Onboard Solar – Making off grid living easy. A 2021 update.

Back in 2012 I wrote a series of articles on boat electrical systems, power management and an introduction to solar systems. At the time I had just completed the first full year as Onboard Solar, at the time of writing I was on my vintage tug at Penkridge in December waiting for Park Gate lock to reopen after maintenance so I could get back to my winter mooring that year at Alvecote. This time I write from Woodend Lock, a beautiful spot on the Trent and Mersey in the midst of the January 2021 Corona virus Lockdown. If you have not read the articles they do make a good preface read to this article to save repetition.

This new article updates on where we are with solar systems and also shares all the experiences with customers technical challenges over the intervening years, highlighting issues that have come up often many times.

Since 2012 there have been some advances in technology, which I will go through in detail later in the article. Though not the major advances that are normally associated with modern technology. The main thrust of this piece is the learning of what makes successful off grid living not only possible but also easy and simple. I have tried to focus on the things that have come up time and time again with customers over the years.

There are 3 sections depending on your area of interest you may want to skip to the relevant section headings.

Section 1 – ***BACKGROUND, TECHNICALITIES AND PREPARING*** the boat for off grid living sharing my experiences.

Section 2 –***ONBOARD SOLAR HISTORY AND DEVELOPMENT*** Early history and development of Onboard Solar Systems

Section 3 - ***ONBOARD SOLAR – WHAT WE OFFER NOW*** and how to get the very best out of a solar setup, how to monitor it.

SECTION 1 BACKGROUND, TECHNICALITIES AND PREPAING FOR SOLAR

Is your boat setup for "off-grid" living?

This is perhaps the biggest issue that I come across on a day to day basis. A very common call I get is from alarmed new boaters. Very often they have purchased a boat, more often than not a "used" boat but increasingly a new build. The fundamental problem discovered very soon after ownership is that power capacity drops very quickly after stopping the engine, often within a few hours. The concerned owner immediately believes the solution is a solar system. The problem however is always the same – the boat has been setup to be plugged in at a marina or other mooring that has access to shore power. Many new continuous cruiser folks are buying boats to live aboard "on the cut" that have been lived on often for many years in a marina. Other boaters have themselves lived in a marina for a good while and are now wanting to venture out on the cut for extended periods. A third category – new build customers, most notably a problem in wide beam boats but also new narrowboats that these days are often configured by the boat builder to be primarily plugged in.. So what are the problems? They split broadly into two issues, technology choice for the boats onboard equipment and appliances, and secondly a mindset that changes the way you live off grid.

The first and main technology issue is too greater reliance on 240v mains power. While plugged in a boat can be configured almost exactly the same as a house with 240v fridge and freezer, 240v kettle, 240v TV, 240v washing machine and 240v sockets in which to plug the huge range of device chargers USB power blocks etc that we now all have. The power is coming straight from the shore line plugged into the boat.

Most boats have an onboard battery charger (often a combi system inverter/charger of which more below). This means the batteries are kept in a charged up "float state" while plugged in. These charging systems are also acting as a 12v power pack, this means when 12 v systems such as lights, pumps etc are used the charger system actually provides the power not the batteries. This gives the end user – the boater – a seamless power for 240v and 12v systems – effectively everything on the boat is being driven from the incoming 240v supply. The upshot f all this is the boater does not have to worry everything works and keeps working 24 hours a day 7 days a week to an abundant level. There are many many boats sitting in marinas configured like this right now.

What happens when you unplug then – what is so different?

Once unplugged the boat has two completely separate power systems. 12V power for things like lights and pumps and of course the 240v power for all the typical domestic appliances. The problem is once unplugged where do the 240v appliances get their power from? The answer of course is an Inverter. An inverter on paper is a great idea. It takes power from your 12v battery bank and steps it up to 240v and converts it from direct current to alternating current. However to do this there are great inefficiencies in multiplying the power 20 fold. Most modern inverters are around 95% efficient but it is the raw Amp conversion that causes the issue. Remember volts is your tank of power, Amps the flow though the cable and Watts the thing that is consumed by the equipment. We can work out how many amps a consumer draws using the simple formula ***WATTS/VOLTS=AMPS***

Example – 240V typical mains fridge rated at 150W Running of mains directly

150W/240=0.6A

The key ting here is only Amps drawn at the high 240V are very small – why is this important? Batteries store AMP HOURS , a fixed amount of current that can be delivered under a much lower "pressure" of 12 instead of 240 volts therefore at 12V many more amps are needed to run the same piece of mains powered equipment.... Are you keeping up so far? So therefore....

Running the same 240V fridge rated at 150Woff mains through a 12V inverter

150W/12=12.5A

That means over 24 hours your 240v mains fridge will consume 12.5 Amps per hour for a total of 300AH. Now of course there are A+++ mains fridges might use say 80watts so you might well get the draw through an inverter down to 6.5A ***BUT the inverter will still have to be switched on 24 hours per day. Big inverters can consume 2A just sitting there switched on in ready state...***

Typical 12V Fridge

Most 12V fridges use a 12V 40W Danfoss compressor which using the formula consumes under 4A of power. So big power saving in AMPS but also remember when the fridge thermostat switches off there is no inverter still running so in reality over an hour a 12V fridge likely uses about 1.95A per hour.

So the point of all this is? Using a 12V fridge is the ***MOST important*** thing that will dramatically reduce the amount of power that you draw – indeed the ***MORE*** you can do at 12V the better for lower power consumption. I would say this 12 or 240 fridge issue is the biggest one I come across on a regular basis, with many customers starting out with 240v refrigeration but quickly biting the bullet and changing to 12v units.

Key things to keep in mind in preparing your boat for off grid living.

So here are the key things that I highly recommend you add to your tick list in order of priority of things to do if you are planning to live off grid. You may not be able to achieve them all but the closer you can get to having each one ticked the easier off grid living will be... Remember the key to living afloat is compromise – it will benefit you and your power ***NOT*** to have a huge chest freezer and ***NOT*** to have a 56" TV for example.

1. Go 12v on refrigeration and try to have a combined fridge/freezer
   Make sure you ***ONLY*** use compressor fridges not the cool boxes for use in cars as these run full time and consume a lot of power they are designed for use in a car while travelling with the engine running.

2. Do have 12V sockets fitted. These can be used with low cost adapters that present USB ports for charging of phones and tech. If you use lap tops then buy 12V car chargers for them and again use them with your 12v sockets to charge/power your laptop.

3. Make sure all light bulbs are changed to 12V LED – incredibly efficient compared to normal bulbs typically consuming 1 tenth of the power. Most 12V light fittings you have can simply have the bulbs changed.

4. If you use 240V table type lamps or floor lamps etc again these can be converted easily to 12v. Simply change the bulb and change the plug to a 12V one.

5. Use 12v or latest generation solar TV. 12V TVs these days are commonly available and great specification flat screen LED type a far cry from a few years ago. A new development is the solar TV . I have one of these now it is a 32 inch LED and has a built in lithium battery pack. It comes with its own dedicated solar panel and charges during the day giving up t 10 hours of viewing on one charge, very impressive.

6. Look carefully at other electronic devices such as 4G internet routers most are capable of running at 12V – just ditch the 240V power block and connect to a 12V socket.

So you can see 12V and 12V sockets are a very good thing.

These simple measures will dramatically reduce day to day power usage.

Change your State of Mind!

Firstly adopt a view if you really don't need it - don't have it! Coffee machines can be replaced with percolators or similar for example.

Have two systems, one for use when plugged in, one for when unplugged. For example I keep a 240V kettle and toaster for when plugged in the winter, but use a hob top “gas” kettle and the gas grill while out cruising..

If you need to run heavy duty mains equipment such as a washing machine – through your inverter – then make sure you do this when the engine is running. The large output domestic alternator should be able to put back in a large number of amps that the heavy duty equipment will need.

OK so hopefully you have a good picture now of what is needed technology wise to effectively live on battery power – now we need to focus on off grid charging systems and talk about how things have developed over the years we have been installing systems.

SECTION 2 ONBOARD SOLAR - HISTORY AND DEVELOPMENT

Right from the onset I decided rather than supplying a myriad of options, panels, controllers, cables, brackets etc, I decided to spec up complete fully operational systems sourcing all the best available, right type equipment and then fabricating bespoke brackets and cabling looms allowing Onboard Solar to supply *And FIT* a complete working system designed for the job on a narrowboat. This also involved a process driven installation method where we effectively arrive with a pre configured kit which enables me to accurately cost the installation offering fixed prices to all wherever your boat is located – this has proved to be a very popular approach. The process we use on the day means that we can retro fit solar to a boat in a tidy manor critically ***without*** seeing the boat first.

Solar technology 2011 - 2021

So let's look at how the technology has changed... The key issue in the UK is we do not have guaranteed super sunny weather very often – far from it! Solar panels do generate power in any light conditions and there are ways of elevating the power output even on dull days (coming up below) but generally we need to over spec the power capacity (watts) to reflect the fact that on a dull day a lets say 500W solar system may only generate 150W. One good thing that has happened is the cost per WATT of power has dropped somewhat over the years meaning that one of the main differences in 2021 is we can to a degree over spec the solar giving great output on the poor days and an abundance on the sunny days.

The solar system is simply a battery charger. Your onboard consumers will be taking power from the batteries all day long and therefore the batteries need to be recharged. This is generally achievable in 3 ways...

1. Running the engine – spins an alternator which charges the bank – most newish boats have very large output alternators for the domestic batteries and a smaller output separate alternator for the starter battery.

The important thing to note about alternator charging is it pretty much a "dumb" charge – technically called a "taper" charge it means in practice that when a battery is low on charge the alternator will output a high current but quite quickly the high current will fall away and within only a few minutes assuming batteries are not too low may well back off to a few amps. This is the reason why it is key to run the engine while running a mains powered washing machine. The washer will likely draw over 100A from the battery bank. While the engine is running the alternator will "see" this as a low battery situation and up its load accordingly to suit the demands of the unit. Say you have a 100A alternator and your washing machine draws 125A while heating up then 100A will come from the alternator and 25 from the batteries, as soon as the washing machine cuts out the alternator will switch back to providing current to the batteries to make up the shortfall and very quickly drop back to only a few amps..

2. Built in battery charger

Most boats have a built in battery charger, either a separate unit of part of a combi system – where inverter and charger units are combined in one box. In this instance the system acts as a charger when plugged in and swatches to providing 240v from the batteries as an inverter once unplugged. Combis can cause a big problem in marinas as if the marina power trips (which it often does) the system switches from battery charging to inverter automatically without you being aware – until your batteries are quickly flattened as while sitting on shore power you will likely not be paying much attention to what may be switched on! Most combis have a charger only setting to prevent this problem. Either way these shore chargers are much cleverer than an alternator and charge batteries through a multi stage process where empty battery receive a bulk charge as it is known, then an absorbtion charge, then switch to a float state when fully charged. In float state the batteries are monitored and as soon as a consumer such as your fridge or a pump for example cut it the charger ups it output to reflect that so effectively once charged your batteries stay in a fully charged idle state. It literally becomes as if you are running your 12V equipment directly from the mains “hidden” by the clever charger.

3. Solar charging. This is the solar systems we are talking about here. What the solar imitates is the built in shore line based charger described above. It is very important though to understand the complete solar system is more than just the panels. In the same way you require a battery charger system between the mains and the batteries, in the case of solar a device called a charge “controller” is required.

Solar Systems

So a solar system consists of a panel or panels and a charge controller that sits between the panels and the batteries.

Panels

Panels are rated in WATTS and have an output voltage that generally gets bigger as the panel gets bigger. In the early days of solar the controllers we used were simply voltage droppers that lowered the voltage to a level that was safe to charge the batteries. In those days the problem we had was if we used fairly high voltage large panels say 250W then they would have a high voltage output – usually around 48V. As most were being used for domestic 240V use this was fine however our early 12V controllers simply droped the voltage to a safe level. Dropping a panels voltage from say 48V to 14.4 – the safe maximum charge voltage meant huge loss in current as the difference between that peak output voltage and the safe charge rate was simply wasted. The second issue was domestic spec panels were very large and not best suited to the roof of a narrowboat. For this reason in the early days we used 100W panels that were rated at 18V output – quite close to the 14.4V needed for charging so a suitable early PWM type controller was only shaving a few volts off the panel voltage so little was wasted. In those early days we offered a 2, 4, 4, 6 or 8 panel setup offering from 200 to 800 watts. With a 25% loss of power with the voltage drop and other inefficiencies the 200W system would offer an output of about 10A rising to 40A on the vast 8 panel system (in reality 6 x 100W panels being the most that would fit on a narrowboat but not on a widebeam). What size systems did people need? This of course would depend on how the boat was setup – good 12V orientated boats as described above would typically go for 200W 2 panel, 300W 3 panel or 400W 4 panel. The bigger systems giving between 10 and 20amps output on dull days. The larger systems more typically used on wide beam boats which in my experience tend to be more 240V orientated as they are designed to sit in a marina plugged in. So in the early days 6 8 or even 10 panel systems were specified for wide beams with separate 240V fridge and freezer onboard. These days I much more strongly recommend changing to 12V refrigeration prior to going out and living without shore power. There is however an unwritten rule that you can never have too much solar – the more you have the better the charge rate in Amps even on dull days. Those who live without shore power ALL year round also benefit hugely from a bigger system as light levels in the winter are much poorer – les of an issue if you over winter in a maina plugged in of course. The 100W panels of course had the added advantage of being small in size so they didn't take up much room on the roof – later I will talk about our mounting systems that mean these small panels can be mounted in such a way that you can easily walk past them on the roof – very important consideration for single handing owners who tend to use the roof a lot.

Charge controllers

1. PWM Type – these early controllers we used to use in the beginning are essentially just voltage dropper units that make sure the output of the panels is latterly "controlled" down to the safe charging maximum of 14.4V.

2. MPPT Type – These came along in a mainstream way around 2014 and are a computer controlled system that effectively has two sides. One side controls the panels themselves and establishes an output voltage at the panels that "maximises" the current flow in amps and thus *regardless* of a panels voltage output , will generate the best output . The other side of the MPPT faces the batteries and to the batteries looks like a 3 step battery charger as would a mains powered one described above. So effectively there are several game changes with the mppt controller.

MPPT advantages

Panels can run at their maximum voltage with no loss of power in regulating down to safe charging levels

They operate at low light levels far better than old style PWM controllers

The 3 step battery charging is far superior to earlier taper charge from PWM controllers

MPPT controllers allowed us to overcome a real limitation with the low voltage panels. In 2016 we moved from 100W panels to 165W panels. These were slightly larger but allowed us immediately to offer larger capacity systems with the 2 panel moving from 200W to 330W ad the 3 panel from 300W to 495W. However they were still 18V output. With the earlier PWM dumb controllers this had the advantage of not wasting too much power as the max of 18V was not much greater than the 14.4 required for bulk charging. However this had a huge disadvantage in low light levels such as early morning, evening or just dull days. The voltage only has to drop by 20% to hit the 14.4 level, once it drops below this the ability to properly charge the batteries is lost. So a huge disadvantage of PWM controllers was that we had the conundrum of needing low voltage panels so as not to waste power but the low voltage characteristic meant poor charging in low light levels. MPPT controllers however not only allow higher voltage, they actually thrive on it. The higher the voltage entering the controller the more it can maximise output to the batteries in low light levels. However by 2015 compact panels suitable for boats including the new 165W versions we started using were still 18v output – what we really needed was higher voltage small panels but at that time they did not exist. The solution was to use a series and parallel connection into the mppt . So a two panel system would be 2 panels daisy chained together in series giving 36v to the MPPT. A three panel system would be 3 in series giving 52V at the controller and a 4 panel 2 in series plus 2 in series connected together in parallel into the controller (effectively 2 x36V solar arrays). 6 panel systems would of course be 2 arrays of 3 in series. This method of connection worked extremely well especially on the 4 and 6 panel system as it meant each array connected in series were independent of the other, so any shading of one array would not affect the other. The ***ONLY*** downside is if part of an array of 2 or 3 panels were shaded, then that whole array would loose output and in the case of the popular 495W 3 panel system all were connected as one serial array and any shading anywhere would bring the output of the whole 495w system down. After lots of testing though we took the view that the enhanced low light performance hugely outweighed the shading issue. It was not until 2020 when finally the ultimate solution appeared in the form of high current, medium voltage but still compact panels had arrived giving us the ability to offer even better output over a multi panel array with ***ALL*** panels connected in parallel, each panel outputting at 37V s with 215 Watt so lots of headroom above the 14.4 optimal charge rate and high current so good low light performance and all configured in parallel so at last no shading issues.

Shading Issues

Shading a panel is a big issue. The cells are connected in series – 36 of them normally. Most panels have two separate arrays in them of 18 cells each. If one cell is shaded all the others will drop their output. So trees and other obstacles are to be avoided!

SECTION 3 – ONBOARD SOLAR – WHAT WE OFFER NOW

My approach is to offer a complete functioning solar system mixing best available panels and controllers with in house developed mounting and cabling systems Customers will often ask us to deviate from what we do perhaps using other panels, controllers or mounting systems however we don't deviate from what we know works well as we have a very well tried and tested system now with over 2000 boats out there. We are in 2021 on our 4th generation of systems . The basic proven qualities of the systems however have pretty much remained unchanged.

Tilting Bracket System

We use an in house designed triangular shaped laser cut bracket system that enables the panels to tilt up to 40 degrees to the left and right and also a limited tilt for and aft. The top of the bracket is shaped so that the brackets can "lock" at the top or panels may be slid down a slot on the bracket to sit flat on the roof.

There are many advantages to using the tilting panel system.

1. Panels can be tilted into the sun.
2. Panels keep cool and thus perform at optimum levels
3. Panels can be easily cleaned under
4. Roof is protected from dirt trap and rust trap under the panel
5. Panels can "ride over" roof furniture such as mushroom vents.

Does tilting make a difference?

Yes it very much does, of course it relies on your mooring being in the right place e.g., sun up on the port side and down on the star board side. However tilting into the sun reduces the oblique spread of the sun and significantly up the output especially when the sun is low in the sky. E.g. evenings, mornings and most of winter.

Our brackets are laser cut.

Where to position panels on the roof.

The tilting bracket system means we do not have to worry too much about roof furniture and particularly roof vents (mushrooms). Lots of factors affect where the panels can go but the absolute ideal that we strive for is to have them ***in a row, down the centre line of the boat*.** Most of the time this can be achieved but the following factors can affect where they can go.

1. Length of the boat

   It goes without saying really that shorter boats have less room available for panels.

2. Roof hatches

   Some boats have triangular raised pigeon boxes, some have glass "Houdini" hatches or lift up lids above side doors where side doors are designed as an access point.

3. Pole and plank racks

   These racks designed to hold a boarding plank and a pole plus usually a boat hook of some kind can be a real nuisance. Panels can of course be mounted above them as the tilting brackets allow this ***BUT*** if we mount them over the rack then it tends to limit the tilt in that direction. I always point this out on the install and debate the options with the customer. Sometimes we can offset the panels one way but still close to centre, sometimes if we are lucky the brackets are far enough apart so that the panel will tilt in-between them. Sometimes though especially on a bigger multi panel system where there is plenty of power "headroom" we just accept loss of tilt one way on one panel.

A look at different Installations – 2 Panel our entry level system

This is the basic 2 panel system. On our current system options this would be 2 x 215W for a total of 430W. A popular system for boaters mainly plugged in but those who like to go out for extended periods during the summer. This system does assume you have done all the eco things discussed earlier in this article but most particularly that you have a 12V fridge.

Note this is a "text book" installation with the panels installed in a row central to the cabin top. This means you can walk by on either side and easily tilt them regardless of which way round the boat is tied up.

Three Panel System – The most popular good "all round" system

A three panel 645W system. Once again installed in the absolute optimum fashion. I.e. down the centreline of the boat. This is our most popular system. Offering 645W of power it performs well generating 40A of charge on a good summer's day, but a high average even on duller days. It will support a 240V fridge most of the time but as I bang on all the time – 12V fridge always a better option.

4 Panel System 860W

Another perfectly positioned 4 panel system. Probably our second most popular setup. This gives a very comfortable 40A on most summer days and a very high average at other times. Ideally suited to long term cruisers and those living all year round on moorings with no power. Don't forget for success to do all the things I discuss earlier in the article, but assuming you do this is a great system.

When we started in 2011 an 8 panel system retuned 800W and was very hard to consider fitting on a narrow boat roof.

6 Panel System 1.2KW

This is really the largest system that can reasonably be accommodated on a narrowboat. It usually requires a length of at least 60ft and with very clear roof (probably only mushroom vents). This comes with a 60A controller and easily achieves this output on average to good days. For those boaters insistent on relying on 240V fridge, 240V freezer and other power hungry appliances, and assuming they have a long enough boat and a fairly deep pocket, this is the one!

Other Considerations

I have mentioned that pole and plan racks can be an issue, as can hatches other issues can cause grief. However there are other things to think about.. Offset mushrooms can be an issue. Some boats, especially older ones can have mushroom vents dotted around on the roof rather than in a straight line down the middle. This can again mean panels will have a limited tilt one way unless we offset them to avoid the off set mushroom.

Chimneys

Chimneys are another issue as they can shade a panel, recommendation here is to have a chimney cap that will allow it to be removed in the summer.

The centre line

The centre line is another big consideration. Most boats have a centre eye which the centre rope attaches to. ***I always recommend two centre ropes, one for each side***. I would even recommend this were solar panels not installed as you can have a line running down each side back to the steering position ready to grab when you step off without having to flick it across the cabin roof. Once solar panels are in place this of course becomes more critical. The second problem with the centre line is it is normally used in wide locks to secure the boat. In wide locks the boat can move forwards and backwards quickly meaning the centre line can be at quite an angle. This means we have to leave a sensible gap between the centre eye and panels. On most boats of the standard 58 to 60ft length I generally find it's very possible to fit two panels at the back before the centre line, then a gap of 18 inches or so before the centre eye then another gap then two more panels forward of the centre line.

Some boats have "pipe rails" these are raised handrails made from a pipe. Often these are used to tie the centre line to which is great as any issues with "snagging" the panel go away. Where there are pipe rails and a centre eye I tend to recommend the centre lines are fed under the pipe rail while cruising which also stops the lines from "interfering" with the panels. **Installations were we can't use the optimum positioning: -**

2 Panels side by side

This is a rare option, installation of panels side by side. It can generally only be done on boats with little tumblehome (the sloping sides of the boat are more straight, thus a wider roof). It is also more difficult on a narrowboat with the newer 215W panels due to their greater width. However the ***b biggest*** issue with this configuration on a narrowboat is they have to be so close together it massively impact s on the ability to tilt the panels as one panels quickly shades the other and of course when do you use the tilt? When the sun is low in the sky.. For these reasons we try very hard to avoid it but this was a small boat with roof storage boxes and a pigeon box as can be seen so once I has explained the limitations to the customer, that was the only way to do it.

Panels Athwart the Boat

“Athwart” lovely nautical term, just means across the boat! A very rare option on narrowboats as the roof of most boats is usually curved (often quite considerably). This boat had a unusually flat and wide roof and again limited space so we were able to do it. Even though the roof is comparatively flat you can see the centre of the panel touching the centre of the roof.

Wide Beam

Wide beam boats give far more scope for panel positioning. Again there is an ideal and this is to have panels located in either a single linear row or two linear rows. Here are some examples.

Panels in a row. In this 4 panel setup on a 10ft wide beam the panels have been located in the centre of the boat exactly as we would on a narrowboat. Somewhat unusual on a wide beam as I would normally recommend two rows of two but this arrangement was preferred by the customer who had previously had a 4 panel system on a narrowboat and liked the way it worked.

On this 6 panel wide beam system the panels are installed in two sets of three ensuring there is a decent enough gap between the two arrays so that they may be tilted without causing shading issues.

A note about our cabling systems

This is a good photo to see our bespoke cabling system. We use multi core armoured cabling. We run a heavy duty multi core to the first array and then lighter duty armoured multi core to the next array. These cables are pre made on the bench to a high standard and are bomb proof. The problem with regular solar spec cabling is it is designed to be used on a building roof where there is no chance it will be walked on or have bags of coal dropped on it. The other disadvantage of single core solar cable is of course you end you end up with many individual runs which on a boat where you see the roof up close every day would look quite messy.

A 4 panel system on a wide beam Euro style cruiser, positioned around the huge ceiling skylight.

Another 6 panel system on a wide beam. Notice the break between the first pair of panels and the other 4 to allow for the centre line to swing without any issues. Particularly important while in a wide lock controlling the movement of the boat from above. Note the customer was advised as I stated earlier to purchase a second centre rope so one could be drawn to the back each side.

Wide Beam Observations

We have tended to fit larger systems on wide beams, not just because there is more space to play with but also wide beam boats tend to be built and configured to live in a marina plugged it so they have big 240V fridges and freezers and 60 inch TVs etc etc. So the power requirements are much higher. Strangely (I think in part because hey are not expected by the boat builder to be cruised much) they often have quite small battery banks so often the solar project also involves adding extra batteries. Will come back to batteries later.

8 Panel System on a wide beam hotel boat.

This is approaching the realistic maximum that we go to. With our latest generation panels this would be 1,720W of output. We would run this is two separate 860W arrays with dual 40A controllers. This was a wide beam hotel boat with very high power requirements in the form of multiple refrigeration devices plus microwave ovens etc.. Note the shading in the photo and you can appreciate why you would not want panels side by side on a narrowboat.

Examples of compromise systems

Here are a couple of examples of systems where my ideal of having all panels in a row down the centreline could not b achieved and show possible solutions to get out of these problems.

Here is a 6 panel system on a narrowboat. The customer had already had the centre line points moved to the side of the boat meaning we didn't have to worry about a gap there but the pole and plank rack presented an issue for tilting the first two panels. The solution on this occasion to maximise the flexibility of the whole system was to offset the first two panels. We could indeed have kept them in the centre, but the first two panels would then have had a limited tilt to the right...These are the sort of issues we debate on the day of the install, often until we put the panels u on the roof it is hard to see the issues!

On this 4 panel system on a wide beam we had a number of issues, pole and plank rack at the back, chimney and a requirement for a future storage box and satellite dome further forward. We also had a technical issue of hitting the limit on cabling length – not a problem additional cables could have been added but would have not been pleasing to the eye. Hence the solution above of two in a row in the centre – the best option and two forward side by side.

These system photos are a small selection of the 2000 odd systems we have installed. But hopefully go to show there is always a way of making it work in such a way that it is fully functional and pleasing to the eye. We always start with an ideal of where they should go then work from there.

Fitting Methods

Brackets are made of aluminium to match the frame of the solar panels.

Mounting Panels to Bracket

The panels are drilled and threaded on their narrow ends. We then use a button head A4 marine grade stainless machine screw to attach the panel to the bracket. Now both brackets are fitted the panels are set to lodge in one of the notches in the top of the panel. When in a single line we take care to ensure all panels are orientated on the same side of the bracket for neatness ***AND*** most importantly that all panels are perfectly lined up. As the panels have grid patens on top where the solar cells are located any miss alignment is very off putting to the eye. The button head machine screw and A4 marine stainless washer used are shown in the bottom photo lower half. The screw can be tightened or loosened with an Allan key (provided as part of the installation)

Fitting Brackets to the roof

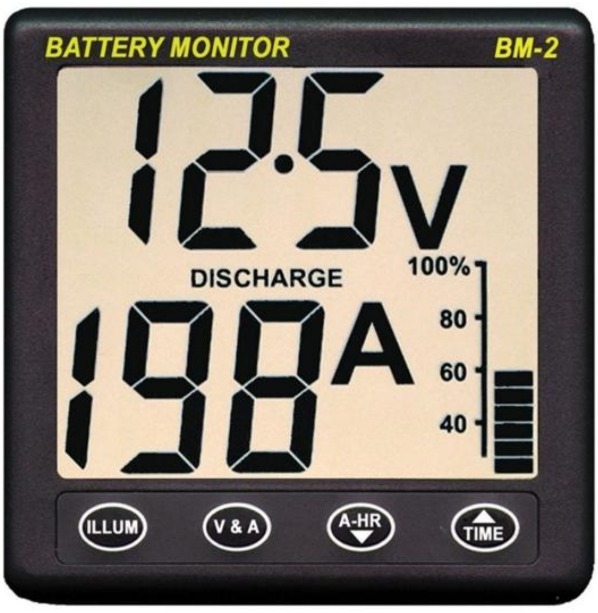
Here we drill and then cut a thread in the roof (tap). We then screw in a type of stud called a grub screw. This is bedded in with a compound called marine flex a high quality underwater grade sealant.

Once all 4 grub screws are in place we drop the assembled panel and bracket straight onto the studs. Then a washer is added and a flange nut for neatness, both A4 marine stainless. Before tightening down there is enough play in the bracket holes to allow for very fine alignment adjustment.

Controllers

We have adopted the Tracer (now known as Epever) range of controllers for all our systems. These are very highly rated MPPT controllers within the industry. At one time we used to offer them with a secondary remote display but the new generation Xtra units we are now using have a much more comprehensive built in display and also have the option for those who love modern tech, of being managed from an app on your phone via Bluetooth. This app and the display on the controller allow you to see what you are putting into your batteries.

I also recommend consideration of a full battery monitoring system. The solar controller tells you what you have going in from the solar, but not hat is going in from the engine nor does the solar system have any knowledge of what you are drawing in the boat. A full battery monitor would give all of this info.



There are many makes of battery management system. This one the NASA BM2 is a nice one as it gives all the info on one large screen. It shows battery voltage, current in and out via all charging methods and a percentage state of charge. While not directly connected with solar it is a great additional tool for off grid living.

Batteries and Battery Banks

The intention here is not to go into lots of technical detail about batteries but to give some general advice and comment on the technologies at a practical level.

Batteries are ultimately the key to a good power setup but in reality have a very limited amount of stored power as you may only access around the top 1V of the batteries capacity as the remainder is required to keep the battery in good condition.

Traditional analogue volt meters show the entire voltage range but this is not very useful when we are only interested in the range 12.6 to 11.6

State of Charge	12 Volt battery	Volts per Cell
100%	12.7	2.12
90%	12.5	2.08
80%	12.42	2.07
70%	12.32	2.05
60%	12.20	2.03
50%	12.06	2.01
40%	11.9	1.98
30%	11.75	1.96
20%	11.58	1.93
10%	**11.31**	**1.89**
0	**10.5**	**1.75**

This table shows what we call your "usable" window of power.

Batteries will be between 12.6 and 14.4 when they are charging off of solar, alternator or charge but once charged will sit at 12.6. Roughly each 0.1 of a volt is 10% of your battery capacity. I generally don't recommend regularly going below 11.6. So 12.6 to 11.6 in 0.1v increments is your 10% chunks of power.

Your solar controller gives you a ***DIGITAL*** readout of battery voltage so using this simple voltage guide you can keep a close on where your batteries are in this tiny voltage range. Alternatively a true battery monitoring tool as described in the pages above will give you a very accurate percentage state of charge as it records all power that goes IN and OUT. However as I say a basic understanding of the voltages gives you a very good idea. I am amazed how many boats I install solar on that until that point have no way of monitoring voltage.

Another low cost alternative is A battery condition meter. This doesn't have volts on it and is set to measure the 11V to 14Vv range with green, yellow and red sections. When charging the needle heads to the charge area and then works its way though the yellow to the red discharge area once you hit below 11.3v. These are also available in LED form with red amber and green LEDs. At the end of the day though a digital readout and an understanding of voltage ranges is all that is needed.

Battery Banks

To give plenty of stored power batteries are banked together. The common battery seen out there is the 110AH lead acid leisure battery. Generally 4 of these is the minimum needed for successful live aboard use. Alternatively a minimum of 3 x 130ah slightly larger lead acid is also the minimum sensible battery bank. Newer 130ah batteries these days are the same physical size as 110ah batteries so a 3 battery 110ah can easily become a 3 x 130ah for example. These two specs of batteries are the most common I see out there. It is very important ***BEFORE*** thinking about solar that the batteries are known to be in good condition and the bank of sufficient size. As batteries age they do not hold onto a charge as well as they did, eventually not holding a charge at all. The give away here is after doing a long run the batteries only keep things running for a couple of hours. This problem does not go away by fitting solar. They will merrily charge all day off the solar but do not hold it though the evening and night. This is a sure sign that batteries need replacing!

AMP HOURS or AH is a measure of how much they store. Going back to my recommendations for trimming your power down you could see that a unit on the boat such as a 240V fridge could draw 10amps lets say. This would equate to 24 x 10 or 240ah per day... So the bigger the bank the better right? Not exactly as too big a bank will take too long to charge hence optimum bank size. ***Remember once you have solar the batteries ONLY have to get you through the night time period. Short in the summer and LONG in the winter.*** The 4 x 110 or 3, 4 x 130 is a good optimum size to achieve this. It is gnerlly considerd the max sensible bank is 5 batteries.

Gel orAGM batteries

These use a non liquid electrolyte and were originally designed for applications where the battery might get tipped over – planes, yahts etc. They are available in various AH sizes running up to large capacity 300+ah units. Gel batteries cost more but have a longer service live – I’ve seen them up to 10 years old and still performing well. Capacity and power delivery wise though they are the same as the lead acid type.

Lithium

Lithium batteries are the latest thing – using the same technology as in your mobile and all other tech devices they offer the ability to be drained right down while delivering steady voltage and current so in theory a smaller bank will deliver power for longer than a traditional battery. This is the same technology used in electric cars. At the moment however there are no real standards for lithium batteries and they require very carefully managed charge regimes so connecting an alternator directly to a lithium battery without the right power management in place is not good. Additionally right now they are very very expensive. I think I would advise waiting a bit before considering lithium as your domestic bank though I should point out our controllers do fully support lithium charging its just not quite mature enough yet or cost effective to be a good option in my opinion.

Living with Solar

The system is pretty much maintenance free. However there are some useful tips:-

1. It is worth keeping the panels clean (quick wash over with something like washing up liquid and water, rinse off with canal water).

2. Tilt into the sun. This will depend on lots of factors. If you have motored all day and are only staying overnight then off again in the morning it probably doesn't matter too much. But if you are staying somewhere for a few days then it pays to make use of the tilt if the sun position is good (you will learn the places where solar can be best optimised). Given you are there a few days its worth tilting them into the evening sun then before bed tilting them in the direction of the rising sun. Works great in the summer when the low sun comes up at 4 and hits the panels. Often batteries are fully charged by the time you get up to make the first cup of tea (or coffee!)

3. Pick your mooring spot. Again if staying overnight only it probably doesn't matter, but if staying for a few days make sure there are no trees to shade the panels and avoid cuttings or buildings close to the canal. Often it pays to check "round the next bend" for a better option if you know you will be sitting there for a few days.

4. Monitor the system. During an average to good day, during the daylight your controller should show a charge voltage of between 12.6 and 14.4 volts. Then once it goes dark rapidly drop to 12.6 as stated in the section above. It is then worth checking periodically where that voltage has got to. This gives you a clue as to how quickly you are depleting the bank. On a dull winter day there may be minimal charge coming off the solar array and you may notice voltage already at say 12.1 at lunchtime. This would quickly tell you there is not enough charge coming in and you may have to supplement it with engine running. If your ***solar system, battery bank and power draw*** have been setup correctly though and ***IT DOES NEED ALL THREE OF THOSE THINGS, then you should only rarely need to run your engine and only on the very worst of winter days.***

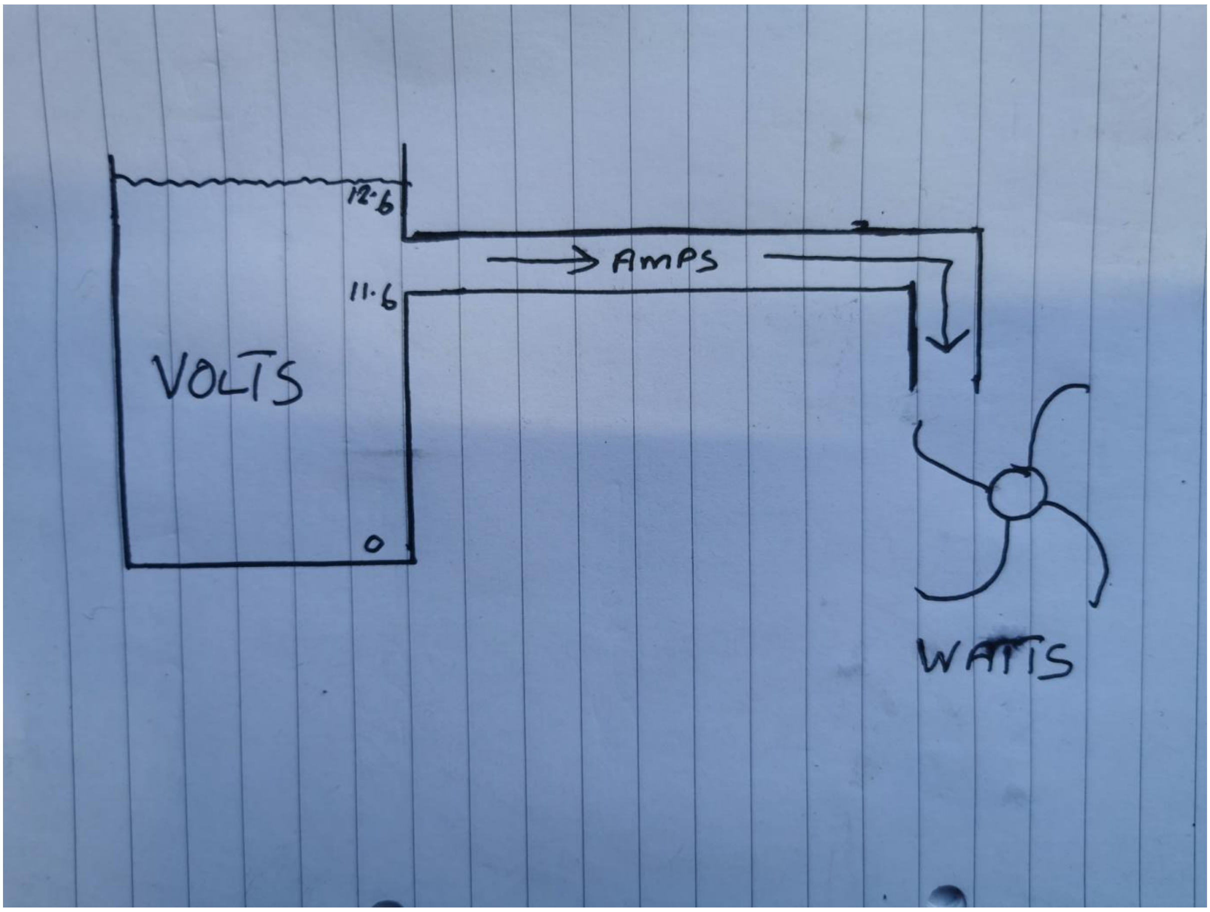
Example System Pricing - Jan 2021

All prices include installation wherever your boat is.

2 panel 430W system	£1,050
3 panel 645W system	£1,395
4 panel 860W system	£1,695

onboardsolar.co.uk

Understanding VOLTS, AMPS and WATTS in a 12V System



The easiest way to understand the relationship between Volts, Amps and Watts is to treat them as if they were water...

- **VOLTS** – This is your stored "tank" of energy. The main problem with a 12V battery "tank" though is that the water outlet is very high up in the tank as can be seen in the diagram. Imagine a pipe above the tank flowing into it – this would be your alternator, charger or solar

- **AMPS** is the flow of "current" or water from (or to in the case of charging.

- **WATTS** is the actual thing using the power (or generating it) suh as a fridge, pump etc