watt Carrizo PV array that I picked up at an energy fair a few years ago. The PVs feed a small synchronous utility-intertie inverter. The wind system is a Whisper H1500 HV on a 100 foot tower. This sends 220 volt three-phase wild AC to a rebuilt Gemini utility-intertie inverter, one of the first synchronous inverters made. This inverter shuts down when the grid fails, and I have to manually restart it. It's far safer than all those Y2K backup gensets that are improperly wired and can backfeed the lines.

Our system has been up and running for about two years. Because our house is all electric, our bills are high, especially in the winter months here in the north. We use baseboard electric heat, with wood heat to supplement it in the coldest times. Our bills have been cut in half since I put in these systems. Our average winter bill used to be $100-120. Now it's only $45-65. Everyone said that this is not a good place for wind or solar. I didn't believe them and now I've proved them wrong. I am thinking of upgrading to a Whisper 3000 and maybe 1 KW of PV. Then I won't have to pay a utility bill at all!

The local power company is not at all friendly to small-scale renewables. They have ratcheting meters, so I can't actually sell power back to them. All I can do is offset our peak usage here. When our PVs and wind genny are making more than we are using, I'm giving our surplus to them. That rubs me the wrong way! But for me to go legal, they want a large disconnect and a separate meter. And they want to charge me a $20 per month meter reading fee!

I also have a 4 KW Trace inverter and a 1,000 amp-hour battery bank. I can divert the wind and solar to this standby system and go totally off-grid. If my utility rates keep going up, I might just do that...


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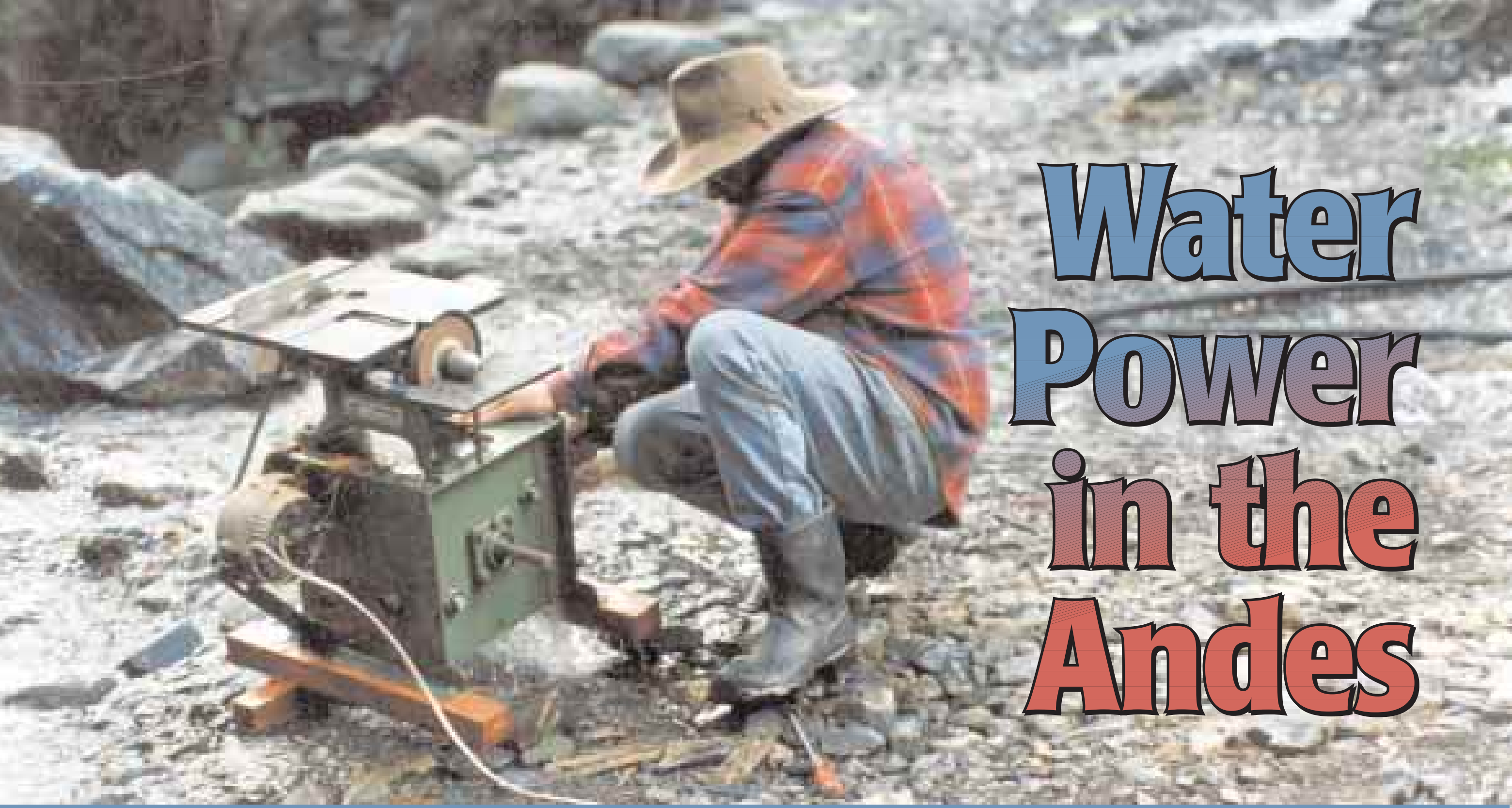


Water Power in the Andes

Yesterday's Solution For Today's Needs

Ron Davis

Ron Davis tests an early Watermotor: falling water powers a saw, grinding wheel, and alternator for electricity.

Going to work these days is always a bit of a thrill for me—often more than I care for. It means crossing a 15,000 foot (4,570 m) pass over the Bolivian Andes and snaking down a muddy one lane road carved into the face of immense cliffs. *The Most Dangerous Road in the World* was the title of an old *National Geographic* article about this spectacular route.

World's Biggest Solar Machine

Actually I'm entering the world's biggest solar energy machine—the Amazon basin. Towering glacier-topped 20,000 foot (6,100 m) peaks are clearly visible from our tropical water power demonstration site. The eastern face of the Andes so thoroughly captures the Amazon moisture that the western side—the Atacama desert—is said to be the driest place in the world. Sometimes rain only falls there a few times during an entire lifetime.

But on this side, it's just the opposite. Uncounted streams and waterfalls abound, some falling hundreds of feet directly onto the roadway! About 80 people die each year on this short section of road, since it is very narrow and slippery. Vehicles that slip off the road can simply disappear into dense vegetation a thousand feet (300 m) below. It's incredible to think that this is the only road into a tropical part of Bolivia the size of Texas.

Leaving the narrow road, it's a relief to arrive in the lovely town of Coroico at 5,500 feet (1,676 m), near our demonstration site. Green hillsides are covered with coffee, citrus, and bananas. This also happens to be the home of Bolivia's traditional coca leaf production, so the area is much affected by the U.S. "war on drugs."

Campo Nuevo—Meeting People's Needs

Over fifteen years ago, Diane Bellomy and I founded Campo Nuevo. We started our family-sized appropriate technology organization to improve lives by bringing simple technology to Bolivia's indigenous people. We teach them how to use their local natural resources for energy. We want to show people how easy it is to employ the abundant small local sources of water power to improve their lives. This can help make it possible for them to remain on their land and in their own communities.

We are working with Aymara-speaking native Americans, one of the largest and most intact indigenous cultures in the Western Hemisphere.

Notable for having withstood the Incan conquest, and later the Spaniards, the Aymaras are now succumbing to the pressures of modern global economics. Like rural people all over the "third world," they are being forced to relocate simply to survive. They usually migrate to a desolate 13,000 foot (3,960 m) suburb of La Paz, in order to compete for unskilled, low paying, and often temporary jobs.

A New-Old Solution

Although they may not realize it, what visitors to our demonstration site see is not really new. It's actually a revival of the nearly forgotten traditional use of water power. For thousands of years before the invention of centrally generated electricity, water power was employed to directly run machines, something it does very well.

What *is* new is the development of a modern low-cost turbine specifically for this purpose—a "motor" driven by water power. We call it the Watermotor. It can provide the energy to drive a variety of machines, replacing the mid-sized electric motors upon which nearly all modern production depends.

Lester Pelton, who invented the Pelton wheel, produced a variety of these water powered motors. They were in use before 1900, powering individual machines. Pelton even used one to run a sewing machine! The direct drive hydro units were replaced by electric motors after centrally produced electricity became the norm.

Few people realize how closely rural poverty is related to the lack of machines necessary for local production and services. In the third world, the power grid is usually confined to cities and large towns. Rural people still use muscle power as everyone did in the past, and they do without electric lights. The need to generate cash to buy anything they don't produce themselves causes a focus on cash crops. This further reduces their self-sufficiency, encouraging a downward spiral towards dependency on a system that cannot be depended upon!

Demo Site

Water power is nature's most concentrated form of solar energy, and by far the easiest to convert into usable mechanical power. At our new Campo Nuevo demonstration site, we are featuring practical machines, directly powered by water. There are woodworking tools, air compressors, and water-powered water pumps. We also run an auto alternator to charge batteries and provide lighting. This can be switched on when mechanical power is not being used, and is driven by the same belt drive that powers the tools.

The main attraction at our site is a Watermotor driving a small multipurpose woodworking unit. The machine is

Campo Nuevo assistant, Iran, rips a board.

suitable for producing doors, window frames, and furniture—necessities usually purchased from the city. It processes locally grown timber instead of wood carried up from the Amazon forest.

The Watermotor at our demonstration site is provided with power from a water source located 65 feet (19.8 m) above the machine by four 170 foot long (52 m) 1 1/2 inch (38 mm) polyethylene pipes. At the heart of our turbine are two Energy Systems & Design plastic mini-Pelton wheels, mounted on a single shaft and driven by two water jets each. With a flow of 82 gallons (310 l) per minute, we get power similar to a 3/4 HP electric

The first Watermotor—the start of a revolution.

Plumbed to the power and ready to rip.

motor, at about 1,450 rpm. Unlike an electric motor, the Watermotor costs nothing to operate and can't be burned out by hard use.

It's Not Easy

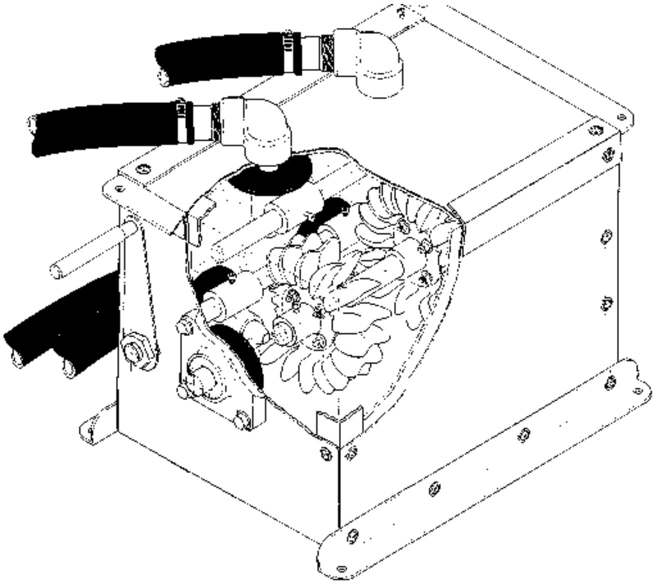
Not much of this area is served by roads or the power grid. The U.S. owned (and U.S. priced) power generating system has little incentive to provide long distance lines to a widely scattered and typically impoverished rural population. Water power is the sole available practical source of energy to run machines. There is not a good wind resource in the mountain valleys and PV is just not economical, compared to the abundant water power here.

There are major obstacles to the introduction of unfamiliar technology to an indigenous population that has traditionally used no machines of any kind. These people have little money to invest in anything that does not promise a practical return. In addition, the Aymaras are unlikely to be reached by advertising in the city newspapers. This is why we felt that a local demonstration site was necessary.

Other problems are encountered when machines, however useful, need to be professionally installed, maintained, or repaired. Outside the city, such services are frequently unreliable, hard to come by, and expensive when available.

The Watermotor on its side with twin turbines exposed.

Cutaway View of the Watermotor



Keep It Simple

In order to overcome these obstacles, we designed the Watermotor to be user installed, maintained, and repaired. Because it is locally produced from common materials, all parts can be easily replaced. Only the Pelton wheels need to be obtained from other than local sources. A Watermotor can be made with hand tools and a drill press, though some welding is required. Most builders will find it convenient to have the hubs which connect the Pelton wheels to the shaft made by a local machine shop.

The efficiency of direct drive water power is a big advantage. A surprisingly small amount of water falling a short distance can produce the 0.5 to 3.5 HP of mechanical power required by most common machines. This means that many potential water power sites are available, and a minimum of civil engineering is required. Water is carried to the turbine by low cost, easily transportable plastic pipes. Rigid large diameter penstocks which require skilled installation are not necessary.

Other projects by Campo Nuevo include ferro-cement water storage tanks, ram pumps, hand powered water pumps, electric and treadle spinning machines, and adobe brick and plastic greenhouses.

The Watermotor itself is very simple to build, operate, and maintain. It functions efficiently in a variety of water power situations. By merely experimenting with easily changed water jets of different sizes, it is possible to vary maximum power output. This also allows the turbine to maintain efficient output over seasonal water flow variations. Control handles connected to the jets are used to divert water flow away from the Pelton wheels, cutting power.

Power Output

Regarding output and efficiency, you can determine how much energy you could get from a particular water power source by using this formula:

$$HP = H \times F \times E \times 0.18 \div 746$$

where HP is horsepower, H is total head (fall) in feet, F is flow in gallons per minute, and E is efficiency in percent. For the metric equivalent to this formula, see pages 42 and 43 in this issue.

Several things need to be considered along with this formula. Pelton wheels are usually about 75 percent efficient. There will always be some pressure loss due to friction in the water supply pipes. Your local supplier should be able to help calculate this for different products. Tables for pressure loss in pipes of various sizes can also be found in alternative energy catalogues.

The power output of the Watermotor depends on the fall and the amount of water used to run it. Here are some examples of other possible installations and the energy output that they would produce:

• A 100 foot (30 m) fall and 110 gallons (416 l) per minute would produce 2 HP at 2,050 rpm.

• A 150 foot (46 m) fall and 184 gallons (697 l) per minute would produce 5 HP at 2,550 rpm.

The Basics

The Watermotor can be used to drive most stationary machines normally driven by an externally-mounted electric motor or small gasoline engine in the 0.5 to 3.5 horsepower range. Power output can also be increased by simply lengthening the housing to accommodate more Pelton wheels, without basic design change.

Machines are driven by standard belts and mounted directly on or beside the turbine housing. The shaft between the Watermotor and the tool is 7/8 inch (22 mm), and the housing is about 12 by 12 by 14 inches (30 x 30 x 36 cm). The turbine must be mounted to accommodate the outflow without having water back up. We use a cement box as a tailrace, with a 4 inch (10 cm) drain pipe which returns the water to the stream.

Make the Comparison

How does the Watermotor stack up against the competition? I asked a couple of RE experts to give me the rough cost of a wind or PV system capable of producing 2 1/2 HP of mechanical energy 24 hours a day, including installation in rural Bolivia and technical expertise for maintenance and repair.

Richard Perez of *Home Power* said, "Well, the PVs alone will cost about US$35,000. And the requirement for 24 hour power at that level means a very large battery bank which will bring the system cost up to around US$70,000. And we still need to add small stuff like racks, inverter, and controls. Overall, I'd say about US$80,000. It really points out how cheap hydro is."

North American wind power guru Mick Sagrillo said, "My guess, using off the shelf equipment, would be that you'd need a 10 KW Bergey Excel. While it's larger than what's needed, it's cheaper than putting up several smaller turbines. The cost for both genny and controls is about US$20,000, less tower, wiring, batteries, and balance of systems components. Total system cost would be roughly US$35,000. The one message I always deliver at my wind power workshops is that if anyone has a good hydro site, they're in the wrong workshop. While wind is cheaper than PV, it's no comparison for a hydro site with a 100 percent capacity factor."

Now, this is not a scientific comparison, and these are admittedly rough figures. But the Watermotor can produce 2 1/2 HP continuously—with a system cost of less than US$2,000. It's user installable and maintainable (two lubrication points), and easily repairable. It has only one moving part, can be locally produced in a small shop, and is immune to damage from hard use. Also consider that PV and wind equipment are imported, and that there's a good chance of damage from misuse or poor maintenance.

Watermotor type designs were abandoned about l00 years ago in the developed world in favor of electric motors. To the best of my knowledge, there are no machines equivalent to the Watermotor being produced today. Generally, very few products, no matter how useful, are produced with the aim of promoting self-sufficiency among the world's rural poor.

Water Power to the People

The best advertisement for our water driven machines is for them to be seen hard at work by the many people passing the demo site daily. Woodworking machines in particular have a substantial per-hour cash value. Because the Watermotor is immune to damage from hard use, it is suitable to rent or lease. At current rates, the entire cost of a Watermotor installation should be recovered in only a few months.

We expect visitors to our demonstration site to have their own ideas about how they can use the Watermotor. The experience gained at this site will provide us with knowledge and incentive to build similar sites in other parts of Bolivia. Plans are available—contact us for more information about building and using the Watermotor.

While Bolivia is especially rich in water power resources, many other parts of the world have similar conditions, and similar needs. We would like to see this clean, self-renewing, easy to use natural resource made available to all.

Access

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TOP SECRET

GUERRILLA SOLAR PROFILE: 0005

DATE: June, 1999

LOCATION: Somewhere in the USA

INSTALLER NAME: Classified

OWNER NAME: Classified

INTERTIED UTILITY: Classified

SYSTEM SIZE: 500 watts of photovoltaics.

PERCENT OF ANNUAL LOAD: 50%

TIME IN SERVICE: 1 year

NOTES: My system is based on a Trace SW2512 inverter, as you can see from the photo. I have eight Siemens PV panels producing over 40 amps. My battery pack consists of eight Trojan L-16s. This is my base system--I plan to expand when needed.

Right now, I use solar to power my TVs, stereos, and computers, plus several lights, including exterior lighting. I've been living in my custom 5,400 square foot home for about a year now, and the system is great. Even with this large house, my power bill last month was only $28. Before I put the system in last year, my bill was about $60 a month.

I'm also using a Stargate home automation system. The Stargate uses X-10 technology, and sends its signal through the existing electrical wiring in the house. I need to have the inverter in sync with the sine wave from the grid to reach throughout the house. The inverter must be in sell mode to do this.

This automation system is also an energy saver. Lights and other loads never get left on unnecessarily. I'm working on a summer home up north and I'll set it up so I can control the heating automatically from down here.

I have a strong desire to be independent. I want to give back what I can in terms of energy. I built this custom home and I can control the various independent systems. I'd like to have one of your T-shirts to proudly say I'm a Solar Guerrilla.

Will Your Utility Interact With You?

Utility Interactive Inverter Safety

Joe Schwartz

Take a look at today's market for utility interactive (UI) renewable energy systems. In the U.S. alone, utility interactive inverters capable of safely placing clean, independently-produced electricity onto your local utility grid are being sold and installed by the thousands. The grid intertied RE market is booming as Americans spend big money on state of the art equipment. In most cases, people are doing so without any hope that their system will ever provide a monetary payback. What's their motivation?

For one thing, they want a cleaner environment and they are willing to pay for it. And with the addition of batteries, a UI system takes on a greatly expanded role as an uninterruptible power supply (UPS) for both residences and businesses. Homeowners now have the ability to back up critical household loads like well pumps, furnace blowers, freezers, computers, and lighting. Today's business environment absolutely requires an uninterruptible and high quality source of power, since information transfer is expected to be seamless.

Think about it. Virtually every hospital, bank, and large business has invested in a UPS. The utilities' lack of confidence in their ability to deliver continuous high quality power is obvious as we watch them recommend surge suppressors and UPSs for customers with home computers.

UI inverters give us the ability to safely place energy from the sun, wind, and water onto the utility grid and share it with our neighbors. UI inverters give our homes and businesses a source of electricity when the grid fails. UI inverters give some utilities a headache.

Who's Above The Law?

Utility response to small-scale generation from renewable energy has ranged from caution to downright foot dragging. If you're living on-grid, you probably already know that your local utility has what amounts to a monopoly on the electricity you're buying. Don't like the service? Tough.

Americans have had to resort to legislation in order to liberate clean energy from the grasp of repressive utilities. Currently, twenty-seven U.S. states have enacted net metering legislation, which forces utilities to pay their customers a fair price for independently produced renewable energy. However, even in states where net metering is law, many local utilities are making implementation so difficult that the laws are meaningless. Citing safety, reluctant utilities are skirting legislation by requiring UI customers to have excessive insurance policies and expensive, redundant safety equipment.

It doesn't even stop there. This past year, utilities in both Maine and Iowa challenged state net metering laws, attempting to have them repealed outright. Fortunately, clean energy supporters handily defeated utility interests in both cases (see Bill Lord's article in *HP65).* Remember, as a utility customer in a net metering state, you are simply attempting to exercise your legal right to put clean electricity onto the local utility grid, and receive a fair payment for your investment.

Are You Above The Law?

Take a look at today's market for utility interactive renewable energy systems. In the twenty-six states without net metering legislation, you'll begin to see RE systems being installed without the benefit of statewide legislation or even the approval of utilities. Take another look and you'll see that the number of installed UI systems in the U.S. may have just doubled.

Regardless of the local utility's position, Americans are purchasing and installing UI inverters and renewable charging sources because it's the right thing to do. If you come up against a stubborn utility, you just might find yourself quietly hitting the "sell" button on your inverter. The result? De facto net metering without jumping through hoop one. It's painfully obvious that the technology of UI power systems—and the human ingenuity behind them—is outdistancing ineffective regulation and unwilling utilities.

While most *Home Power* readers give a quiet nod to unauthorized or guerrilla RE systems, disregarding obstructionistic utilities is an uncomfortable position for some. What's their big issue? The safety of utility line workers, without exception.

Utility Interactive Inverters

Modern synchronous inverter technology allows for safe and efficient home-based utility-interactive generation systems. These inverters are capable of synchronizing the frequency of their AC output to the waveform of the utility grid. The popular Trace SW series inverters, manufactured in Arlington, Washington, have revolutionized the grid intertie market and represent the majority of UI inverters currently installed in the U.S.

Trace sine wave inverters are available for both battery-based UPS and battery-less applications. Battery-based UI units are available with outputs of 2,500, 4,000, and 5,500 VA (volt-amperes) at either 120 or 240 VAC/60 Hz. Export models are also available with 230 VAC/50 Hz outputs. Battery-less UI units offer outputs of 4,000 and 5,500 VA at either 120 or 240 VAC/60 Hz. Export models are also available for the battery-less UI units. If power demands are higher than the rated output of a single inverter, two battery-based units can be operated in series with the addition of a stacking interface cable. This configuration effectively doubles inverter output.

Multiple inverters can be used for outputs of up to 30 KW. Can't afford 30 KW of PV right out of the gate? On the other end of the spectrum, Trace offers small synchronous inverters with a rated output of 100 VA. The MicroSine inverter is available with 120 or 240 VAC/60 Hz output. Again, export models are available. This synchronous inverter is designed for battery-less installations using one 24 VDC PV or two 12 VDC PVs.

Advanced Energy Systems (AES) of Wilton, New Hampshire, also manufacturers a synchronous, module-integrated inverter with a rated output of 250 VA. In addition, AES is currently manufacturing the conveniently sized GC-1000 UI inverter, with a rated output of 1,000 VA. Both of these AES inverters are designed for battery-less, UI applications.

All of these inverters have been tested and approved to meet the safety standards established by Underwriters Laboratories (UL). These listed products are certified to perform safely, as advertised. Because the Trace SW series inverters currently make up the majority of installed UI inverters in the U.S., their safety features deserve a closer look.

Safety Break

The protective systems of the Trace SW series inverters are exceptional. These systems are designed to protect utility personnel and both private and utility owned power generation and transmission hardware. The protective features address all situations where disconnecting a UI inverter from a failed utility grid is essential, including open circuit, short circuit, and islanding conditions.

The safety features specified by the manufacturer have been approved by all utilities who have undertaken testing of the inverters. No shortcomings in the units' protective circuity have been documented. In fact, in some applications, poor utility power quality has actually limited some customers from using their SW inverter in UI mode. The inverter's preset power quality parameters will not allow the unit to become synchronous with the utility if grid voltage varies +/-10 percent or frequency varies +/-2 Hz. To meet proposed IEEE (Institute of Electrical & Electronic Engineers) standards, an upcoming software revision will preset this frequency window at +/-0.5 Hz.

Open and Short Circuits

Wind and ice storms take down power lines across the U.S. quite frequently. This typically results in either an open circuit, if the downed lines are cut, or a short circuit, if hot and neutral wires come into contact. In an open circuit condition, the Trace SW series inverter will disconnect from the utility grid within one second of the loss of grid power. If a short circuit occurs on the grid, the inverter will reach its overcurrent limit and disconnect its output from the utility in under four milliseconds.

It's important to note that the inverter does not arbitrarily attempt to re-synchronize with the grid after a separation from the utility has occurred. Before reconnecting to the utility grid, the inverter monitors for excessive variations in either the frequency or voltage of the grid for eight seconds. If grid power quality is within specified parameters, the inverter's output will synchronize its waveform with the grid for an additional eight seconds. During this period, the inverter's microprocessor will continually monitor for unacceptable voltage and frequency variations, and phase angle differences greater than two degrees. Only after the grid is determined to be stable will the inverter open an internal relay and resume parallel operation with the utility.

Islanding

A slightly more complex safety concern related to UI inverter use is a condition called islanding. This refers to a fragmented utility grid where a UI inverter or engine generator could possibly energize the lines within this island. Imagine, for example, that the power lines were cut in two places, leaving you and your neighbor's houses connected to each other, but not to the grid. Your UI inverter or engine generator could theoretically energize the lines between the two houses.

Islanding first became an issue when generators were incorrectly installed and backfed an islanded utility grid. Without the addition of advanced power conditioning equipment, most engine generators lack the control logic incorporated into all UI inverters, and will not disconnect from an islanded utility grid. Unfortunately, irresponsible generator use has both injured and killed utility workers. It has also made many utilities hesitant or straight out unwilling to allow any non-utility generated electricity onto the grid.

Trace has eliminated the possibility of their UI inverters causing an islanded condition by incorporating an active islanding detection circuit. This circuit relies on a zero point crossing strategy to ensure disconnection from an islanded utility grid. The circuit monitors the waveform of the utility grid every time the sine wave crosses the zero point. That's approximately once every 16 milliseconds. If a loss of source is detected, the inverter is offline within one second.

This hypothetical islanding situation can be stretched even further. Say your neighbor fires up an improperly installed engine generator and backfeeds the same fragmented grid. Your inverter would initially attempt to sync up with the output of the generator as if it were the utility grid. In this instance, the inverter relies on its over/under frequency and voltage circuits. Again, if the frequency varies +/-2 Hz, the inverter is offline in under one second. If the inverter senses +/-10 percent variation in voltage, it is offline in under one second.

Trace Engineering's literature states that "since the inverter is locked onto the frequency of the islanded utility grid, the frequency of the system will drift out of regulation in a short amount of time during an islanding condition." The conclusion is that the islanded system will be overloaded in terms of generator/inverter capacity and that the frequency, voltage, or both will drop below spec, causing the inverter to disconnect from the islanded grid. But let's be clear—the inappropriate use of the engine/generator is the cause of this situation and the owner of that system should be held responsible.

As an aside, Trace SW inverters have the capability of auto starting engine generators based on either preset voltage or time parameters. The inverter's control circuitry will not allow a connected generator to attempt to operate in parallel with the utility.

Additional Safety Features

Concerned *Home Power* readers have argued, "What if the inverter's protective systems fail and injure a line worker?" The protection circuitry of each Trace SW inverter is tested and certified before the unit is shipped from the factory. However, no equipment can be guaranteed never to fail, and Trace Engineering is aware of this. In addition to the safety functions of the inverter's main processor, five additional dedicated safety circuits continuously monitor the main processor. In the unlikely but not impossible event of a main processor failure, these circuits will immediately shut down the inverter and will not allow it to restart.

You might ask, "What if all five of these protective circuits fail?" To threaten a line worker's safety, all of the inverter's redundant safety features would need to fail simultaneously. With thousands of UI inverters installed, this type of catastrophic failure has never occurred. In addition, this undocumented failure would need to occur while the inverter was feeding electricity onto the grid, within 16 milliseconds of a grid failure, and the inverter would need to synchronize with a utility grid that doesn't even exist. Finally, in order to be injured, utility line workers would have to ignore the same protocol they rely on every day they are in the field (assume that it's hot, and ground all potentially energized conductors). Remember, utility workers are trained professionals and routinely work under hazardous conditions.

Demand Clean Energy

Utilities are responsible for the well-being of their line workers and they need to be thorough when evaluating the safety features of unfamiliar equipment. Our obvious first step is to educate inexperienced utilities regarding the power quality and redundant safety features modern synchronous inverters incorporate. If a given utility is still reluctant to approve an installation for reasons of safety, then their motivation is suspect.

What else could possibly motivate them? Try money and control. Utilities despise the thought of having their rates legislated, but then they're the ones that make this a necessity in the first place. Many utilities will also assert that the transmission of your renewable energy amounts to a subsidy and that it is unfair to expect the utility or its entire rate base to bear this cost. You can point out that they don't seem too concerned about the entire rate base breathing their pollution.

And don't fail to mention that U.S. utilities have been subsidized from day one. Federal subsidies fund the construction of their dams and transmission lines. U.S. citizens subsidize the utilities with our tax dollars as we undertake the nearly impossible task of revitalizing dead salmon runs and cleaning up their failed nukes. All we ask is that the utilities place our renewable energy onto the grid and pay us a fair price for our investment. It sure doesn't seem like too much to ask.

And if you do ask, and your local utility plays obstructionist, you will find yourself facing the same decision hundreds of other Americans continue to face.

How important is clean, renewable energy, and does the utility have a responsibility to distribute it? In a perfect world, the utilities would welcome our renewable energy onto the grid and there would be no need for unapproved, guerrilla RE systems. The funny thing is that the people the utilities are so concerned about are the very ones trying to make the world a little more perfect.

Utility Interactive Checklist

Anyone interested in installing a utility interactive RE system should have a thorough understanding of what makes a given system safe. Ask your equipment supplier any specific questions you may have. If you come up short, try the equipment manufacturer or your local utility. If you still have any doubts, then hire a local RE dealer to install the system for you. Here's a checklist for anyone planning to install a UI system.

• All products used in your system should carry a UL or equivalent listing. This ensures that the gear that you, your neighbors, and utility line workers are relying on has been certified to be safe.

• Your system should be installed to meet NEC code. This includes appropriate wire sizing, fusing, disconnects, and equipment accessibility and clearance. Your system should also be inspected by your local electrical inspector. This inspector is concerned primarily with fire safety and typically does not operate in conjunction with utility personnel.

• Above and beyond the UL certified safety capabilities built into utility interactive inverters, both the NEC and utilities typically require either a manual disconnect or a satisfactory visible open point at the location of interconnection. This establishes a means for utility workers to disconnect all on-site sources of power generation. Accepted options range from utility workers simply removing the meter from the meter base and capping it off, to providing a separate, lockable disconnect that only utility personnel can access.

• The means of disconnect should be clearly labeled as such, for example "Solar Electric System Disconnect."

• An attempt should be made to get approval for your UI system from your local utility. The more aware and educated the utilities are regarding the use of UI inverters, the more commonplace they will become. Currently, twenty-four states offer net metering for RE systems. But beware—local utilities can make approval of your system virtually impossible even with net metering legislation in place. This scenario forces customers to either go guerrilla or worse yet, abandon their project altogether.

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