Alternative Power Systems – Our Experience

www.underthechokotree.com

Sustainable Living in the Suburbs

By Nev Sweeney

Note: Check your local regulations to ensure DIY wiring extra low voltage is OK before starting your own system

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1.0 Introduction

Here at the Choko Tree, we have had some form of functioning alternative energy system providing us electrical power in one form or another for almost 40 years. That time can be broken up into two 'eras' for want of a better term – the earlier 12 volt era and the later 24 volt era. The changeover came in late 2016/ early 2017 due to the convergence of a couple of factors –

- One of the 12 volt battery banks was at the end of its projected life and would require replacement shortly, the other was also very old and already showing signs of failure so requirement for a serious investment was looming, and
- While we had a 1 kW back to the grid system through an inverter at the time for about 6 years, its economic benefit to the household was about to diminish considerably as the government sponsored feed in tariff of 60c per kilowatt/hour was about to drop to 8c per Kilowatt/hour and is now running at 5c per kilowatt/hour.

With the intersection of these two things, it was time for a change!

But from what to what?

The original system was based around 12 volts, using a mishmash of panels, through deep cycle batteries, was designed and built by myself over a period of many years, the details of which form the basis of this eBook. It powered, through two separate systems, our lighting and our fridge, both of which were powered directly and running on 12 volt without the use of an inverter. Some smaller bits and pieces were also powered directly or through the use of a small inverter.

The new system was based around 24 volts and was developed and installed professionally because it powers the whole house through an inverter big enough for the job and through nickel iron batteries. The new system interfaces directly with the grid-based 240 Volt AC system and because I do not have any electrical qualifications the installation and set-up had to be done professionally rather than by an amateur such as myself. I have just enough sense that I don't want to electrocute myself or burn the house down. It does not put power back to the grid, but uses the grid as a back-up.

We still have the 1kW back to the grid system and it still functions but doesn't give us much back. There is also talk on the street that they are looking to charge us to put electricity back to the grid and if that is the case the system will be switched off.

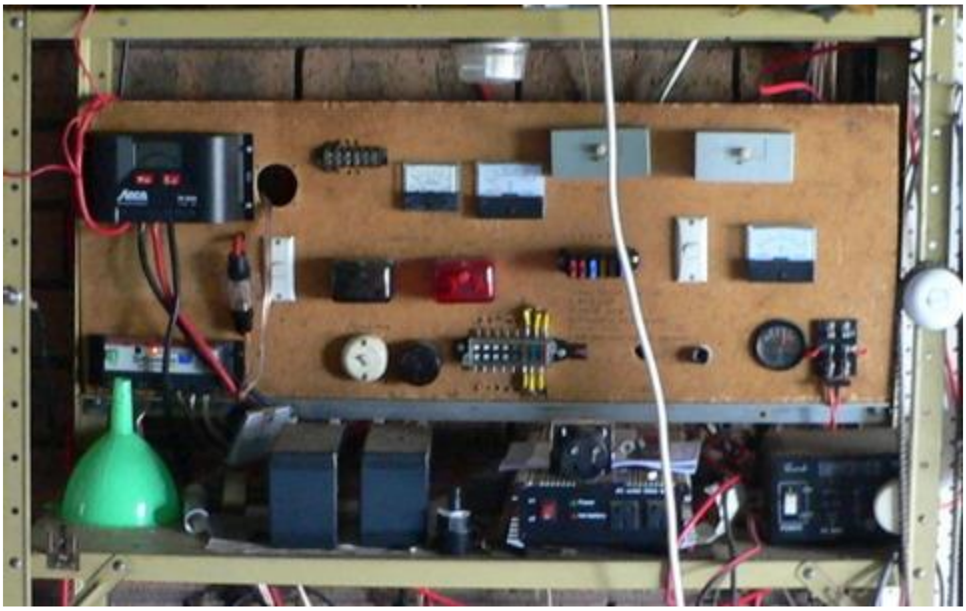
Anyway, the following eBook reflects our experiences with both of these systems.

2.0 The 12 volt DC Power System

2.1 Introduction

We live on a 600m2 suburban block in western Sydney, Australia in a late ‘70s vintage brick veneer house. The suburban location has driven some of my decisions.

This all started around 40 years ago when I decided to put in a 12 volt back up/emergency electricity supply into my house. The catalyst was a series of random blackouts/brownouts which happened due to the condition of the NSW electricity system back in the early 80’s, one of which caught my wife in the shower one night while I was in town at a meeting. That was not going to happen again!



The 12 volt switchboard in its heyday!

The system started out in reverse: instead of getting a power source, storage system, then wiring, I did some initial wiring, put in some lights and switches and then got a couple of batteries. To charge the system originally I used a 240v battery charger.

The 12 volt system evolved, and worked well, for over 35 years. I have no training in this field, but put it all together based on reading books, discussions with other enthusiasts and learning from my own mistakes. The system was the vindication of the amateur and on one of our open days a gentleman asked me if I was an electronic engineer (turns out he was!). If I can do this, almost anyone can.

The following information is current up to the time the system was partially decommissioned and replaced by the new system in February 2017.

2.2 Wiring

All the wiring used in the circuits throughout the house is multicore, plastic coated, two run (ie two sets of wires) polarized (ie one wire has white marker along it so I can tell at any point in the circuit which is negative and which is positive), and the thickest wire that I could afford at the time. Originally that was 3.5mm thick (including plastic coating) and obtained from Tandy, the wire I use now is from Jaycar Electrical and 5.0mm thick. The multicore is more flexible and generally thicker than the single core used for 240 volt house wiring.

The original lighting circuits have up to half a dozen high efficiency 12 volt fluorescent lights or 12 volts LEDs on them. The longest circuit with the fluorescents on (the bedrooms, bathroom and hall) can have a problem with the fluoros not starting up if the batteries are down a bit and there are two or more fluoros already on. This effect has not been an issue with the LEDS.

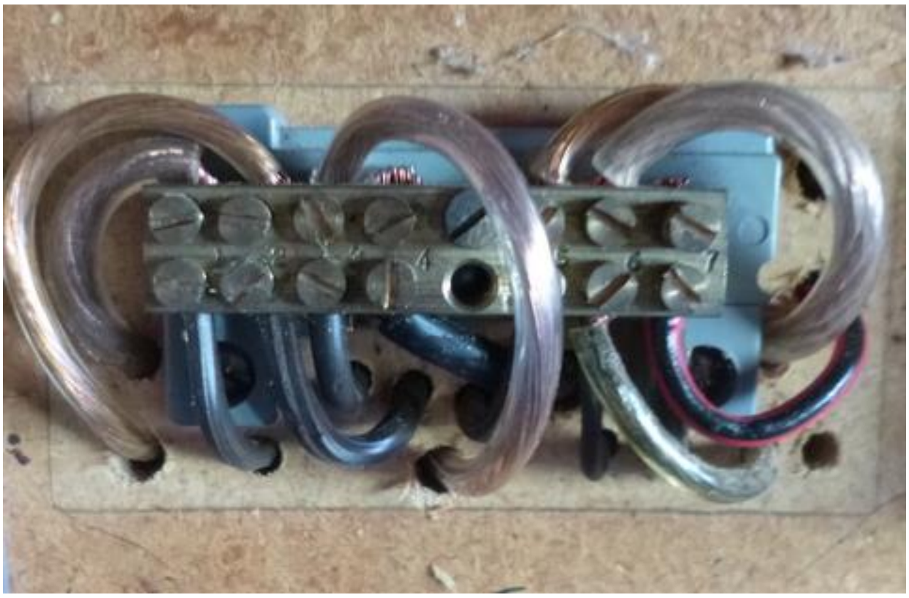
The newer circuits have only two lights per circuit and with the thicker wire, there is little or no dimming. This is the result of line losses which can be devastating in a low voltage system, so to reduce this to a minimum keep your wire runs as short as possible and your wire as thick as possible, or rather as thick as you can afford!

To connect the wires I originally used the 3M Scotchlok connectors which are designed for use on auto wiring. They usually give a quick, solid connection but can be difficult to get, and over a long time due to build-up of corrosion or whatever they can give a bit of trouble and lights can refuse to work. These days I tend to use 240v terminal blocks – cheap, accessible, easy to use (although not as quick as the Scotchlok) give a good solid join and they can accept the thicker wires much more easily. I have replaced almost all of the Scotchlok with the terminal block type.

Each circuit has a wired in auto-style fuse on the positive wire so that any short circuits do not result in a fire, and this is critical as one short circuit can burn your house down! So the lesson is – don't energise any circuit until there is a fuse in line. Initially I used the cylindrical glass automotive fuses, which did the job, but each fuse had to have its own separate mount, which is spring loaded. Over time the little plastic lug that held the spring and fuse in place would harden and eventually snap, so that at the least convenient point in time the lights would go out and I would have go into the garage and play hide and seek with the fuse, (annoying!).

Fuse block and fuses

The system I use now is based on the European style blade fuses in a fuse block that can take six or eight fuses in a row, the new system also allows me to use the push on type spade terminals to attach the wire, where the other type required soldering (which I never got around to). Overall the new system takes up less space and allows me to number each fuse so that I can record what is on the circuit that each fuse covers.



Bus bar

Bus bar - Cover in place

Wiring between the solar panels and the batteries and between the batteries and the bus bars is single run, either red or black plastic coated (red for positive and black for negative) 8mm multicore copper wire. To run multiple circuits I run a single supply wire to the bus bars, then run the multiple circuits from the bus bars (one positive one negative) otherwise you get a messy collection of lugs attached to the main battery terminals which can cause supply issues if they become corroded (due to the sulphuric acid). The bus bar system is much simpler, tidier and makes it easier to prevent interruption to supply.

Lessons:

- Get the thickest wire you can afford
- Run a number of smaller circuits rather than one long one
- Use bus bars to run the circuits.
- Don’t put too many loads on each circuit
- Install a fuse on EVERY circuit!

2.3 Switches

I use the normal surface or wall mounted 240v switches. The books say that the surface mounted switches give a faster break of the connection and so result in less sparking and therefore less erosion of the switch terminals. They also say that the normal wall mounted type are unsuitable for low voltage and erode quickly. While not being sure of the theory, all I can say is that I have had some wall mounted 240v switches in regular use for over 30 years and have yet to see one fail in service. I have had one fast-break type act up intermittently, however.

← Wall mount switch

Surface mount switch ↑

Lessons:

- Most switches will be OK

2.4 Batteries

When you decide that you are going to use battery storage it is important to decide where your battery storage area will be, while modern batteries are reasonably robust they do need some basic amenities in their accommodation. The area must be out of the weather, not too hot or cold (ie below freezing) and have good ventilation. Charging batteries results in hydrogen gas being produced which is highly flammable and too much of a build-up that come in contact with a source of ignition (which can be as little as a light switch being turned on) and you have a most disconcerting bang! You will also need to be able to get to them easily, that will make it more likely they will get maintained. If you are using lead acid batteries they are also likely to leak sulphuric acid and so they should be placed in tubs or whatever to contain any spillage, I originally used small melamine trays but the couldn't cope with the sulphuric acid, so I moved over to plastic trays, slightly larger than the base of the batteries and about 50mm high.

I still have my copy of Wind and Wind spinners by Michael Hackleman and it was this book that advocated the use of 6 volt batteries in series to obtain 12 volts. I have used that system mostly since. My first batteries were obtained in 1983 and they were a pair of 138 amp hour reconditioned second hand truck batteries and they served me well for 4 years, but they were not deep cycle (Note - deep cycle batteries are specifically designed to survive deep discharge and recharge cycles, but having said that repeated deep discharge will reduce their life). Some time after I commissioned the first set, I put in a second set, the same batteries from the same reconditioner, but they never would hold a charge and when connected in parallel only served to drain the originals. They were certified as OK by the reconditioner, but I was never able to make them work. I suppose this illustrates the first law of battery banks – thou shalt always buy all thy batteries at the same time and install them together.

In 1987 I was offered 8 x 90 amp hour deep cycle batteries ex telecom, standby batteries out of a telephone exchange from a friend of mine (see the B&W photo in the intro). They could have been in the exchange for ten years, and my friend had them under his house for five years, by the time I recycled them 13 years later they wouldn't carry a charge in a bucket but I got pretty good use out of them. In 2000 I inherited some money about the same time that the batteries shuffed off their mortal coils and used some of it to buy 4 x 6 volt 220 amp hour deep cycle batteries. They are American – (US2200 made by US Batteries) - generally I prefer to buy Australian but they were by far the best price per amp hour that I could get.

6v US 2200 Deep Cycle battery bank

This gave me 440 amp hours of storage, but I got greedy and put on another bank of 4 of the same batteries. Initially I broke the above rule and wired them into one large bank, but the performance was down so I had split them and manually change over the charging lines to keep both banks charged. There are regulators that will automatically switch between banks as one becomes charged, they are expensive but I got one (the Morningstar SunSaver Duo 12 volt) but it only lasted a couple of months before refusing to transmit any charge at all to either battery bank. I have a replacement (under warranty) which I installed but it lasted a similar amount of time. They are rubbish.

In the end I set up the two banks completely separately, powered by different sets of solar panels through 2 separate regulators. The top bank ran the lights and a few small plugs for 12 volt appliances, including a 12 volt pump on the 5500litre water tank around the side of the house and the bottom bank ran the 12 volt fridge.

About 15 years ago several batteries in the original bank had cells collapse, rendering them useless. This necessitated buying in another bank after only 6 years. This was my own fault as I had discharged the batteries to a ridiculously low level (9 volts) and let the electrolyte reach critically low levels before topping up. The result was poor battery life. Thus the second law of batteries is – look after them and they'll look after you. Check the electrolyte levels at least monthly and give them a wipe over to clean off dust, and don't discharge them below 12 volts if you can help it. Deep discharge means 12 volts not the 6 to 9 volts I originally thought it did!

12 volt Superstart MF86B 130 amp hour marine maintenance free batteries

I replace the faulty battery bank with another set of four 6 volt 220 amp hour deep cycle US 2200s from US batteries and they lasted 12 years, up until the new system went in. About 10 years ago the other bank of batteries failed and I shopped around actually getting four 12 volt Superstart MF86B 130 amp hour marine maintenance free batteries, which were just about ready to fail when I replaced them with the new system.

Lessons:

- Get deep cycle batteries and understand what that means!
- Replace whole bank rather than one or two batteries in the bank
- They will leak sulphuric acid
- They will give off hydrogen
- Check electrolyte levels regularly!

2.5 Generating power

Early on I tried several ideas here but only one with any degree of success. The first method has direct connection to the power grid via a battery charger…..hardly self-sufficient but it helped me test the system before I could come up with anything more sustainable. The second was a 12 volt petrol generator that I build based on a car alternator and motor mower engine, for obvious reasons this was also a flop!

The third idea was a SolarexX44 BG photovoltaic panel, which cost $351 about 35 years ago (it is based on the old round solar cells). It is rated to produce 1.35 amps but on a good summers day will hit 1.8 amps, and after 35 years it was still in place and there had been no loss of output, up until the panel was replaced by the new system.

The original panel collection used to power the lights

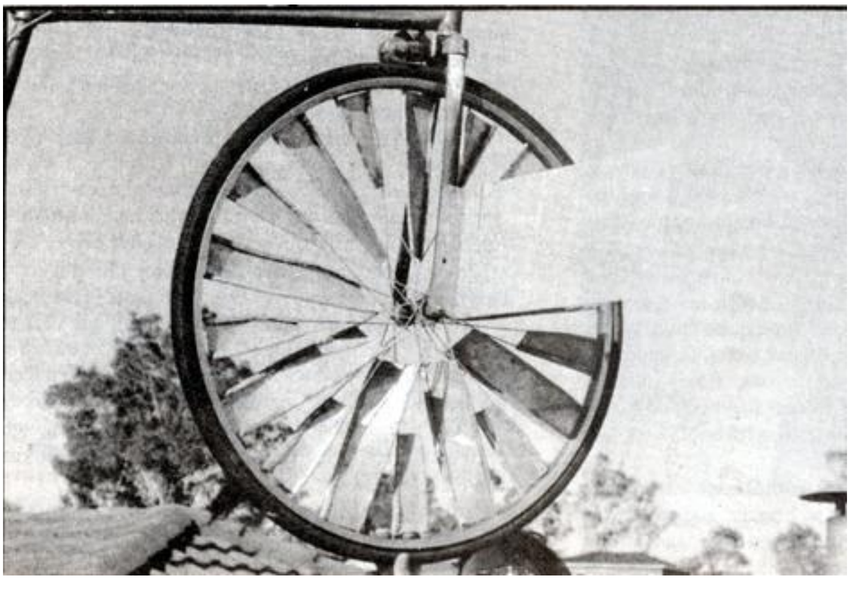
About 27 years ago I added a BP Solar Panel to the system which gives a peak output of about 2.5 amps (Sorry I can't be more technical here, the specs went west long ago) and likewise it is still going strong. Twenty years ago I saved up my pennies and added a third solar panel, a Photowatt International PW 750 which on a good day can pump out 4 amps which about doubled my generation capacity at the time. It cost a bit at $600 but was the best cost per watt unit that I could afford. All of these units continued to pump electricity into my batteries whenever there is light shining on them, up until the system was replaced.

The bank of 4 Solarex panels for the fridge battery bank

The last addition to the old system was 4 x 80 watt Solarex panels, donated by my brother – or at least on loan – I could charge up to 25 amps – a huge boost to the system. One of the down sides of a system which develops like this, all wired in and running through a single regulator was that over time the charge degraded and from an original 25 amps, over time it dropped to a 15 amp maximum charge. This worked for us but designing a system from scratch and obtaining it all in one go can provide better performance.

As mentioned in the battery section, I originally had all of the batteries wired together but this did not work very well, so I ended up separating them into two battery banks with separate regulars. The top one (4 x 6 volt batteries) powered the lights and was charged by the original mish mash of panels, the bottom one (later to become the 4 x 12 volt low maintenance batteries) ran the 12 volt fridge and was powered by the 4 x 80 watt Solarex panels.

I did some work about 30 years ago on a bicycle based wind generator. It was a bicycle wheel, forks and head set, with metal over the spokes and a roller style bicycle generator. After being a local landmark (and eyesore) for a number of years it finally bit the dust about 25 years ago. It proved to be all that the photovoltaics were not: it was not attractive, gave off a noise in high winds that did annoy the neighbours, required frequent maintenance and at full belt delivered less that an amp to the system. It was just not practical, even if it was home made from recycled parts.



The lure of the wind generator is strong. However! I always wanted to make my own, hand crafted and based on a car alternator, but with so many projects I never go the time. In early 2005, there were some Chinese wind generators doing the rounds, producing around 200 watts at 12 volts, the kit was self-contained but the whole thing weighed 70kg, add wind load to that and it was a substantial amount of kit to mount on the garage. It was also comparatively large with a blade diameter of 2.5 metres. I figured I better get council approval (it was a bit difficult to hide!) and after the obligatory 1 minutes silence for weirdo identification the told me that inspections etc would cost over $300 which added considerably to the original $450 price tag. In the end I shelved the idea after concerns about the weight as well as council hassles, it was donated to Mamre Farm in 2010.

As I said above, the lure of wind generators is strong and while overseas 10 years ago I saw some much smaller and less obtrusive units. After research back in Aus I found the AirX 400 watt 12 volt wind turbine. It was double the cost of the Chinese unit but it also produced twice the power, only had a blade diameter of 1.17 metres and weighed 6.5kg, it was about as obtrusive as your average TV aerial! Needless to say I bought and installed one on the side of the garage and afforded me endless pleasure as I watched it rotating in the wind while working in the garden.

The airX wind generator

Unfortunately what it didn't do was produce much power due to turbulence. It should probably have been mounted about four or five metres higher, but then it may have attracted attention, possible complainants, followed by the ire of the council. In the event, for the 8 or so years it was installed it did not cause any issues. With advent of the new 24 volt system (the wind generator was 12 volt) it became redundant and I passed it on to a mate who has a farm in Cootamundra and tiny house of sorts on top of a hill in the country. A much better situation to get power out of a wind generator.

Lessons:

- Go with solar (no noise, doesn't upset the neighbours, less hassle)
- Wind is only good for very windy sites
- Get an engineer to look at your wind system installation if you are going to get one

2.6 Regulators

For those who don't know, the whole point of a regulator is to prevent the batteries of your 12 volt power system being overcharged by your solar panels (or whatever you are using to charge them). When I first built my system I did not have a regulator, I had read that if you are charging at less than 10% of your battery storage capacity (ie below 44 amps for a 440amphour battery) you didn't need one. It turns out this is rubbish and after seriously decreasing the life of a brand new battery bank it turned out a regulator was something I should invest in.

Both regulators after they were decommissioned

Originally, as referred to above in the battery section, I got hold of a Morningstar SunSaver Duo 12 volt to keep both banks charged from the one input, but it turned out to pretty much be a waste of space (and money). The Sunsaver debacle resulted in me splitting the two banks into two totally separate systems, but it did have one redeeming feature which I will talk about in the 'Metering' section.

For the top battery bank (powering the lights) I bought myself a STECA 30 amp photovoltaic regulator, it cost several hundred dollars but seemed pretty much what I was looking for. I installed it and while it worked well, the place where you insert the wires from the panels and to the batteries was a connector block designed for wire about 3 - 4mm thick, but I used wire 8mm thick. This meant that I wasn't able to get all the wire into the connection block and over time the end of the wire got a bit ratty with little bits of frayed copper wire all over the place. The more I tried to push it in, the rattier it got and evidently the less wire was available to transfer the current.

It got to the point where the wire would occasionally fall out and the system would stop charging. This is where the remote voltmeter in the kitchen earned its keep and allowed me to see there was a problem. Anyway I had come up with a fix but had not implemented it when disaster struck. Due to a lot of amps going through not much wire the increased resistance caused the regulator to heat up, then make expensive smells, then cease to work. Yes, my friends I had burned something in my regulator out due to stupidity.

To replace the one I had fried with an equivalent was several hundred dollars, but for under a hundred I could get a new regulator that would do the job – a Powertech Super Solar Charge controller (it was, after all, SUPER, so how could I go wrong?) It also had spade lugs for attaching wires from the panels and the batteries. This meant I could solder on a spade lug and not have to worry about things overheating. Winner!

A slight diversion at this point… The Steca regulator works by sensing the charge of the batteries and then allowing power from the panels to flow into the batteries, cutting back slowly as the batteries approach full charge. This approach worked very well. After reading the instructions on the power tech, it appears that it acts like a switch, switching current from the panels on when the batteries are below a certain DC voltage (13 volts) and then switch it off when it hits around the 14 volt mark, allowing the surface change on the plates to be absorbed, dropping the voltage below 13 volts and switching on the panels again. Makes sense to me.

Unfortunately in practice, not so much. As soon as the new regulator went in the battery voltage drop at night (as we used the lights) was much sharper than with the Steca regulator, even if we only used a couple of lights. The system was working but not as well as it had so it looked like I needed to revisit my options and have a go at fixing the original regulator. Fortunately this did not prove as much as an issue as I thought it would be.

Now that I had access to it (after removing it from the system and could open it up) I found that the plastic terminal block connector for the positive side of the solar panel output had just melted due to the heat from the poor connection, hence the expensive smells. I was able to replace the burned out section by cutting that bit off and inserting a new section cut off another terminal block (bought from the hardware for the purpose), but that still left me with the problem of fitting the wire into the connection block.

As alluded to previously I did have a fix. I got hold of some Gold Locking Banana Plugs, (from Jaycar Electronics) two with red rings, two with black rings. I have no idea what their official use is but they accept the 8mm wire easily in one end and allow it to be secured with two grub screws. The only issue is that there is a ferrule on the outside of the plug which makes it a bit wide to go into the connection block on the regulator without touching its neighbour. It is not necessary for my use so I just unscrewed it and left it off.

The pin out the other end can then be easily fitted into the connector block in the regulator and secured with the fitted screw, allowing sufficient power transfer so that they don't even get warm, let alone hot.

By contrast, the regulator which used I for the bottom bank of batteries which supplied the 12 volt fridge was a Powertech MP3129 20 amp regulator, which performed flawlessly until it was decommissioned along with the Steca 30 amp regulator when the new system was installed.

Lessons:

- Use one!
- Install one per bank of batteries

2.7 Inverters

My original idea was to run what I could using 12volts directly, so I needed 12 volt appliances and whatever. Unfortunately a lot of 12 volt gear has been designed to be cheap and nasty for the auto/camping market and can lack power and certainly longevity. Also there were some things which were just not available in any power requirement other than 240vac, and this is where an inverter (which converts 12vdc or 24vdc into 240vac) is needed, hence my journey into the world of inverters!

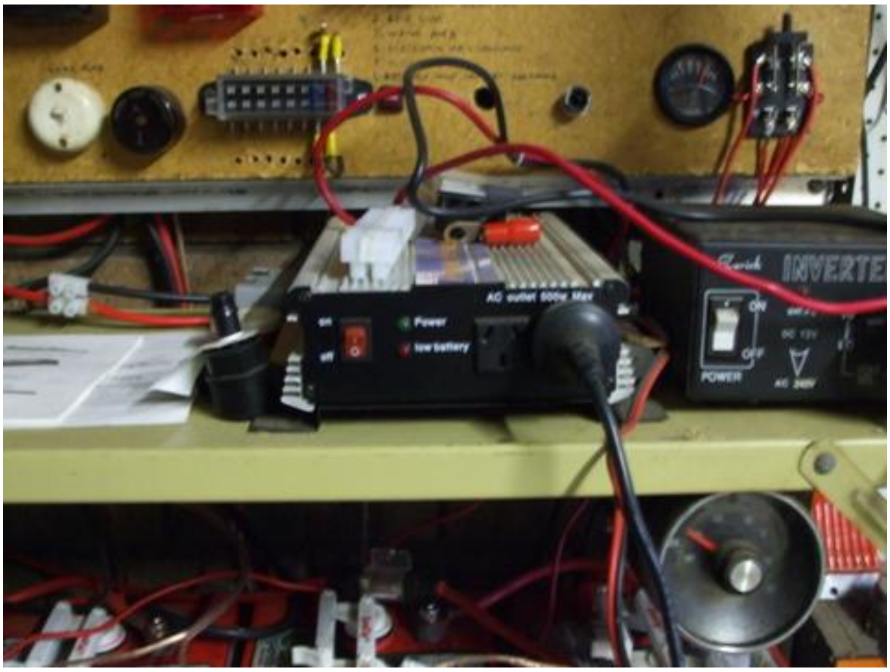
The little Zurich

Originally I purchased a little Zurich DA-100 inverter for less than $100, it is a small inverter providing 100 watts of 240 volt AC power and is a square wave not sine wave inverter, this results in a hum when I use it to run my CD player. Theoretically 100 watts is enough to run a small TV and video but my experience seems to suggest that it is either/or and not both. I tried to find out if running my computer on a square wave power source will do terminal things to it but any computer techo's that I ask just go quiet and walk away muttering something about weirdos.

The original monster (sorry about the photo quality)

I also have a 500 watt invertor and my brothers' old 1400 watt monster that will handle 5kw in short bursts, both are modified square wave invertors. While they do produce 240volt AC it is not the same as the stuff delivered to your house by the power company, you have to be a bit careful, I killed the charger for a cordless drill with it, but it does power the charger for my electric bike (mind you I contacted the bike manufacturer first and asked if it would be OK). I used the big one to run my power tools, a whipper snipper and an old Hoover twin tub washer that also used water from the rainwater tanks pumped in by a little 12 volt pump.

If you are wiring up your own system and intend to include an inverter, please be aware that the stuff that is produced by the output sockets of the inverter is every bit as lethal as your house current and deserves the same amount of respect. Any permanent wiring of the 240 volt output must be carried out by an electrician.



One of the sine wave inverters

If you still want to get an inverter to run some of your 240volt gear from your solar or wind system, the theory on how they work needs to be understood and it took an electrician friend several goes in very simple language to explain it to me. Even then I wasn't sure I believed it until I took some independent measurements and confirmed it was exactly as he said.

Say you want to run a 100 watt, 240 volt AC appliance, at 240 volts it will consume 100/240 or 0.4 amps but when run through the invertor at 12 volts it will consume 100/12 or 8.3 amps which is a pretty solid drain on the batteries. As you can see if you want to run a 1000watt 240 volt heater it ain't gonna happen with a small stand-alone power system like mine.

Lessons:

- Go with Sine wave if you can afford it
- Ask the manufacturer of what you want to power if it will cause a problem if you can't
- Don't leave them connected (especially the bigger ones) they draw power
- They put out 240vac which can kill you!

2.8 Metering

A DIY power system, at least in my experience, is not a set-and-forget type of experience the way the 240vac system is, it needs to be monitored because you don't want your first indication that something is wrong being when everything stops working. You want to have time while the batteries still have some life to identify, diagnose and fix any problems that crop up. This means that you need to have some indication of how the system is doing, and I found that to be a piece of equipment which tells me the battery voltage in real time.

Now I know I bagged out the Morningstar SunSaver Duo 12 volt regulator which I installed, but it did have one redeeming feature – A remote meter which I could install anywhere within the range of the 50 metres of telephone cable which connected it back to the regulator. When I decommissioned the Sunsaver I left it connected to the batteries, not in any regulatory capacity, but still connected.

While the remote meter did provide lots of information, the main thing I used it for was to keep tabs on the voltage of both banks, but particularly the upper lighting bank. I mounted it on the wall of the kitchen, where I would be walking past most often. I would keep a check regularly and if something was off (usually a reading lower than I was expecting) I would follow up and check things out. It saved me heaps of hassles over the years.

Lessons:

- Use a good quality digital real time remote voltmeter and monitor it regularly

2.9 Loads

Lights

The use of lights has been a continually evolving part of the system. I started out using round, clear steel and plastic trailer lights with festoon 18 watt (double ended) bulbs. They were cheap, gave good light in a small area and were readily available. I still have one operating at the side of the house over the wood pile. Robust ones have become difficult to source and they have been replaced by other, much better technology.

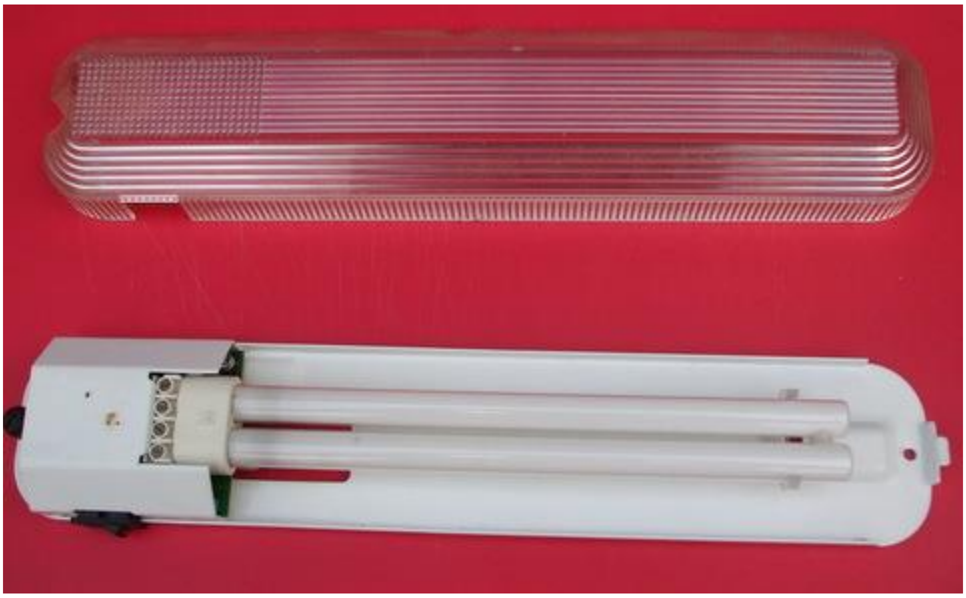
An original trailer light

As previously mentioned the trailer lights are good for small rooms, but for large rooms or where enough light for reading or for detailed work like the kitchen/dining room or lounge room they do not give enough light. I even found some fittings that held two festoon bulbs in a boating shop, they looked more professional but the cover/diffuser absorbed most of the light. So much for that idea!

Originally I did a bit of experimentation with a hand held fluoro but is seemed less effective than the trailer lights so they were it for a number of years. Eventually I did get onto caravan style fluorescent lights from the same boating shop and gave them a go. They worked very well with a few reservations. At $30 (at the time) they were still reasonably priced and with two 8watt tubes they gave considerably better light, to the point where I could read in the lounge room, for less power consumption. You beauty! On the down side each tube cost $4-$5 each (two per light, remember) and under heavy use could last as little as a few weeks and that gets expensive! They are very sensitive to low voltage and while the old trailer lights kept going, getting dimmer and dimmer, the fluorescent lights refused to work and the tubes wore out rapidly. They also show up line losses like nothing else!

Caravan style 12vdc fluorescent light

Then I discovered halogen down lights – cheap, good point lighting and the bulbs last a long time. I installed two over our bed as reading lights and they have given good service for 10 years or so. Now I have one over the stove, one over the sink and two over the dining room table. The down side is that they chew power, and as a hint, use the 20 watt bulbs not the 50 watt ones supplied otherwise you're likely to give your batteries a heart attack!



High Efficiency 12vdc fluorescent light

The search goes on and when the fluoro in the lounge room finally expired I consulted a specialized 12 volt remote area power shop. They turn me on (pardon the expression) to high efficiency 12 volt fluorescent lights, and they are very impressive. Low power consumption, the tubes are rumoured to last forever.

The light level they produce is as good as any 240 volt light I've ever used but the downside (there always is one!) is that they cost $120 each! At the point of their maximum use, we had a high efficiency 12 volt fluorescent lighting installed between the kitchen and the dining room, in each bedroom and the hall, one in the bathroom and two in the lounge room plus one out over the back deck. They can be difficult to get hold of, the average hardware shop has never heard of them, but the specialist alternative power system suppliers do carry them. While they do give excellent light and last for long time (mostly 10 years plus), when the light does fail it is usually the whole light rather than just the bulb requiring replacement of the entire unit. That gets expensive!

Downlights, were halogen, now LED

At the moment we still have high efficiency 12 volt fluorescents (powered by the new system via a 24vdc to 12vdc converter) in 2 bedrooms and the hall, plus one in the lounge room and on over the back deck. All the halogen downlights previously mentioned have been replaced with 12 volt LED downlights 8 years ago and as the 12 volt fluoros fail they are replaced by 12 volt LED downlights which are much cheaper, use less power and give almost as good a light.

Lessons:

- LEDs are the way to go!
- Keep a few spares

The 12 volt fridge

There are compressor based fridges that run on 12 volts on the market but they are expensive. I was also not sure how our system would cope with the drain, the batteries charge during the day but the fridge runs 24 hours per day. I know of people turning off the fridge over night to reduce the power drain, but when I mentioned this strategy to a refrigeration mechanic friend his hair just about stood on end!

My original idea was to get a Danfoss 12 volt compressor and absorber from Bias Boating Warehouse (Which was running at about $1000 at the time) and then build a super insulated chest fridge around it. My lovely wife was unsure how that would look and so expressed some concern (IE was dead against it!) so back to square one. Fortunately the above-mentioned fridge mechanic had his own business and was interested in 12 volt cooling so he said if I got a fridge and paid for a Danfoss 12 volt compressor he would put them together for nothing - Woo Hoo - sounded good to me!

So we went out and bought a "Homemaker" brand el cheapo 317 litre fridge from Kmart for $350 or so and stuck it in the back of the station wagon we had at the time. It is a very basic fridge and somewhat smaller than the main fridge we were using at the time, but with the kids moving out, and this being and experiment I thought it would suffice. My friend got the compressor and I reimbursed him the $600 or so, gave him the fridge and away he went. Two weeks later and I had a 12 volt fridge!

In any case, it became clear that the current system would not support the fridge in longer cloudy periods or around the winter solstice so I bit the bullet and bought two $1000 7.5 amp solar panels and added them to the fridge system. I still kept a Powertech 12 volt 12 amp DC power supply (ie it converts 240 VAC to 12 VDC) to run the fridge off the mains power in the event that the 12 volt system has troubles. It operated successfully up until I decommissioned the old system.

The 240vac to 12vdc power supply for the fridge

Strangely enough I ran the 12 volt fridge on the 240v off grid system using the DC power supply for about 12 months after the change over, but it then became obvious even to me that to generate 24vdc, convert it to 240vac, then back again to 12vdc just to run the fridge was a bit silly. The 12 volt fridge went to my mate with the tiny house and we got a bit bigger ‘fridge only’ unit which works on 240vac, has better insulation and is frost free.

Lessons:

- If you are going to make your own fridge, automatic defrost is good!
- The poor insulation level of the el cheapo fridge means it uses more power than it should.
- This experience REALLY focussed us on the amount of power refrigeration uses.

Others

We have a few other loads that have stood the test of time and are still in operation even after the changeover, that run on the new system through the 24vdc to 12vdc converter. We have a USB plug that fits into a car style 12 volt socket I wired into the dining room which we use to keep our phones, ipads etc charged. There is also the 12volt pump connected to the 5500litre tank which we use to water the front and back yards. There is also blower for the forge in the garage which is a 12vdc ex-car fan. We played around with other stuff over the years but most had been decommissioned as not being practical by the time the new system was installed.

3.0 The 24 Volt DC/ 240 Volt AC System

3.1 Electricity Usage

Over the years we have worked hard to reduce electricity consumption to the point now where our electricity bills are telling us we consume between 4 and 6 kW hours per day for a two person household. Anyone thinking of going off grid should first conduct an energy audit and get hold of an energy meter (as we did) and then work at bringing their electricity consumption down as far as they can. This will reduce the overall cost of the system you put in and ensure that the system is sized appropriately for your needs.

There are other factors to consider too, and to size our system so that we could still operate but it would not cost the national debt to install, we had to make some decisions. After much to-ing and fro-ing we decided to do the following –

- We would design the system so that several large, but rarely used loads would still draw from the grid, but all of our power points and the few lights still using 240v would draw from the new off grid system. These grid connected loads consisted of –
- the electric boost for our solar hot water heater (used 3 times last winter),
- the air con, (used a half a dozen times a summer to keep Linda from melting on those hot western Sydney summer afternoons), and
- a 15 amp socket in the garage, used to power my electric welder, which I have used approximately 3 times in the last 5 years.
- We would leave the current 1 kW back to the grid system in place, even though we would receive considerably reduced compensation for the electricity we put back into the grid. The idea being that it would work towards covering us for when we used the above mentioned high consumption but low usage loads.

3.2 Batteries

The low maintence deep cycle 12 volt battery bank which powers the fridge have had one battery fail in service already and from their current performance it was likely that others were heading the same way. The entire bank (4 batteries) were decommissioned and recycled. The original lighting bank of 4 x 6 volt deep cycle lead acid batteries are 10 years old and while they are still working well and retaining a charge, they are nearing the end of their projected service life. They were integrated into the new system originally, but only lasted a few months before they too failed and had to be decommissioned and recycled.

The two new battery banks for the off grid system are each composed of 19 x 1.2 volt 100 amp hour nickel iron batteries. The batteries in each bank are connected in series to provide 24 volts and then the two banks are connected in parallel to double our storage capacity. But the issue is that the original system was designed around 12 volt lead acid batteries, whereas the new system is set up to be based on 24 volt nickel iron batteries. So, why change?

In Terms of Voltage

The change in voltage is all about current draw. To power the lights meant we were drawing somewhat less than 100 watts at 12 volts (or <8.3 amps) and so the wiring had to reflect that. The larger number of amps, the thicker the wiring needed to be to withstand the current otherwise the wiring could overheat and cause a fire. Another contributing factor was I wanted to be able to use comparatively cheap and readily available 12 volt technology like fans, radios, pumps etc directly without having to go through any extra electronics.

It is a general rule of thumb that you should not have a continuous current draw from your system in excess of 100 amps. While my inverter is oversized at 3000 watts, my usual draw is < 500 watts (42 amps at 12 volts or 21 amps at 24 volts) but I can draw 1500 to 2000 watts over time when we are using the microwave, sandwich press, vacuum cleaner or washing machine. This will result in a draw of up to 167 amps at 12 volts but only 83 amps at 24 volts, hence we designed our system to run on 24 volts. To design a system it is a good thing to start by looking at your projected draw in terms of amperage then work backwards.

In Terms of Batteries

I know lead acid batteries. I have talked, read and experienced them and that familiarity meant that was the technology I turned to first, but there have been some new (and old) technologies becoming more available lately. The things I learned from working with lead acid batteries were that –

- They use sulphuric acid solution as the electrolyte and some WILL leak during charging. So make sure that you have something to catch it in (plastic trays under batteries etc), that it can't come into contact with metal components like steel shelving and that you wear acid resistant clothing when working with them. I have not increased my popularity in my household by getting large acid holes in new shirts, jeans etc.
- Deep Cycle does not mean DEEP CYCLE – to make sense of this you need to understand that I thought that you could discharge a 12 volt deep cycle battery down to ohhh, I dunno…….9 volts? When I did this I found it reduced the life of the battery bank significantly (ie they got less than half normal service life). It seems that lead acid batteries of the type used in cars are designed to start the car then run back up to full charge straight away. Deep cycle batteries can be run down to 12.0 volts, but the more they cycle down this low the shorter their service life.

- The reverse is also true. If you overcharge the batteries their service life will be drastically reduced as well, so it is really important to have a good quality battery charge controller to prevent this happening. This is important regardless of the amount of charge going into the batteries, even if it is just a few amps trickle charge.
- The best possible performance you can expect from your batteries ie how much charge they will store, will be the very first time you hook them up. After that it is a (very) slow decline to where in 8 to 10 years, even if you treat them well, they won't carry a charge in the proverbial bucket. If you don't treat them well, as referenced above, it will be a lot shorter time than that.

Nickel iron batteries are new to me, but I am learning quickly and what I have learned is –

- They use potassium hydroxide solution as the electrolyte. This is nowhere near as rough on clothing or steel parts as sulphuric acid is, and there is no external leakage from the batteries, so your chances of coming in contact with it are reduced considerably. If you are buying your batteries dry and making up your own electrolyte, please be aware that potassium hydroxide solution is more hazardous to the eyes than even sulphuric acid is – so PLEASE wear chemical goggles and/or a face shield!
- Deep cycle means DEEP CYCLE! My 24 volt banks of batteries can be run down to a bit above 19 volts and will still be OK the very next day when the sun comes up to start charging them again.
- These batteries are robust! You can charge them up to 30+ volts without damaging them too.
- When you connect your batteries up and use them to power something, and you keep an eye on battery voltage (as you should) you may be shocked (as I was) to find that initially they hold charge like a sieve holds water. DO NOT be alarmed! This is the way this type of battery works and may take a month or more to bed in and hold a full charge.

Another thing in favour of nickel iron is that they have a projected life that may be 20 or 30 years and I am aware of one set that is still going after 50+ years. So this set will see me out!

My problems mostly stemmed from thinking of the nickel iron batteries in terms of lead acid batteries, but in some aspects (as discussed above) are totally different animals. So while I thought I had a lack of storage capacity, I actually needed more generation capacity.

The big hint is – do your research! Don't take my word, or anybody else's for that matter, have a look at some of the good info out there on the net, and see how you

3.3 Power Generation

The solar panel part of the system basically developed in three distinct spurts –

Spurt 1

On the day we did most of the work on the installation I had a working bee at our place to give people an opportunity to learn how to do this. My solar guru (I dunno……. Let's call him Mike!) ran it, I charged people to come and it covered the cost of his services for the day. (win – win!).

On that day the guys made up a support frame for the 6 solar panels I already had which were going to form the nucleus of the new system, ie 2 sharp panels (130w 22v 8.09 amps each) already in use plus the four SolarE panels (130w 17.3v 7.51 amps each) which had been sitting in the garage since I bought them some years ago. They made the support frame out of 50mm x 50mm x 2mm aluminium angle, bought specifically for the purpose, and pop riveted them together.

The southern end of the panels are supported by the framework made up of a top and bottom horizontal piece, connected by four vertical pieces to support the panels at an angle of 45° approximately. The top horizontal piece is pop riveted to the panels and bottom is pop riveted into the roof of the garage (more about that later). The bottom of the panels are supported in a single horizontal run of aluminium angle which is also pop riveted into the roof of the garage.

Now, the roof of the garage is composed of steel Hidek profile roofing, which means that it has wide flat bits, with stiffening ribs every 200mm or so. Anyway, I have always mounted panel supports on the top of the stiffening ribs to reduce the likelihood of leaks, but the guys installed the panel supports on the flat bits in between. I expressed my concerns but was told the pop rivets would be tight enough to stop leaks. Word to the wise – they're not!

With the system installed and the panels in place it was just a case of waiting to see how much power we developed, unfortunately it was not enough! Hence….

Spurt 2

To increase the power we were getting to somewhere (hopefully) where it needed to be, I bought in four Stion brand 140watt thin film panels, they were recommended by mike as being particularly good in low light conditions and that has certainly been the case.

They were installed professionally with their own isolator on the western facing back roof of the house. We have only a small amount of north facing roof which has, for the last 35 years or so, been home to one sort or other of solar hot water system, so the new Stions were installed on the back as it was the largest continuous bit of roof we have.

This resulted in a total power output of 1200 watts, maximum, which in high summer is fine. Our house consumes about 5kWhr of electricity per day, minimum and so on the shortest day, and for a month or two either side, 1200 watts would not be enough. The output of the panels was still well within the maximum amperage the MPPT could deal with, which was 50 amps, so this lead on to –

Spurt 3

To make sure that I had enough power for the shortest day I bought and had installed professionally another 8 Stion brand thin film panels. I had them installed in two sections so that it would spread my power generation over the course of the day, rather than flood the batteries with power and exceed the ability of the MPPT to direct all the power to the batteries. So five panels went onto the western side of the roof, just north of the original four, and the remaining three we put on the front (eastern side) of the house roof to catch the early morning sun.

The closest 5 panels were in Spurt 3

Theoretically the system would yield a bit less than 2.5 kW but practically the maximum we get is about 1.8kW, which is a bit more than the MPPT can deal with but anything over the 50amps it is rated for doesn’t get fed through to the batteries, it hasn’t caused a problem so far.

The result is that if the shortest day is clear, we get about 5 to 5.5 kWhrs for the day so it works!

3.4 Electronics and Control Gear

3.4.1 The Maximum Power Point Tracker (MPPT)

To get the best out of an off grid system there needs to be some form of charge controller or regulator between the energy source (in our case, solar panels) and the energy storage, in our case nickel/iron batteries. The original solar/lead acid battery system I had put in years ago did not have a regulator originally, because I had read that charging at a rate less than 10% of the battery storage capacity meant you didn’t need one. In practice it turned out that not having a regulator resulted in reducing the battery life by over 50% and this was a pretty basic, low tech system. In the newer more high tech off grid power systems having an appropriate regulator is even more critical.

For my previous systems I had used regulators which operated as Pulse Width Modulators (PWMs). They work by sensing the battery voltage, then switching the voltage coming out of the solar panels off and on, and varying the ‘on’ and ‘off’ cycles of charging so that the battery gets charged effectively without overcharging and wrecking the batteries. They also prevent charge being lost from the batteries by power being fed back to the solar panels at night, although some panels do have diodes in place to prevent this too.

The MPPT (or Maximum Power Point Tracker). Rather than switching voltage off and on uses algorithms to constantly adjust itself so that the voltage output from the panels is constantly at the optimum required to charge the batteries. Due to the fact that MPPTs are more efficient at extracting power from the solar panels, they provide improved power harvesting low light/overcast situations.

Certainly our new off grid system is more productive on cloudy days than our original PWM regulated system. There are other differences between systems also but this does seem to be a critical one.

Our MPPT

The MPPT we installed is a Victron Energy BlueSolar Charge controller MPPT 50/100 and the way it is configured it will accept up to a maximum 50amps from the panels at 24 volts. As we are up to (and at times a bit over) that from the existing panels, if we want to install more panels we would need another MPPT.

All outputs from the three arrays of solar panels (Front roof, rear roof and garage roof) are all run through the single MPPT and while I have had people comment that it would be more efficient to have a separate MPPT for each panel array, the current system works for us.

As the batteries are charged by the panels through the MPPT, they go through three different states which are managed by the MPPT –

Bulk – This is the first state, which starts up when the sun first hits our panels, and when the batteries are less than 80% full, allowing the panels to feed in as many amps as possible thus charging the batteries quickly.

Absorption – depending on the voltage this is set for, usually when the batteries are 80% - 90% full, the batteries remain at a pre-programmed voltage (which will vary depending on the type of batteries used) with the amperage being provided to the batteries slowly dropping as the batteries fill.

Float – at this point the batteries are fully charged, as read against the pre-set voltage and the amperage fed into the batteries becomes a trickle, set to maintain that pre-set voltage.

Our MPPT has three lights in the lower Right hand corner, showing whether the batteries are in the bulk, absorption or float state.

There is another term of interest here – Equalisation charge – This is where a pre-set overcharge is fed into the batteries on a regular basis (automatically or manually) which removes a build-up of sulphate on the batteries, improving battery life. This is also managed through the MPPT.

Our MPPT is set up so that we can monitor the system from inside the house (all the solar electronics being in the garage) to an app installed on our phones but it can only be read up to about 15 metres away from the MPPT and on one phone at a time.

There are three screens on the app providing data on how the system is operating –

Status – real time readings of solar charging wattage, current and voltage, and battery voltage, current and charging state (see photo at left).

History – Daily kilowatt/hour total for today and the last 30 days, maximum solar current and voltage for each day and maximum and minimum battery voltage for each day.

Trends – real time graphs of what is happening in the system over time for two of the following: solar current, solar voltage, solar power, battery voltage and battery current.

The MPPT operated pretty flawlessly for 4 years. There was a bit of an issue about 12 months ago when it appeared to have stopped working. I was able to get a replacement to trial within a couple of days, but it showed the same symptoms as the original. The problem turned out to be a burned out switch.

Unfortunately, due to a loose connection on the main positive line from the battery

It is important to have the right gear to control and monitor the operation of your off grid energy system and we have found the MPPT which works well for us.

3.4.2 – The Inverter

The inverter, in a sense, is the heart of our system, it takes the energy produced by the solar panels and stored in the batteries and turns it into something that can be used to run the entire house. An inverter takes DC current, in our case 24 volts DC, and turns it into 240vAC, allowing mainstream appliances and lighting to be used with an alternative energy system.

I have fooled around with inverters before as part of our old 12 volt system, going from 12vDC to 240vAC, but most of the old house system was built around 12 volt lighting and appliances so the inverter was for small and specialised gear not available in 12 volt.

All that had to change when we went with the new system, because it was designed to operate the house as it is, using the standard 240 volt system wired in when the house was built. Needless to say the wiring up of a built in inverter is not something I could do, it needed to be done by someone with electrical qualifications and experience in this area.

The discussion around how big an inverter to get (ie how many watts at 240v it could supply) was interesting. There are two main things we needed to know when sizing our inverter and the first one was – how much power were we likely to want at any one time? We just looked at the sorts of appliance we would run regularly and then worked out the one which used the most power. We found the dishwasher at about 1800 watts maximum was the most energy hungry appliance, but we still needed enough energy over that to continue to run lights, the fridge, freezer etc at the same time.

We sized our inverter at 3000 watts to be able to do what we wanted to, but if we run the microwave or the sandwich toaster at the same time it will crash the system, but more on that later. So once we knew what we wanted to run it was then a case of asking how much energy the system could supply. In our case it was a moveable feast and I added more panels in a couple of steps until the system has a nominal generation capacity of 2500 watts total although in reality it produces somewhat less than that at any one time.

At this point I would like to mention that we left three things off the new system so that they draw directly from the grid due to their high power draw but low usage rate ie we don't use them much, but when we do they really suck power! These items are –

- The air conditioner,
- The electrical boost on the solar hot water system,
- A single 15amp socket in the garage which I use to power a small electric (stick) welder.

The inverter reads the power in the batteries and the sucks it out to power whatever it is we want at 240 volts. Obviously it can't do this indefinitely or the system will run out of power, but what does that look like? Basically the inverter reads the battery voltage and when the voltage from our 24 volt system drops below 20 volts the system shuts down, and that is exactly what it sounds like! All power coming to the house from the inverter stops.

Thankfully, because there are some lights which were part of the original system and are still connected directly to the batteries via the 24vDC to 12vDC converter, when the system shuts down we still have some lights. And when we were first getting used to the system we shut it down A LOT! It still happens occasionally if we do something stupid but we are much better than we used to be.

The inverter does have the capacity to remain connected to the grid, and switch across to the automatically and seamlessly (most of the time, occasionally there is a glitch that will shut the system down even if the inverter is operating on back-to-the-grid mode). There is a black switch in the switch box next to the inverter which allows us to take the entire off grid system off line and go back on grid full time. The second (orange) switch allows us to be totally off grid (down) or have the option for the inverter to switch us back to the grid if needed (up). The problem is if the inverter is left in the “auto back to the grid mode” it will consume a small amount (20w – 40w 240vAC) of power from the grid in maintaining the link. Because of this, in mostly I leave the switch in the “off grid” mode.

Maintaining us in off grid mode means that we occasionally have accidents if the weather is not good for charging but I keep tabs on the batteries through the MPPT phone app and change over as required. The inverter has worked well since installed, with the exception of the aforementioned glitch that will occasionally shut the power down instead of going back on the grid.

3.4.3 The 12vDC to 24vDC Converter

The off grid system puts out 24 volts DC, which then goes to the inverter and is converted to 240 volts AC, so it can power all of the 240 volt stuff in the house. However, there are parts of the old 12 volt system still in use, including all the lights, a small pump and a few other bits and pieces. Rather than go and replace everything, I wanted to keep it operating.

The answer to my prayers was a small DC to DC converter (ie 24 volt to 12 volt converter), which would enable me to run the old stuff on the new system. I still wanted to be able to run the old stuff on the old lead acid battery bank if I needed to. Having the lights running on the old system proved to be particularly handy when I was bedding the new system down. Every so often I would get things wrong, overstretch the new system so that the inverter shut down and we lost power. If this happened at night, we would have lost the lights as well but because they were still operating on the old system, I could at least see to work out what I had done wrong with the new system.

Unfortunately, as mentioned above, they operation of the old 12 volt batteries became a moot point when they crashed and had to be decommissioned and recycled. The lights and a few other selected bits of gear still run on 12 Volts and this is both good and bad. It is good when we (still) try to run too much and shut the system down, which is easier to do at night when there is no charging, and the lights still work. It is bad when we have protracted bad weather, particularly in the cooler parts of the year when we get less sun anyway. This is because the system uses the grid as back up, but does not put charge back into the batteries so that they are drained by the lighting, with little charge going back in. This is not a huge problem and probably happens for a few days less than once a year so we generally make our way through it if we are mindful of what we are using.

4.0 Conclusion

There you have it, the results of over 35 years plus of tinkering and experimentation by a person who is non-technical in the field of electronics. My recommendation is that if you want to design and install your own 12 volt DC system, then go for it, but make sure it stays absolutely separated from any 240vac wiring and each and every circuit you install has the appropriate fuse in place before you energise it.

If you are thinking about putting together a system that interfaces with your 240vAC supply, my advice is DON'T! Unless you have the appropriate qualifications and experience it is quite possible to do really unpleasant things to yourself or others, so get the professionals involved, please!

If you are looking at getting the professionals in to design and install a system for you, or if you are looking at setting up something for yourself, before you start you need to understand how much and where you use electricity. Do an energy audit. Armed with the knowledge of what your needs are, go through and see if you can rationalise your power use. Reducing your power wastage can be low cost or no cost and save you money and power now, but also enable you to put in a system that serves your needs without costing an arm and a leg.

5.0 Resources

Some books for your library which you may find interesting!

The Carbon Buster's Home Energy Handbook – Godo Stoyk – New Society Publishers (CAN) 2007 ISBN 978 0 86571 569 1 – This book not only covers home energy usage, particularly electricity, but also covers transportation options and touches on water, and household consumption too. It goes through how and why of energy reduction but figures are based around North American consumption. Home design is also covered and green options for heating and cooling are discussed.

The CSIRO Home Energy Saving Handbook – J. Wright, P. Osman & P. Ashworth – Pan Macmillan (AUS) 2009 ISBN 978 1405 039611 – This is a great book, lots of info, drawing and colour photos. It covers the why and how of reducing household energy consumption not only through direct consumption but also though waste, water, transport and buying stuff. Lots of tips and discussion of options that could be for retrofit or new build.

Converting to an Eco-Friendly Home (The Complete Handbook) – Paul Hymers – New Holland Publishers (UK) 2008 ISBN 978 1 84537 406 8 – a small book with lots of line drawings, it reflects the UK experience but still has great retrofit ideas. Chapters cover light, power, heat, shelter, air, waste and water. Good stuff on new technology and some innovative ideas including a good section on siting solar panels. Overall a very good book.

The Big Switch – Gavin Gilchrist – Allen & Unwin (AUS) 1994 ISBN 978 1 86373 750 2 – This is not so much a "how to" as a "why you should" book. It is a good snapshot of the sorts of things that were going on around alternative energy in Australia in the mid-nineties. Unfortunately events have overtaken the book and it is a bit dated. Photovoltaics, solar hot water and wind energy are discussed at some length. There are a few graphs and line drawings to illustrate the text.

Energy Works! – Keith Smith – Nelson Publishers (AUS) 1985 ISBN 0 17 006577 4 – This book was put together by the people who used to bring out Earth Garden Magazine. It is a "how to" book for home power enthusiasts. Lots of good information on developing small scale solar, wind and (more unusually) water power. There are also sections on batteries, inverters and wiring as well as converting 240 volt appliances to low voltage. Lots of black and white photographs and some line drawings.

The Earth Garden Book of Alternative Energy – Alan T. Gray – Thomas C. Lothian Pty Ltd (AUS) 1996 ISBN 978 0 85091 701 7 – This book is also "how to" but also with discussion of available technology. It has 3 sections – "generate": covering power generation by solar (electric and hot water) wind, micro hydro and steam, based around a power plant by the now defunct Strathsteam Company which was based in South Aus. The second section called "store, regulate, invert" is predicably enough a digest of batteries, inverters and regulators available and their use. The third section, "consume" covers appliances and the energy efficient home. The book has a good mix of line drawings and black and white photos.

Making Your Home Sustainable (a Guide to Retrofitting) – Derek F. Wrigley – Scribe Publications Ltd (AUS) 2005 ISBN 1 920769 49 8 – A retrofitters bible! The book covers solar hot water, improving performance of windows, using wasted sunshine, rationalising electricity consumption, rationalising water usage, making a useful landscape and even some advice for renters. A great book with lots of information with lots of line drawings and black and white photos to illustrate concepts in the text.

Warm House Cool House – Nick Hollo – Choice Books (AUS) 1997 0 947277 22 6 – This is mainly for the new build, although there is some discussion of existing houses, mostly using extensions and additions. The book gives a simple explanation of the principles of low energy housing design and then illustrates these principles with more than 110 examples from around Australia. There a whole stack of floor plans (if that is your bag) which help you work out which of the ideas might work at your place. Lots of line drawings and black and white photos with a colour photo section in the centre of the book.

The Energy Freedom Home – Beyond Zero Emissions – Scribe Publications P/L (AUS) 2015 ISBN 978 1 925106 71 8 – The book helps you work through a series of steps to reduce you household energy consumption including lighting, draught proofing, insulation, windows, appliances and cooking, heating and cooling, hot water, energy monitoring and control and solar power. The last section is about "putting it all together". Most of the info is about what is on the market but there is a little bit that could be DIY, but because it is a new book it can make you aware of the latest technology out there. Lots of colour photos are used to illustrate the text.

The Mother Earth News Handbook of Homemade Power – Staff of the Mother Earth News (US) 1974 ISBN – This is a small, paperback size book but has over 350 pages of information. It is really a digest of what people were doing at the time (think energy crisis) to provide their own energy systems. The book covers energy produced using wood, water, wind, solar and methane. There is some good basic DIY mixed in with interview with people who were developing their own systems. Lots of line drawings.

Energy Alternatives – Editors of Time-Life Books – Time-Life Books (US) 1982 ISBN 0 8094 3494 6 – This is primarily a DIY book for retrofitters (yay!). It starts off with strategies to make your home more energy efficient including window treatments that save energy and superinsulation, then moves on to various ways of harnessing the suns heat including a trombe wall. The third part of the book examines other energy sources including heat pumps, wood and coal, heat pumps, water and photovoltaics. Some stuff (like furnaces) does not apply here in Aus and be circumspect on some of the electrical and plumbing recommendations but this is a good book. Lots of line drawings are used to illustrate how to carry out the work they recommend.

The Green Technology House & Garden – Michael Harris & Claire Beaumont (Eds) – ATA Publications (AUS) 1993 ISBN 0 646 15196 7 – This is a series of articles around improving the energy performance of your home and garden. Some are a bit light on detail but others would enable you to replicate what they have done. The section on turning a disaster into a low energy house is very good. There are also sections on building and design, greening your garden, getting practical and living with alternatives. Lots of black and white photos and line drawings.

Renewable Energy Resources – John Twidell & Tony Weir – Taylor & Francis (UK) 2006 ISBN 0 419 25330 0 – This is a book for the technically minds, with lots of equations and all you needed to know about the physics of renewable energy. Not one iota of DIY in sight! The book covers everything from fluid dynamics to heat transfer, solar heating and photovoltaics, hydro and wind power even biomass, wave and tidal power. Over 500 pages of technical good stuff with the odd black and white photo and line drawing thrown in.

Wind and Wind Spinners – Michael Hackleman – Peace Press (US) 1974 ISBN 0 915238 02 0 – This was another watershed text for me, all about making a wind generator using automotive components and catching the wind with a vertical shaft savonius (S) rotor. The theory and practice are all here, including how to make and secure the tower that the generator sits on. The book has a few black and white photos but lots of line drawings.

The Home Built, Wind Generated Electricity Handbook – Michael Hackleman – Earth Mind/Peace Press (US) 1975 ISBN 0 915238 05 5 – The name is a bit of a misnomer because it is really about finding and refurbishing old pre-US-rural-electrification horizontal wind generators (lots of luck finding any in Aus today). However there is a lot of detail on making and erecting the tower including where to site the tower, use of batteries (lead acid) and how to construct a control box. Lots of line drawings with a few black and white photos.

Better Use of Your Electric Lights, Home Appliances, Shop Tools - Everything That Uses Electricity – Michael Hackleman – Peace Press (US) 1981 ISBN 0 915238 50 0 – The book shows you how to convert appliance etc (old stuff anyway, I don't know how modern appliances would be to convert.) to run directly on 12 volts. Very interesting stuff on the theory around wire thicknesses and which ones to use for low voltage. A bit dated but still has some interesting stuff. Lots of Black and white photos and line drawings.

Harnessing the Wind for Home Energy – Dermot McGuigan – Garden Way Publishing (US) 1978 ISBN 0 88266 117 5 – This is not a "how to" but more a "what's on the Market". Some interesting historical photos and information on estimating wind energy in your area, but apart from that pretty much out of date. Some line drawings and black and white photos.

Wind/Solar Energy (for radiocommunications and low power electronic/electric applications – Edward Noll – Howard Sams & Co (US) 1975 ISBN 0 627 21305 2 –Lots of info in a small book including wind generators, lots on batteries and inverters and a small amount on rudimentary solar which is interesting from a historical standpoint. There is some info on (then) existing installations. Lots of line drawings with a few black and white photos thrown in.