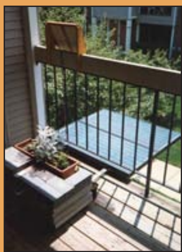
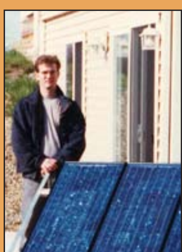




Growing with the Sun

We have all heard that one of the advantages of a photovoltaic (PV) system is its ability to grow and expand as new resources—time, money, desire—become available, and demand for clean, solar electricity increases. This article describes the growth of my system, from its humble beginnings almost ten years ago as a two-panel system installed on the balcony of my apartment, to the medium-sized system it is today, firmly anchored in the backyard of my home in Indianapolis.

Ralf Seip

Even though I have always been interested in eventually generating the majority of my family's electricity with a photovoltaic system, I must say that I did not specifically design my initial system with this goal in mind. I was pleasantly surprised, however, to find out how easy it was to add components as I expanded my system and new technology became available.

Throughout this growing process, panels, power centers, batteries, and controllers have been wired, rewired, taken down, relocated, and put back up many times. This work was fun and a great learning experience, but would have been a bit easier if future expansion had been considered from the very beginning!

Planting the Seeds

My earliest system saw its first rays of the sun in February 1996. At that time, I was living in a second-floor apartment. I mounted my first two Solarex MSX-60 panels on the balcony, without worrying too much about true south, panel shading, the perfect mounting angle, or even what other tenants or the landlady might say. I was harnessing the energy of the sun to power my computer and two compact fluorescent lights—that's all that mattered at that time!

From the very beginning, this system included an automatic transfer relay commonly used to switch loads to a generator when the battery voltage is low. I used it to switch loads between the solar-electric system and the utility. This allowed me to install this system in an apartment without modifying any of the existing AC wiring, and provided automatic switching to the utility to give the panels time to recharge the battery bank.

The first solar-electric "seeds" of the Seip system—two 60-watt PV panels—were installed on an apartment balcony.

The system began to grow as two panels were added, and the array was relocated to the Seips' first house.

At the time, I made two decisions that proved invaluable—I configured the system as a 24-volt system, and I chose a sine wave inverter. This allowed me to use thinner and less expensive wires, and run practically all sensitive loads without having to worry about noise or interference. Systems at 24 volts were just coming on the market then; today, most systems use this or higher voltages.

Add Plenty of Sun

Later that year, we purchased our first house, and with it, of course, two additional panels! I got my first experience at tearing my system down and reassembling it at its new location. The panels found a new place under the sun, and my little power center remained unchanged, but it and the batteries were moved to the basement.

Rather than rewiring the house to accommodate the new system, I decided to stick to the transfer relay setup, and installed "solar-only" receptacles where possible. I was now powering my computer, a printer, TV, VCR, radio, two lights, and an electric weed whacker. I was happily surprised that the little 500 W Exeltech inverter was up to the task.

I monitored the batteries with an E-Meter, another good investment that I purchased at the very beginning. It has allowed me to keep track of the batteries' state of charge from the day that they were purchased, and I never allowed discharges greater than about 30 percent. If the batteries did fall below this level, I would turn the inverter off. The transfer relay would immediately switch all connected loads to the grid, with barely a flicker. The transfer from solar electricity to grid electricity was thus simple and easy. The

E-Meter also showed me how much the various loads were consuming, important knowledge for anybody wanting to use solar electricity to charge batteries, no matter how big or small the system.

It also showed me one other thing—I was consuming energy faster than I could produce it! The inverter spent many hours in its "off" position, waiting for the sun to recharge the batteries. This was solved a year later by the addition of four more panels. I now had a fairly respectable, small-sized system—480 W of solar-electric panels, 5.3 KWH of battery capacity, 500 W of sine wave AC, and state-of-the art battery monitoring capability—powering many small loads in my house.

This year, we moved again, this time into my wife's dream home. With its long, south-facing backside, it's also my dream home.

Watch It Grow

Two years later, I took a new job in a different state. Tearing down the system turned out to be simpler than expected. I was able to take everything down and pack it up in about a day, except for the extra solar-only wiring that I had installed in our house—that stayed. I was now getting good at mounting and rewiring the modules. Subarrays consisting of four modules each (two series strings of two modules) turned out to be excellent building blocks to assemble the full array, consisting of three subarrays.

Some interesting things were beginning to happen. Systems at 24 V were becoming more commonplace, the price per module was dropping (from US$398 for 60 W in 1996 to US$282 for 60 W in 2001), and my demand for clean electricity kept on increasing. I was now truly hooked on solar energy!

I added Hydrocap recombiner caps to reduce the amount of water I needed to add to my now aging battery bank, and discovered additional interesting ways to run separate solar-only wiring and receptacles throughout the house. This was made especially easy because the new place for the batteries and inverter panel in our second home was underneath a centrally located stairwell. I was now powering a few additional loads, including another light, a DVD player, and my wife's sewing machine. My demand had again outgrown my supply—it was time for a major overhaul!

Again, this turned out to be simpler than I thought, especially because of the 24 V choice, the four-module subarrays, and the relay transfer box setup. I added a new 1,800 W sine wave inverter, increased the battery bank to 11 KWH of storage, and added 512 W of solar-electric modules.

During this expansion, only one originally purchased item had to be outright replaced. The 20 A charge controller was undersized for the 1,232 rated W at 24 VDC of solar generation capacity. The Heliotrope charge controller was retired after more than six years of excellent service. I

Demand quickly outgrew supply, prompting the addition of four more panels.

Why Not Grid-Tie?

Grid-tie systems were not common in 1996 when I started planting the seeds of my first solar-electric system. Besides, batteries provided a nice backup and true feeling of independence when grid outages did occur. These were quite frequent during our stay in Michigan, so a battery-based system made sense. Outages have not been common in Indiana, reducing the need for batteries since then.

Hassles, regulations, and requirements associated with utility-interactive systems have also kept me from using them. Furthermore, grid-tie systems require a much larger initial investment than small, battery-based systems. It is not uncommon to read in *Home Power* about "entry level" grid-tie systems that require at least 500 watts of PV (preferably more) and at least a 700-watt inverter before any electricity can be produced at all, with initial investments approaching US$5,000.

It is, of course, still possible and easy to further grow such systems by adding more modules and inverters, while following similar guidelines as those outlined in this article. Growth with these systems, however, typically comes in larger "spurts," rather than the more affordable and smaller steps that I took with my battery-based systems. Our current home does have a larger, south-facing roof that looks a bit empty without solar-electric panels. Finances permitting, a grid-tied system could definitely be a nice addition to our current solar-electric farm!

Seip System Costs

Initial System: February 1996	Cost (US$)
2 Solarex MSX-60 panels	$796
Exeltech SI500 inverter	580
E-Meter (RS232, with shunt)	233
4 Trojan T105 batteries, 220 AH, 6 V	228
Heliotrope CC20 charge controller	175
TS-30 transfer relay, 30 A	60
Cables	50
Mounting hardware	40
Battery box	25
Subtotal	$2,187

First Enhancement: September 1996	
2 Solarex MSX-60 panels	$760
Battery box vent fan	50
Mounting hardware	40
Subtotal	$850

Second Enhancement: April 1999	
4 Solarex MSX-60 panels	$1,040
Mounting hardware	80
Exeltech inverter repair	50
Cables & hardware	50
Subtotal	$1,220

Third Enhancement: January 2001	
4 Solarex MSX-60 panels	$1,130
4 Lightning arrestors	140
12 Hydrocaps	100
Mounting hardware	80
Cables & hardware	50
Subtotal	$1,500

Fourth Enhancement: June 2002	Cost (US$)
8 Solarex MSX-64 panels	$2,260
Prosine 1800 inverter, 24 V	1,109
Solar Boost SB50 controller, with display	398
4 Trojan T105 batteries, 220 AH, 6 V	272
DC250 disconnect	231
TCB10 Combiner box & fuses	192
Mounting hardware	160
12 Hydrocaps	104
Cables & hardware	100
TS-30 transfer relay, 30 A	58
2 CD60 DC breakers	54
Battery box	40
Lightning arrestor	35
Subtotal	$5,013

Fifth Enhancement: June 2004	
4 Solarex BP365 panels	$1,040
Mounting hardware	60
Cables & hardware	25
Subtotal	$1,125
Grand Total	$11,895

constructed a new battery box and a new power panel, and the new inverter was mounted beside the older 500 W model, with its own transfer relay.

The new panels (again set up as subarrays of four modules each) were added in parallel to the existing array. A new array combiner box simplified this setup, and has left ample room for future expansion.

The price of solar-electric panels and related equipment had dropped again (the same US$282 for a 64 W module in 2002), and we were now powering the home refrigerator with this system, and sun permitting, an older washing machine. This new system also permitted us to plug in an iron (1,200 W!), and newly installed solar-only receptacles in the house allowed for plugging in the vacuum cleaner every once in a while.

This was great! Seven years into the expansion of my initial two-panel solar-electric system and about US$11,000 later, we had transferred a lot of our everyday loads to solar electricity, increased our electrical independence, and were reducing our electricity bill to the tune of US$13 to $15 each month (about 30% of our total consumption).

Reap the Fruits

This year, we moved again, this time into my wife's dream home. With its long, south-facing backside, it's also *my* dream home. It is located in a subdivision governed by covenants that actually permit solar installations, as long as they have "a minimum detrimental effect on adjoining properties."

After the architectural committee approved my solar-electric system proposal and we closed escrow on the home, it was time to dismantle my system yet again and prepare it for the move. During this disassembly and reassembly, I took the time to recheck and tighten all of the electrical connections of the overall system. The array racks were anchored in concrete. (We are planning to stay here for a while.)

Outfitting this new home with solar-only receptacles had now become second nature, and now the solar-electric system loads included two computers, two printers, four lights, two TVs, two VCRs, two DVD players, the refrigerator, a few small tools in the workshop, and the washing machine. The final enhancement occurred last year with the addition of 260 more watts of solar generating capacity.

Now some more interesting things were beginning to occur. The price for solar-electric modules had dropped

Tips for Growing a System

System voltage. Choose the highest system voltage to reduce resistive losses in the wiring and allow the use of thinner and cheaper wires. Changing system voltage later during system expansions can become costly, since battery-based inverters need to be replaced, and the system's panels and batteries need to be rewired completely.

The voltage setting of some charge controllers available today is user selectable. This allows you to purchase one charge controller and initially configure it to operate at 12 V, for example, and later reuse the same charge controller in a 24 or 48 V system, all with a simple jumper setting change. In addition, some maximum power point tracking (MPPT) charge controllers are designed to convert a higher PV array voltage to a lower battery voltage. These controllers allow a variety of array voltages, which may mean that modules can be added in smaller increments.

Array mounts. Choose an array mounting scheme that can be easily duplicated as more panels are added, allowing the aesthetics of the system to remain unchanged. Also, choose an initial array location that will accommodate more panels in the future. It can be costly to add additional wiring or combiner boxes to accommodate arrays located in a different place than those previously installed.

Wire size. If permanently installing and burying power cables/conductors, choose the correct gauge wire for the maximum planned capacity. Increasing wire gauge or adding additional conductors later to accommodate larger arrays or battery banks is more trouble than it is worth.

Inverter. I did not find it necessary to purchase a large inverter from the very beginning. Inverters can be added as demand increases, connecting a few subcircuits to one inverter, and moving other circuits to the new inverter as needed.

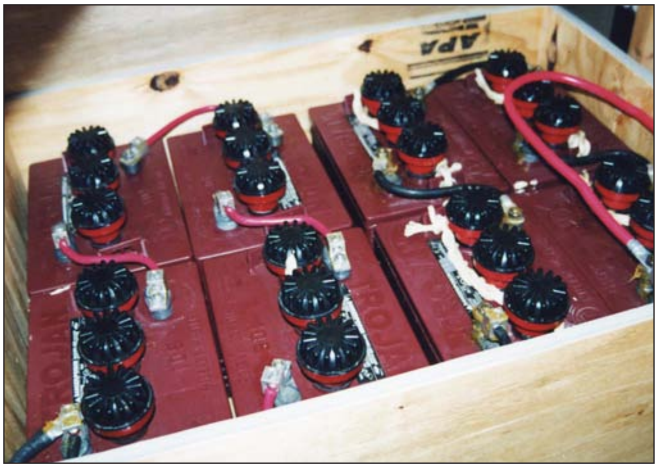
One big advantage of multiple inverters is increased system reliability. If one unit fails, the other inverter continues to power loads until the defective inverter is repaired. The disadvantage of multiple-inverter systems is that idle consumption increases with the number of inverters added. Multiple inverters will also usually cost more for the same total capacity.

Charge controller. Invest in a larger charge controller, to handle the higher charging current from added solar-electric panels. Most small systems could easily use more panels to provide more energy from the very beginning; a larger controller allows for just this.

Battery bank. Make sure that you have enough space available around the present battery location to allow for expansion. Moving the power center to a different location when you upgrade the battery bank can be expensive.

Overall system design. Finally, always design your system with expansion in mind, even though it seems adequate (or maybe even excessive) for your present needs. Believe me, once solar seeds have been planted, they keep growing!

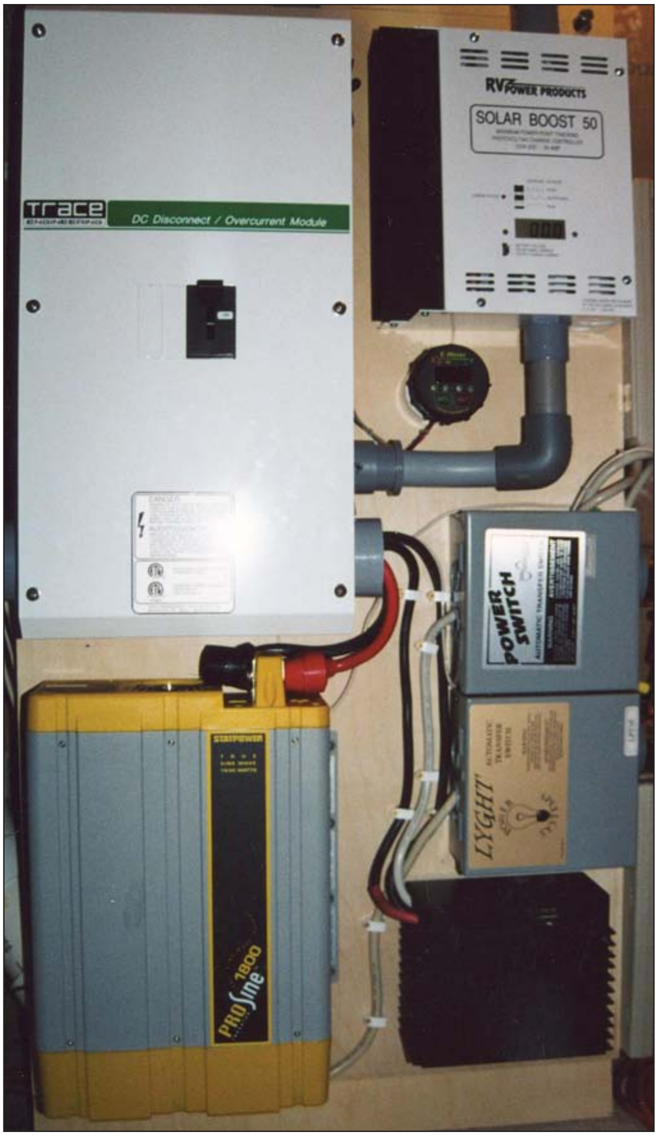
The battery capacity doubled after the last major system expansion.



again (to US$260 for 65 W in 2004), and I noticed that I could no longer obtain the MSX-60/64 modules with which I had started building my array back in 1996. They had been discontinued! BP365 panels (with aluminum frames I painted black) were the closest replacement for size, and worked nicely, allowing for more expansion in the future.

So far, this has been the only drawback of growing my system slowly—specific solar-electric modules may become obsolete. This has been offset, however, by the smaller investments over time, and the ability to buy better and more state-of-the-art hardware as the system grows. Over the years, I've spent almost US$6,000 on solar-electric modules, at an average price per watt of US$4.86.

My system now consists of 1,492 W of solar-electric panels, 2,300 W of inverters (sine wave), a 10.6 KWH battery bank (in dire need of expansion), a 50 A maximum power point tracking charge controller, and code-compliant interconnect and overcurrent protection hardware.



The new power panel with two inverters, charge controller, transfer relays, and overcurrent protection breakers for safety.

For all practical purposes, our living room, home office, game room, basement, and half of the kitchen and laundry room are now completely powered by this solar-electric system. This midsize system is now able to provide approximately 35 percent of the electricity we consume in our household, and it has been a pleasure watching it grow over time. It is amazing what the right seeds and a little bit of sun can do. May your growing season and harvest be as rewarding and plentiful as ours has been!

Access

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Backwoods Solar Electric Systems, 1589 Rapid Lightning Creek Rd., Sandpoint, ID 83864 • 208-263-4290 • Fax: 208-265-4788 • info@backwoodssolar.com • www.backwoodssolar.com • PVs, charge controller, inverter, transfer relay

Electron Connection, PO Box 203, Hornbrook, CA 96044 • 800-945-7587 or Phone/Fax: 530-475-3401 • bob-o@electronconnection.com • www.electronconnection.com • E-Meter and shunt

Sun Electronics International Inc., 511 NE 15 St., Miami, FL 33132 • 305-536-9917 • Fax: 305-371-2353 • info@sunelec.com • www.sunelec.com • PVs

Mr. Solar/Online Solar, PO Box 1506, Cockeysville, MD 21030 • 877-226-5073 or 410-308-1599 • Fax: 410-561-7813 • sales@mrsolar.com • www.mrsolar.com • Inverter, charge controller, array combiner box, lightning arrestors

Northern Arizona Wind & Sun, 2725 E. Lakin Dr., #2, Flagstaff, AZ 86004 • 800-383-0195 or 928-526-8017 • Fax: 928-527-0729 • windsun@windsun.com • www.windsun.com • Hydrocaps

Affordable Solar, PO Box 12952, Albuquerque, NM 87195 • 800-810-9939 or 505-244-1154 • Fax: 505-244-9222 • sales@affordable-solar.com • www.affordable-solar.com • PVs

BP Solar, 630 Solarex Ct., Frederick, MD 21703 • 800-521-7652 or 410-981-0240 • Fax: 410-981-0278 • info@bpsolar.com • www.bpsolar.com • PVs

Xantrex Technology Inc., 5916 195th St. NE, Arlington, WA 98223 • 360-435-8826 • Fax: 360-435-3547 • info@xantrex.com • www.xantrex.com • Inverters, breakers, DC disconnect

Exeltech, 2225 East Loop 820 North, Fort Worth, TX 76118 • 800-886-4683 or 817-595-4969 • Fax: 817-595-1290 • info@exeltech.com • www.exeltech.com • Inverter

Blue Sky Energy Inc. (formerly RV Power Products), 2598 Fortune Way Ste. K, Vista, CA 92081 • 760-597-1642 • Fax: 760-597-1731 • sales@blueskyenergyinc.com • www.blueskyenergyinc.com • Charge controller

Trojan Battery Co., 12380 Clark St., Santa Fe Springs, CA 90670 • 800-423-6569 or 562-946-8381 • Fax: 562-906-4033 • marketing@trojanbattery.com • www.trojanbattery.com • Batteries