Learning to Live with Solar Energy in Southern Spain

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Preface

Two years ago we brought a partly built cortijo in Southern Spain. Mostly, we used local craftsmen to finish the building but after some thought we decided to use an English speaking company for the solar installation. We got some general quotes and then selected “Remote Energy” an English registered company trading in Spain who are based in north east Almeria.

Their web site was well presented and in our discussions all seemed well. However, there were problems from the day the system was installed. After a few weeks it became apparent that the system was not functioning as expected. Then there were equipment failures. From the outset the batteries did not seem to be functioning properly. Then the inverter/battery charger failed creating endless problems. After a few months we involved a Spanish solar engineer and started to change the system. Nine months later we have a functioning system. The system has been redesigned and apart from the panels, their mountings and some battery wiring nothing remains of that installed by Remote Energy.

Before we installed our system, I read general articles on the web and talked to a few people about their systems and had come to the conclusions that they were straightforward. I could not have been more wrong. Indeed the Spanish engineer and Remote Energy approach solar energy with totally different philosophies and these are reflected in their installations. As the problems began, I read more and talked to others about their experiences. Most of the people I spoke to had problems with their systems which did not meet their needs. A longing for a mains connection was common. Necessity made me experiment and I began to develop a system which I believe meets our needs in a cost effective manner. However, if I knew then what I know now, I could design a system that would have been closer too our needs and would have cost substantially less. As it is we have had to pay a premium.

The whole experience has not just been costly but also very stressful. For much of last year we were living with the generator running, to the annoyance of neighbours. There was also the perpetual anticipation that the system would shut down if not monitored. Then there was the hours spent, reading and on the phone, trying to find information which was in a form that I could understand. Without the understanding it was very easy for the “experts” to dismiss our concerns. Now most of those anxieties are in the past and I am writing this article in the hope that others can benefit from our experience and make choices that are in their interest rather than those who install their system.

I do not claim any expertise but I have learnt from experience. I completed an electrical apprenticeship some 40 years ago, and that has helped, but since then I have not worked in that field, spending most of my working life in hospitals and universities practicing, teaching and researching psychotherapy.[©]

Some readers will find this article simplistic, others over complex. This is inevitable and reflects my attempts to communicate my understanding to those without any previous experience. The themes discussed here reflect my own experiences and do not seek to totally cover the field.

There are bound to be omissions and errors and I would welcome any comments and corrections.

Introduction

In theory you can install a system that will provide free electricity anywhere in Southern Spain but the cost of that installation will depend upon your power needs and location. From a power point of view the ideal location is one that faces south with continuous sun from morning to evening. Even with this aspect, the cost of the installation is proportional to the amount of electricity required.

Our land faces North and we cannot get a full day's sunshine, even in summer – which can be a blessing. We do get some winds, but these are "mountain winds" which blow up the valley during the heat of the summer's day. In winter and at night we are invariably calm – so a wind generator is not viable.

Our consumption is probably high for those living in a house supplied by solar energy. We designed our house to have a traditional exterior and a modern interior. We wanted a gas fridge freezer but could not find one that was compatible with our style so we choose an electric model which is also more convenient than a gas model. Also my main interest at the moment is focused on the weather and I run a weather system with a computer connected to the internet 24 hours a day.

When we started using solar energy our basic consumption using these items and others such as lights, but excluding heavy use things like washing machines, air conditioning, power tools etc was about 5000wh (5Kwh) a day. (wh – watts per hour is the unit of consumption used in mains electricity bills) At the winter solstice our 6 * 85w panels only supply 600wh. Thus to be comfortable in winter we would need 60 panels! However, in summer, when the sun is above the mountain most of the day, we can nearly supply all our basic needs from the six panels. To cover our winter needs is not affordable using solar panels alone, so we a need a compromise system. In practice this means using a generator for part of the time.

As I write, with experience and management of our system, our consumption from the batteries is much lower and I hope will eventually be reduced to less than 2KW.

In choosing a solar system we have come to realise that there are various choices that need to be made and these were not discussed with us – I am sure all solar engineers will tell you they would discuss these issues with their clients but I have my doubts as the installers that I have encountered tend to have a perspective into which they fit the client.

These issues broadly fall into three areas.

1. What are your wishes for power? You can choose to run a full system off solar power, but at a cost.
2. How far are you prepared to be "hands on" with your system? A hands off system would be seamless, just like using mains electricity. This is what we anticipated but it never materialised. If it had functioned as we expected I now know that the running costs would have been impossibly high. "Hands on" implies monitoring your power uses and switching to the most efficient supply source at any time.
3. How much security do you need in your supply. Can you tolerate it not working for days or weeks?

The article is divided into various sections

1. A description of the basic components found in a solar system; how you generate power, how you store it and how you distribute it to appliances.
2. A discussion of the basic issues that effect the efficiency of solar systems. In an efficient system all the power you generate would be available for use, in practice it is much less.
3. A description of the different ways solar systems can be organised. Basically - there is no such thing as a standard installation.
4. Comments on individual components – e.g. How do you choose a generator?
5. Will your appliances work? Think twice before you invest in that expensive, highly efficient washing machine.
6. Running domestic appliances efficiently – how we managed to cut consumption.
7. Conclusions

The Basic Components

The basic components of an off grid power system can be divided into three major groups concerned with power generation, storage and supply.

Power Generation.

There are three main methods for generating power in an off grid system; Wind generators, solar panels and fuel powered generators.

Wind Turbines.

Looking at the specifications of Wind Turbines, they seem to me to be a cost effective method of generating power. However, you need wind and we have very little. Thus I have no experience with these and will not consider them further. Though there are a number of solar installations in our area none, to my knowledge, includes a wind turbine.

Solar Panels.

These are the main method for generating power in off grid systems in southern Spain. These panels are different from those from those used to heat water. Solar electricity panels consist of arrays of photovoltaic cells, each generating a small voltage when exposed to sunlight. These are combined together in the form of a panel. Those used for domestic solar systems are normally of 12 volts. The panels used in solar electricity systems commonly have a power rating between 40 and 120 watts. The higher the power rating, the more cells required and the larger the panel. Panels themselves can be combined together.

Connecting ***two in series (positive to negative poles) increases the voltage*** *of the system. Thus two 12volt panels connected in series creates a 24v system.*

Connecting ***two in parallel (positive to positive) increases the power****, so connecting two 85 watt panels together creates a system which is rated at 170 watts.*

However, the actual power delivered by the panels can be greater than the rating. We have six panels connected to create a system of 24volts rated at 255 watts. Under good conditions these panels can produce more than 400 watts. The output is always direct current (DC) and this is not suitable for many applications (see comments below). In many systems the solar panels are used to charge the batteries. Once installed, solar panels supply free power and do not require maintenance.

Fuel Powered Generators: The fuel generator consists of a engine which turns an alternator that produces an alternating current (AC), usually at 220volts. The engine can be powered by petrol, diesel, bio fuels or even gas. Because the generator supplies AC, providing it has a stable output, it can supply power directly to the house, and be used to charge batteries. The generator uses fuel and therefore has a running cost. To be reliable, it also requires regular maintenance – much more frequently than a car!

Power Storage.

Batteries:

Although the sun shines most days it never shines at night, so electricity developed during the day needs to be stored. Similarly if a generator is supplying power it is probable that you will want to switch it off during the night. So some of the power generated has to be used to charge batteries which can then be used to supply power during the night. In some systems, the power generated is only used to charge the batteries from which all the household power is taken. The power is stored in the batteries as direct current (DC – the Spanish often refer to this a “baja tensión”). This power can then be taken directly into the house (in the case of a low power system) or converted to alternating current (AC – “alta tensión”) if the house has a high power system.

The batteries used in solar systems differ from those used in a car. The car starter battery is designed to provide a very high current (to turn over the engine) for a short period of time. Conversely the batteries used in solar systems are designed to supply a much lower current over a longer period of time. These batteries are often called leisure batteries.

The batteries commonly come in 12 volt or 2 volt units. These are then connected together (in the same manner as solar panels) to give the required voltage (normally 12 or 24 volts). Confusingly a group of battery units connected together is referred to in the singular as a battery.

Each battery has a rating that describes its ability to supply power. So an individual unit which is rated at 200 ampere hours (ah) could theoretically supply 20 amps for ten hours. Batteries can be connected in the same was as panels – as described earlier. By connecting batteries in parallel the capacity of the system can be increased. Traditionally, the batteries used in solar systems have been made up of a group of 2v batteries connected in series to create the working voltage of either 12 or 24 volts. These individual units can have very high capacities, such as 1200 ah and seem to be the most efficient and reliable. The 12 volt batteries are rarely larger than 250 ah each, which is fortunate because a battery of that capacity can weight over 60 kilograms.

Battery Chargers:

Batteries are expensive and the way they are charged can dramatically alter their effective life. Both overcharging and undercharging can be damaging and so "intelligent chargers" have been developed to ensure that the batteries are charged most efficiently. Although you can charge leisure batteries using a normal car charger it is unlikely they will be fully charged and they risk being damaged. If the generator is being used to charge the batteries then there will be a battery charger. Between the solar panel and the battery is a solar regulator which prevents overcharging. More about these will follow.

Power Supply

Direct Supply:

In some situations the power is taken directly into the house from the batteries or from the output from the solar regulator. These are the DC or low power systems.

Inverter:

Most houses use AC for their power supplies. Before power from batteries can be used in a high power system it has to be converted from DC to AC. This is achieved by an inverter which converts the DC (typically at 12 volts or 24 volts) to AC (usually between 220 volts and 230 volts). Inverters can be created to supply 6KW or more power. However, as the power supplied increases so does the required battery size. It is rare to find an inverter that supplies more than 1500 watts working on a 12 volt battery. One reason being that the size of the cables required to carry the current becomes too great.

Inverters are categorised the type of waveform they produce. In Europe the mains AC supply changes between positive and negative 50 times every second. This is called the frequency of the supply. In a perfect supply this change over is perfectly smooth and takes the form of a sine wave. The best inverters can supply a "pure sine wave" and will run any appliance that can run on the mains. Less smooth, but also much cheaper, is a modified sine wave which will run most appliances. An inverter with a square waveform output should be avoided because many appliances will not work with the output they generate.

Generator:

The generator can function as a power supply into the house. In some systems the generator is the main power supply and the solar system and batteries are secondary. In others the generator is only used occasionally. Most generators produce either a modified sine wave or square output.

Efficiency and Temperature.

Before describing the different types of system it is worth mentioning the important issues of efficiency and temperature.

Efficiency

In the current context efficiency refers to the fact that whenever you convert energy from one form to another you lose some energy in the process. For instance the energy you get out of a generator (in the form of electricity) is always less than the energy that goes into the machine in the form of fuel. The measure of power used is usually the Watt-Hour (wh) which describes the number of watts (volts x amps) being supplied over an hour. This is slightly misleading because when dealing with alternating current the calculations are slightly more complex. But for illustrative purposes it serves. Watts per hour is the unit in which mains electricity bills are calculated. 1 kilowatt hour (Kw) is 1000 watt hours and would be the power used by an appliance, connected to a 220 volt AC supply, using roughly 4 amps over 1 hour, or 2 amps over 2 hours. Theoretically, for a 12 volt battery to supply this power over 1 hour it would be required to supply 80 amps whilst a 24 volt system would need to supply 40 amps. However, because there are inefficiencies in the system the actual demand on the batteries will be greater.

There is a degree of inefficiency in all systems that generate electricity. In a recent booklet, aimed at helping consumers understand the need for efficient use of mains electricity, the Spanish government stated that for every Kw of power delivered to a house the equivalent of 3Kw of fossil fuel had to be consumed.

Currently, solar panels only manage to convert 15% of the energy received from the sun. However, in a solar system you often transform the energy from the panels on many occasions. The more often you transform the energy the less efficient your system. Most solar chargers provide a figure for the amount of energy received from the panels. Thus today my solar charger said that the panels had supplied 2000 wh, unfortunately because of losses due to inefficiency that is not the power available to run appliances. A general figure of 85% efficiency can be used as a guideline for most components. Thus a panel which is supplying 2000wh during a day will be supplying less effective power. For instance the power available from the batteries will be less by 15% (ie 1700wh) and if this is being passed through an inverter before going to appliances then only 85% of that 1700wh will be available. i.e. 1445wh. So my initial 2000Wh translates into less than 1500Wh available to run appliances.

Temperature

Most items in solar systems are effected by temperature. Solar panels are most efficient in freezing conditions and the capacity of batteries to supply power falls off with rising temperature. At least one make of inverter found in solar installations has a rating of 3KW at 20 degrees C but this falls to 2KW at 40 degrees. Elecsol, a manufacturer of carbon fibre based lead acid batteries offers a 5year guarantee in Britain but not in Spain because of the effects of temperature on the performance of their batteries. During the summer, temperatures above 35 are common in southern Spain, so our systems are always least efficient when there is most sun!

Appliances and Efficiency.

It is worth taking the points regarding efficiency a little further. Our system was set up to run the washing machine from the inverter. As we do not have sufficient solar power the batteries would have to be charged up from the generator. As the power moves through each component in the system it is reduced by 15%. So if we start with a 100 units of fuel (in our case gas) we then lose 15% through the generator, 15% through the battery charger, 15% through the batteries and 15% through the inverter. Thus we only have 52% of the original power left to supply the washing machine.
To deliver the equivalent of 100 units of fuel to the washing machine requires a supply of 200 units. To run the appliance from the generator would require just under 120 units. Obviously these calculations are based on the assumption that there is

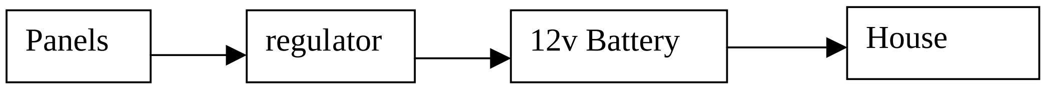
insufficient solar power. If you have the available power then directly running the washer from the inverter is more efficient. (See comments later about washing machines.)

In theory a gas refrigerator is much more efficient than an electric powered model run from the inverter, as it takes its power directly from the gas supply. However, the process which uses heat to produce cold is much less efficient in a gas fridges than in an electric fridges; they also have the disadvantage of generating more heat because they use an open flame as part of the cooling process. So the difference in total power use may not be as great as it first seems. However, if you use an electric fridge freezer it is likely to consume more power in a day than any other item.

Methods of Combining the Components in a Solar System.

When I first started exploring solar systems I assumed there was just one way of going about putting these systems together. I was vaguely aware that there were differences of opinion but only in the sense that some engineers would make disparaging remarks about others installations. Now I realise that there are at least four types of system being installed, each with their own philosophies. I refer to these as the Low Power System, The High Power System, The Nautical System and the Hybrid System. These are my ways of describing what I have encountered and to my knowledge these terms are not used elsewhere. The idea here is to present the basic structure of the system, in practice they tend to merge into one another.

Low Power System.
The low power system is the type most commonly found in the Spanish owned cortijos, mainly used at weekends, in our valley. They consist of three components – solar panels, a battery regulator and battery. The battery supplies 12 volts DC and this is normally taken straight into the house, providing lighting using energy efficient bulbs.

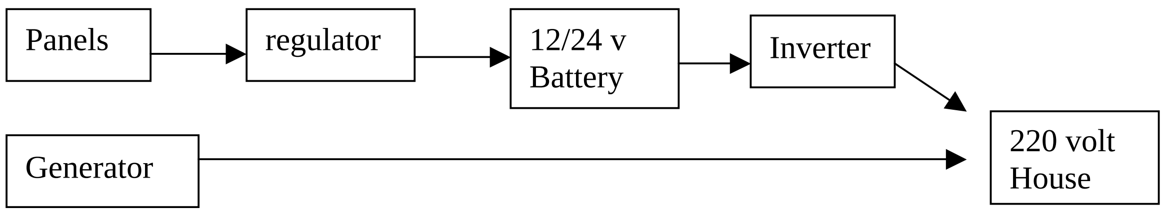


I had not given much thought to these systems until I realised that we knew a couple living virtually full time in a house with a 12 volt systems. He is a retired solar engineer. They seem live quite normal lives! When you think about it, it is not so surprising, anything that you can operate in a car can also be run from a 12v solar system. A small inverter, plugged into a DC socket can supply power for things like Sky boxes, LCD televisions and portable computers. Items like washing machines can be run directly from a generator and all other requirements are supplied by gas.

The point about these systems is that they are comparatively inexpensive to install and having fewer components are the most efficient way of converting solar energy. If I was installing a system in a holiday home this is the route I would consider.

The High Power System.
In its basic form the high power system is a variation on the low power system. However, instead of feeding the supply directly from the batteries into the house, an inverter is placed in the circuit so that the supply is now AC. Usually, in Spanish installed systems, the inverter is quite small and the power is limited to about 600 watts. Items like washing machines can be run directly from a generator and all other requirements are supplied by gas.

If the power required is more than 1500 watts then there is a quantum leap forward in costs. To supply the greater power it is necessary to upgrade to a 24 volt solar system. This means twice as many panels and batteries. Again, items like washing machines can be run directly from a generator and all other requirements are supplied by gas.

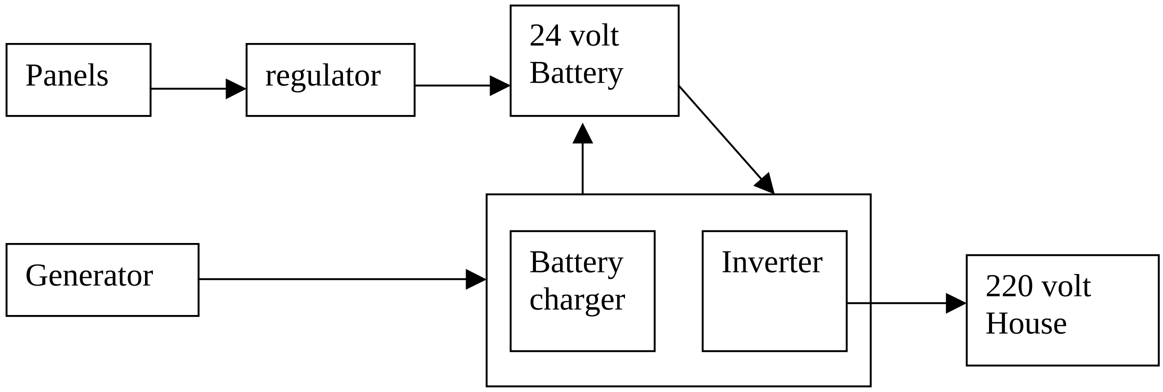


When the Spanish engineer came to look at our system this was the approach he took. What fascinated me was that he was surprised that the house was not wired with two power circuits. Apparently one approach to these systems is to connect the solar supply to the lower capacity power circuit and the generator to the other. Whenever an appliance is plugged into the higher capacity circuit a sensor detects its presence and starts the generator. I have not seen this working but it is an interesting approach. Another variation I have encountered is to use two inverters one supplying lighting circuits and another power circuits.

The main point with the approach taken to this system is that you have to calculate your daily solar power needs, with a calculation for the number of days that need to be supplied without sun and this determines the size of the system.

The Nautical System.
I refer to this approach as the nautical system because it was developed for boats. The assumption is that the solar panels and the generator are seen as equal partners in the process of power generation. The battery charger and the inverter are often in a combined unit (CBCI – for short). All appliances are assumed to run from the inverter; which has to be large enough to supply all the appliances that may be working at the same time. When calculating the size of the battery it has to have the capacity to supply this inverter for a set period of time . When the generator is running, the internal system of the CBCI will usually switch the supply from the generator to the house whilst also charging the batteries. The inverter is disconnected.

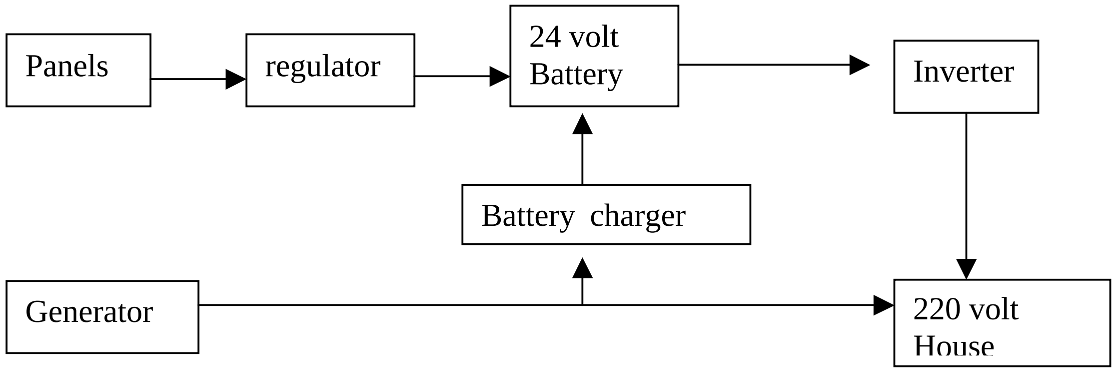
The total power rating of the CBCI limits the combined system, as will be described later. If a low battery switch is incorporated into the system, the generator can start automatically when the battery voltage goes below a set level. Thus in theory it should work seamlessly and from the users´ point of view be like a normal house.



This was the system that we initially had installed, it was expensive, did not deliver its promise and eventually faltered on component failures.

It was when the CBCI failed that I asked the Spanish engineer to have a look at the system. Taking on board his comments, I developed what I would call a hybrid system but, it seems to me only common sense. Some of the problems I encountered will be discussed in the following section.

The Hybrid System.
One of the things that most surprised me about the way the *high power* systems were installed was that they did not have any facilities for charging the batteries. I know of many of these installations, by different companies and none install battery chargers. Indeed, when I asked the Spanish engineer for a reasonably priced battery charger, the battery charger produced was a car battery charger for a garage. Eventually, I brought a pair (more of which later) from Britain over the internet. Later one of my Spanish neighbours asked me to get one for him, at the recommendation of the Spanish engineer. We have now found the same items supplied in Spain but they are much more expensive.



In our hybrid system the main household supply is connected to both the inverter and the generator. When the power from the generator is switched to the house the inverter is disconnected. The battery charger can be switched on or off according to whether the battery requires charging. Whenever a high demand item is used (eg washing machine or irrigation pump) then the power is switched over to the generator. The generator is sufficiently powerful to be able to supply these items whilst charging the batteries. In the winter evenings, when there has not been sufficient sun, the generator is used to charge the batteries and provide the household supply. Thus we can maintain our relatively high load without too much inconvenience.

Comments on Individual Components

Solar Panels.
The basic design of solar panels means that they generate most power when the suns' radiation strikes the surface at an angle of 90 degrees. At the winter solstice, in Southern Spain, this occurs if the panel is set at about 70 degrees from the horizontal at 2pm in the afternoon. However, in summer the panel should be set at 30 degrees because the sun is higher in the sky. Further, as the sun moves through an arc in the sky, the panels should ideally follow the sun – which is what happens in commercial installations. However, most domestic installations are fixed with the panels set at 70 degrees facing due South. In other words they are maximised to supply power during the winter. Does this make a difference – yes it does.

I requested that our panels be mounted on a bracket that allows them to be moved both in the vertical and horizontal planes and Remote Energy did make a bracket for me. I adjust the angle for the time of year. I can move them two or three times a day to maximise the power. I estimate that in the summer I get about 60% more power my moving the panels than I would by keeping them static in the winter position. In other words my six panels function as if they were ten static panels. In the winter this is less effective because the panels are shielded from the sun much of the day and its arc through the sky is much smaller. The most effective gains are in Spring and Autumn because in Summer we have sufficient power.

If you have a static solar system, it is necessary to base your calculations for your power needs, and thus the number of panels, on the available solar supply in winter. The extra power in summer is lost. This would not be financially viable in our system where the available winter power is low. By using the combination of generator and panels we are able to run most of the summer on the six panels alone but in mid winter we are largely dependent on the generator.

A second important issue is the wiring from the panels. I was surprised, and somewhat sceptical, when the Spanish engineer stated that he wanted to renew the wiring to the panels. The panels are mounted about 15 meters from the batteries and had been installed with 4mm cables. These were replaced with 16mm cables and the power reaching the batteries from the panels increased dramatically. When our panels were installed we could not have predicted that the shape of the mountain behind would have had such a dramatic effect on the amount of winter sunlight. We have finally located a point on the property which gives about 40% more sunlight than their present location.

However, this is 60 meters from the house and the cables will have to be at least 25mm thick, if we are not to lose all the extra power in the cables. An alternative approach would be to build a small “power house” to house the batteries, inverter and chargers and then run a cable from the generator to the charger and a second from the inverter to the household supply. This would be cheaper because there is far less voltage loss with AC supplies. However, when the costs of making the changes were calculated – each came out to about 2000 euros. We could get a similar increase in power, by adding two extra panels at the current location! After much heart searching we decided to put the panels on the roof of the house. Here they are more secure, though they ruin the line of the building. They will be accessible and this small movement will increase the mid winter exposure to sun dramatically.

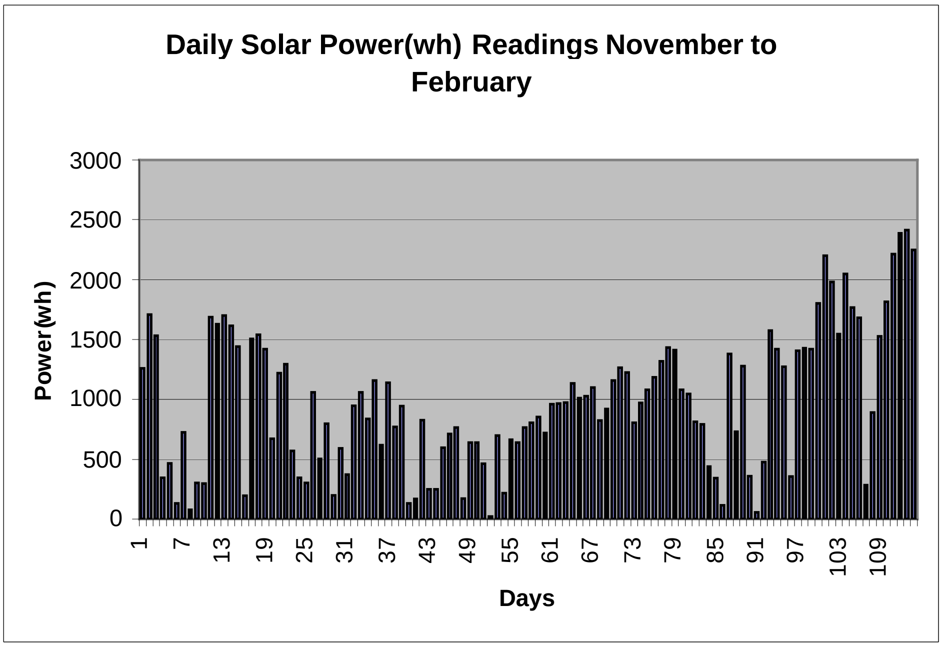


Figure 1

As Figure 1 shows, the amount of solar power we got between November and February was not consistent. Although there are some readings missing from the chart two clear patterns emerge. Day 50 is the winter solstice and the amount of power declines from the beginning of November till then and then starts to increase again. However, there are considerable variations within this trend. Unfortunately, there are blocks of good days and blocks of bad days. It is rarely the case that you get a good day followed by a bad day, followed by a good day. This means that in calculating the number of batteries needed you must to ask yourself, for how long do I want my system to work without a supply from panels or generator?

Generators.

The question most often asked about generators is – what type of fuel is best? However, there are other important issues as well.

Manual or Electric Start:

This question is more important than one might immediately think. Obviously, if you want any form of automatic or remote starting then you must have an electric start model. Another issue is, who will start the machine? I have met several women who were anxious, because they did not have the strength to start the generator which supplied the backup power.

Open or Silenced:

This really is a misnomer because the choice is between loud and less loud. If the generator is to be used a lot and is close to the house a silenced model may reduce the stress both on yourself and any neighbours. However, an electric start, silenced generator is likely to cost twice as much as an open frame model with the same power.

Size

I was advised to get a much larger generator than I thought I needed. This has been good advice. We are dependent upon our generator and so having a unit that easily copes with any individual item is a blessing. When running the generator we have sufficient power most of the time to run the household appliances and charge the batteries at the same time. Generators are somewhat like cars. If you drive them too slowly you get less miles per gallon. In the case of the generator, I feel, it is always best to run the optimum number of appliances – such as charging the batteries, running the household and using the irrigation pump. To use the irrigation pump alone would be much less efficient.

Fuel:

The choice is normally put between petrol and diesel but how about a gas conversion? When we talked of using a gas generator most of the British expats I talked to were sceptical. Using the web, I could not find any Spanish company supplying such generators. Consequently, we brought a converted model in UK and shipped it with some furniture. When the local gas fitters saw it they took it in their stride. Indeed since getting to know our neighbours I have found several who also use gas as their main fuel. This can either be butane as in the 12Kg bottles or, as in our case, the 35kg bottles of propane. The joy is not having to refuel. The generator is permanently connected to the supply. We have a bank of ten bottles (these also supply hot water, central heating and cooking) and the gas supply truck happily braves the entrance track to deliver them. It is said that the generator, a 5KW model, uses 1.2kg an hour on full load. Is it cheaper than petrol or diesel? Having used all types of fuel, gas is certainly the most convenient. In the event of a gas shortage it can also run on petrol.

Last winter our Honda powered gas generator was used six or more hours a day. Regular servicing is an imperative. Oil and air filter servicing is required much more often than I would have expected. The spark plug needs cleaning every six weeks or so and the dusty atmosphere means cleaning the air filter with similar frequency.

Generators and Appliances:

To protect against power supply fluctuations I use Uninterruptible Power Supply (UPS) units on all vulnerable equipment, such as computers and entertainment systems. These protect against power surges but also keep equipment running when switching from generator to inverter supply. Ideally, we would have an "automatic transition switch" this would keep the whole mains supply working for the brief period when switching between generator and inverter. Units which combine battery chargers and inverters usually have such switches built in.

Batteries.

Battery Size.

The basic question is whether to use a 12 or 24 volt battery. Most domestic systems use 12 volts because it is not envisaged that very high currents would be drawn. 12 volt systems seem to be used with inverters up to 1.5Kw. Our old washing machine when connected to the inverter could draw over 120 amps when heating water – on a 12volt system that would have been 250 amps and would have seriously challenged the batteries and the cables. 12 volt systems are substantially cheaper to install.

The second issue about battery size concerns the capacity of the battery? That is, how much power do you want to draw, for how long between charges?

In systems without independent charging systems the size of the battery is calculated on the basis of the power used and the amount of charging from the solar panels. In a typical weekend cortijo the power is used for 2 days and then the panels have 5 days to recover the charge.

If the power is used over 7 days, the battery must have sufficient capacity to cover the total amount of daily power. Additionally there needs to be capacity for days when there is little solar power. As shown in Figure 1 (Pg 12) poor weather comes in blocks so; how many days with little charge do you need to cover? Additionally, when you do start charging, the panels must be able to cover the daily needs and still have sufficient capacity to charge the batteries.

In systems with a backup charging system the calculations are easier. I want our batteries to be able to supply one complete day and if there is not solar power to cover this I will use the generator. When I replaced our batteries I calculated that 250 ah would be sufficient and then doubled this installing a 560ah battery.

Of course if you are using the inverter to supply large loads like washing machines then you need a much larger battery. The higher the current being drawn from a battery the lower the effective capacity.

Battery Charging.

The batteries are a core component of a solar system and over its life time they can turn out to be the most expensive part. In a well used system they may only last 3 years. Apart from simple use, the main reason why the life of a battery is foreshortened is because it has not been charged properly. There are recommended procedures for charging batteries and these require an "intelligent" charger.

When a battery discharges, there are internal chemical changes . When it is recharged the changes are reversed. If the battery is not charged fully, then the chemical reactions are not completed and gradually the capacity of the battery is reduced. Thus a 200ah battery starts to behave like a 100ah battery because it cannot be charged properly. If it is overcharged then a loss of electrolyte can occur.

The key part of the charging recommendations are the first two stages of a four part process. It is usually recommended that, in the first part of the charging process, a battery is charged at about 10% of its capacity. Thus for a 500ah battery the initial charge would be 50amps. As the battery becomes charged the voltage increases to an optimum level (usually referred to as the absorption voltage) , at this point the charge must be reduced. The voltage recommended depends upon the type of battery, e.g. 29.6volts for a 24 volt lead acid battery. Once the absorption voltage is reached the voltage is held constant and the current reduced. As the charge is consolidated less and less current is required to hold the voltage. At this point the charge is completed, though a third stage (float) at a lower voltage can finish the process.

When the charged battery is disconnected from a load the voltage should be 12.7 volts, or 25.4 volts for a 24volt battery. When the battery registers 24.4 (12.2) it is 50% discharged. It is fully discharged by the time it reaches 23.8 (11.9) volts. If there is a load on the battery then voltage displayed will be lower. Most inverters have a cut out that prevents the system working when the battery is low because continuing to use a battery in a discharged state can damage it.

Apart from its capacity a number of factors determine how long a battery will take to discharge. First is the state of the battery; if the charging process is unable to change the internal chemistry then the battery may appear charged according to its voltage but not be charged in practice. In that case the use of a hygrometer to determine the specific gravity of the electrolyte will be a more accurate indication. A second influence is temperature; the hotter the environment he lower the battery capacity. Finally, the nature of the load; if a high current is drawn from the battery then it will discharge more quickly than if a low current is taken.

But how far should you allow a battery to be discharged before recharging? There seems little agreement about this. Many manufacturers say that the life of their batteries is, for instance, a 1000 full charge and discharge cycles which implies that the battery could be fully discharged. I try to keep our batteries above 24 volts.

There are advantages in keeping a battery well charged – apart from the fact that when it is well charged it takes less time to recharge it. Firstly, I was surprised to discover, that the solar regulator tends to adjust the voltage that it allows to reach the battery from the panels, according to the state of the battery. Thus if the battery is partially discharged then the regulator will let less power in from the panels. Apparently, there are regulators can allow the maximum charge from the panels but I have not encountered them. Most solar regulators try to act like intelligent chargers and will also cut of the supply from the panels when the batteries are fully charged.

Secondly, the inverter tends to be more efficient when running with a fully charged battery. I was told that the inverter could be 95% efficient when the battery is fully charged while at 80% charge it will only be 85% efficient.

Battery maintenance.

Unless you have maintenance free gel batteries the levels of the electrolyte in solar batteries should be checked regularly. Our friendly solar engineer was adamant about this – only later admitting that he had wrecked his own very expensive batteries by running them dry. When our system was initially installed Remote Energy supplied an impressive steel rack on which the batteries and inverter were mounted. The Spanish engineer disposed of this racking because it was not possible to check the batteries without disconnecting the leads and pulling them out. The other was that the enclosed rack blocked air circulation and therefore could encourage overheating. Inverters should never be placed directly over batteries because of possible problems with gasses and overheating.

Battery Choice.

Because batteries are such a large part of the initial expenditure thought needs to be given to them. Initially we were supplied with 8, 220ah Elecsol Carbon Fibre batteries, giving a capacity of 880ah for our 24 volt system. These never seemed to work as expected and I repeatedly complained to both Remote Energy and Elecsol, who ignored me. It was not until I was able to measure the power consumption and could show that these were performing more like a 340ah battery that I got a response. Remote Energy have accepted there are problems but refuse to do anything about them unless Elecsol first agree – and say that Elecsol will not communicate with them. On a recent occasion I spoke to Elecsol who said their batteries are not guaranteed for use in solar systems outside Britain, implying that they should not have been installed in the first place. Their reason being that temperatures in Southern Europe are above 30degrees C. They said they would send a booklet explaining all, but have not done so. Neither company has formally responded to letters that I have sent.

The batteries were putting the whole system under pressure because they required the charge of an 880ah battery but they only supplied power as if they were a 340ah battery. Under these circumstances we had no choice but to purchase new batteries. But which batteries should we choose?

The battery of choice was clearly the 2v tubular plate type. These seem to last forever. We have a neighbour that claims his 12v system has lasted for twenty years and others I have met have been using the same battery for between 5 and ten years. However, these are expensive and given the difficult financial position I went for the opposite extreme. We purchased six 180ah batteries, with a one year guarantee, from the garage in the village – the total cost was under 750 euros, less than a third of that for the 2volt units. These were not brought blind, one neighbour has been using them for 2 years on his system. But are they solar batteries – I don't know – I suspect that they are actually designed for fork lift trucks. However, whatever their origin, they outperformed the Elecsol batteries from day one and after four months are still working well.

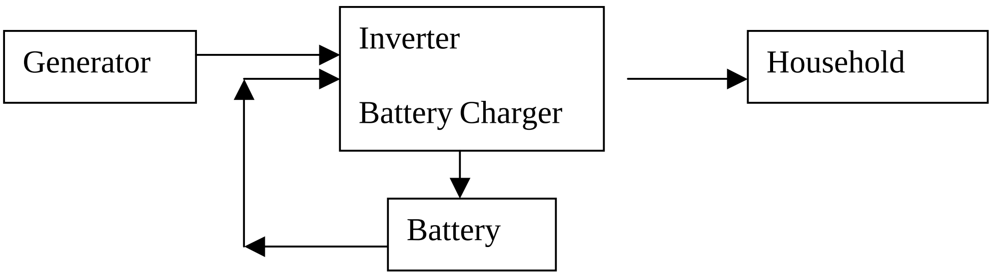
A comparison of the two batteries is instructive. The night before we changed the units the voltage of the Elecsol 880ah battery dropped from fully charged to 22.8 volts when supplying 2721wh over a ten hour period. In other words the battery had been discharged. The new battery with a capacity of 540ah hours was less than 50%

discharged when supplying a similar load over a similar period. In spite of this evidence neither company is prepared to offer compensation.

Battery Chargers and Inverters.

I am initially considering these two items together because they often come in a combined unit. We had a single unit made by Victron which contained a 70 amp charger combined with a 3000w inverter (CBCI). This is less expensive than buying the separate units but, from my experience, I would never purchase them in combination again.

The two component parts of the unit (CBCI), the battery charger and the inverter work in combination. The generator is connected to the CBCI and the CBCI connected to the household supply. Thus all appliances on the circuit are supplied via the CBCI even when the generator is connected. The problem is that the CBCI applies a limit to the power that it can supply –in theory 3000w but as this was taking place in July and the available power might have been less due to high temperatures. This limit includes not just the appliances but also the power diverted to charge the batteries.



From the outset there were problems and although the generator could supply the household alone, when connected to the CBCI, the system would fail the moment any heavy loading item was switched on. The installation engineer then made adjustments to the settings and all appeared well. However, the batteries never seemed to charge even though the CBCI was indicating that it was charging correctly. What transpired was that the engineer had set the charge current and the absorption voltage very low. This enabled the appliances to work and gave the impression that the batteries were charging. But it was set so low that even when there was no load the battery did not charge. Increasing the charge to the correct level caused the appliances to cut out. There was no way of changing the battery charge level to suit circumstances without taking off the case of the CBCI and resetting the dip switches.

This problem was compounded by another. The battery charger developed a fault. However, the item was covered by a return to base warrantee – and the base was in Holland. Neither the manufacturers or the installers were prepared to offer a replacement unit – because, as the manufacturers explained it would take less than a week from the time it was removed from my system till it was returned ! Sceptical of their timetable I resisted, mainly because this would have meant us having to rely solely on the generator for power. Eventually Remote Energy agreed to purchase the unit back – but only after it was repaired under warrantee. We therefore had to buy a new unit and wait for the other to be returned before being reimbursed. I brought a Spanish unit through the Spanish engineer – it was about 3 months before Victron had the original unit was back in Spain in working order!

One cannot protect yourself from equipment failure but even if the system had not failed there were two problems with the CBCI. The initial problem was one of inflexibility, the engineer could not balance the system. The second was a problem of security. Any component failure meant the whole system had failed.

We replaced the inverter part of the CBCI with a Spanish made inverter (a Solener 3000W) which seems to offer more features and cost somewhat less. And unable to find any Spanish made stand alone battery chargers, we installed two Sterling Battery chargers working in parallel. These can be switched independently so that we can choose whether to have full charge, half charge or no charge when the generator is functioning.

Inverters

Only modified sine wave and pure sine wave inverters are suitable for solar installations. Square wave models will not run most domestic appliances. Pure sine wave models will run any appliance that will run on the mains while modified sine wave models will run most types of appliances. Generally speaking, modified sine wave models cost substantially less than the equivalently powered sine wave model.

I had been led to assume that modified sine wave models were not acceptable. In practice they are said to run 85% of all appliances but not voltage sensitive white goods (see the section on appliances). I have been experimenting with a small modified sine wave inverter and found that it will easily run most appliances like computers, televisions and also lighting circuits.

There are two other issues when considering an inverter. Firstly, its capacity to deal with “surges” in power. Many appliances, like fridges and cathode ray tube televisions have a power surge when they start. This surge is far greater than their power demands after they have started. If the surge is greater than the inverters rating the system will shut down. Most inverters can accept surges greater than their rating but not all.

Inverters use power when running even with small loads. The amount of power used (called the quiescent or standby current) can be quite high with some models. For instance our Solener 3000w appears to use about 22wh which means that if the only appliance running in the house is a 2w night light the inverter uses 24wh. I shall consider this issue in the following section.

Will your appliances work with your system?

If the generator/inverter output is a pure sine wave then almost all household appliances can be connected directly. Most will also work with modified sine wave machines.

However, in talking to people using solar systems, the appliance that is least likely to work with a modified sine wave is the washing machine. This was the only appliance that would not work from our generator. It would not even switch on! It had to be connected to an inverter and this made extreme demands on the batteries, drawing 120 amps when heating water. Eventually, we sold it to a friend with an on grid system and replaced it with a Spanish made Balay which works fine. The reason the Spanish made models are more likely to work is that, in Spain, the mains supply has tended to be unstable and Spanish appliances have been designed to cope with this.

It is not just the type of output that can effect the appliances but also voltage fluctuations. You can get considerable voltage fluctuations even with a powerful generator. When our fridge starts up, the generator supplied voltage in the system drops from 220 volts to about 200 volts – our 3000w inverter however only drops from 229 to 228 volts. Washing machines, dishwashers and microwaves are particularly sensitive to voltage fluctuations. Because they use sophisticated electronics, the spin cycle of washing machines can be very sensitive. If I put on too many appliances then the spin cycle will not work and I know of one couple whose washing machine will wash from the generator but not spin.

Because I can vary the amount of power being used by the battery chargers I have learnt the optimum combination of appliances that can work together. For instance I can run the household, the irrigation pump and two battery chargers together, but only the household, one battery charger and the washing machine.

Another point worth considering is the size of the inverter. Spanish installers seem to install inverters with little power – often the smallest pure sine wave they can find. There seems to be a philosophy in this – “if you live in the campo you cannot have the same facilities that you have in the town” one said to me. “Why not”, was my silent response, not wanting to be given another lecture. And why, if you install a 600w inverter, install an expensive pure sine wave model when most of the appliances you run will work on a modified sine wave. It seems to me that a lot of appliances hair dryers, micro waves for defrosting, bread makers etc use between 600w and 1000w for short periods of time. Switching on an expensive generator to run a hair dryer for ten minutes is simply not cost effective and is also very inconvenient. And installing a 600w pure sine wave for a lighting circuit – why?

Many appliances, such as refrigerators and televisions, have a very high start up current. Some appliances will not work though they should because the start up current of the appliance exceeds the power of the inverter.

Just looking at the prices of an English marine supplies company from whom I purchased my battery chargers a 600w pure sine wave inverter costs £210 a modified sine wave £89. A 1000w pure sine wave £420 a modified sine wave £170.

Running Domestic Appliances Efficiently.

It was inevitable that once I started to write this article I would begin examining my own system. When I started writing, we were using in excess of 5kwh a day but now we are using around 3kwh. I am confident that we shall get down to 2kwh when I have finished making the changes I envisage. This has led to a dramatic reduction in the amount of gas used for the generator.

Below I give various figures for the power used by appliances. These figures are based on actual observations of my system. Measures of power used are taken from the display of the inverter and represent the power taken from the batteries. Where figures are given they have been calculated with the power used by the inverter subtracted. Recently, Maplins (www.maplins.co.uk) have been selling an energy consumption meter, which can be used to see the power consumption taken by an appliance. I have used this but it does have a draw back in that it resets itself if switched off as happens momentarily when the power is changed from inverter to generator.

Selecting Energy Efficient Items.

Lights

Probably the greatest single change you can make to improve energy consumption is to use energy saving light bulbs. Though they take a little time to reach full brightness, once they do, they can give the same brightness as their equivalent non energy bulb for small proportion of the power consumption. Be aware, however, that halogen bulbs are not energy efficient. A 60w halogen lamp may be small but it still uses 60w and the same light could be produced by a 7w energy efficient bulb. Fluorescent tubes are also to be avoided if possible. They have a high start up current and the same amount of light can be provided and spread by using several energy efficient bulbs, for much less power.

Domestic Goods.

The energy efficiency of white goods such as washing machines and refrigerators is increasing all the time. However, one needs to be aware that this may come with sophisticated electronics which will only work with a pure sine wave output. Our Balay dishwasher and washing machine seem to work well. Our Siemens fridge/ freezer seems less efficient and uses considerably more power than I would have expected.

Most of the power used by washing machines and dishwashers is used to heat water. I am writing this in April and currently our washing machine is consuming 760wh when washing at 40º C. Most of this was used when heating water, using power at the rate of 3KW an hour - fortunately for short period of time. Our Balay machine can wash cold, which works well with lightly soiled articles. On its lightest wash it only consumes 80wh. This suggests that for cold washes, it is probably more efficient to run the machine from the inverter, particularly when there is sufficient power being delivered from the panels. The reason being that the generator is not being used to its optimum capacity because the washing machine is reluctant to share the system, when powered by the generator, with other appliances – such as a battery chargers and fridge. It appears to me, that when the panels are delivering power the inverter takes priority, so that power goes straight to the appliances and only that not used is delivered to the battery charger.

Televisions vary widely in consumption but the larger the screen the greater the consumption. The older cathode ray types also tend to use more power than the LCD ones.

Computers

When I compared the power consumption of my small desktop computer (with its screen off) with my portable (both running the weather station) I got a surprise. The desktop was using 120wh compared to 20wh for the portable. Given I run this system 24hours a day, the saving achieved by using the portable to collect data was considerable.

Appliances on Standby

Until recently many household appliances were designed to be on “stand by” so that they were never switched off. Perhaps the most notorious of these is the “Sky Box” which is said to cost £26 a year just to be connected to the wall. Just how significant this is can be seen with our sky box and television. When on standby they consume 13watts per hour, when running 20wh. Thus if on for two hours a day (about out maximum viewing times) they consume 40wh – left on standby for the remaining 22hours they would consume an additional 286wh.

Switching standby items off can be problematic. We certainly have to wait for the Sky Box to find the signal, and very occasionally, we have to reset the frequencies. The biggest problem is with the DVD recorder that takes ages to set up and causes havoc in the system. Fortunately, it is rarely used.

Some items may be drawing standby power and you may not even be aware of them. When I first started monitoring power consumption I found a big difference between the consumption of individual items and the total. At first I thought it was an error but eventually discovered its was due to ceiling fans. We have three ceiling fans which are controlled by infra-red hand sets. These were not in use but the light switches were on – amazingly they were taking 50wh between them while doing nothing – this 1200wh over a 24 hour period accounted for the difference. I now look askance at anything with an infra red control. Fortunately, the air conditioning unit which cannot be isolated and uses an infra red control does not use power when not in operation. On the rare occasions when this is used – we run the generator.

Using Timers to cut Consumption

Some items have a quasi standby function. For instance, I have a weather station which regularly exchanges files with other internet based stations. Thus I had my internet connection on permanently using 15wh or 360wh a day. I then realised that I only needed a connection for 15 minutes every three hours. So I put a timer on the modems and changed the weather station settings to use exchange files during when the timer had opened the internet connection.

Our electric fridge freezer is a problem. We prefer it to the gas model. It is supposed to be economic (rated at 960 wh a day) but in practice it uses 1500wh – more than three times the power delivered by the panels at mid winter. The problem is that it continuously monitors the temperatures in the fridge and freezer and starts their cooling systems when the temperatures fall. We have experimented with putting it on a timer that switches on every two hours for 30 minutes. Obviously, you get some degree of temperature fluctuations. I have placed a temperature transmitter in the freezer and find that with this regime there is a temperature fluctuation between –14 and –18 degrees whereas with the system full on there is little or no fluctuation. Using a timer, the power saving is dramatic, using only 670wh over a 24 hour period.

The Inverter

We have a 3000w inverter which was installed because the system was designed to run all appliances via the inverter. Like most inverters it uses a standby current. It does not matter how much power is being used the inverter will take at least 22wh. Thus during the course of a day it uses 500wh. It can be set so that it switches off if no power is being used. However, this leads to a problem. Our hot water is supplied by a gas heater. This uses a small amount of mains electricity to detect if a tap has been switched on and then to ignite the flame. If the inverter is set to a level which is high enough to detect the opening of a tap it uses 22wh. If its set lower then it does not detect the tap. There is a way round this, if you want hot water – turn on a light first! The same problem may arise with other items. For instance, if no other power is being used the inverter will take 22wh to charge a mobile phone.

These high standby currents are a characteristic of pure sine wave inverters. My solution to this is to add a modified sine wave inverter to my system and then create a separate electric circuit that will run all the low power items with minimum overhead, allowing the higher power inverter to switch off for long periods. When the main inverter is switched off, either because it is in standby or because the generator is supplying the house, the small inverter will continue to supply the always on items with minimum overhead. Fortunately the items which I want run from this supply; computer, internet connection, night light and gas water heater are all mounted along the same outside wall and the cables will be easy to install.

Conclusions

What would we do if we could start again?

To some extent we are having to deal with the system that has been installed. We have to adapt to this system because to change it would be too expensive. To my mind that system was unbalanced – most of the cost went into the batteries and the large inverter when it should have gone into the panels. Fortunately, we resisted the initial proposal which had two 3Kw inverters!

What sort of system would we now install if we were starting again within the same budget. It would certainly be a hybrid system like we have now developed but with a better balance. It would be a 12 volt system and not 24 volts. It would have a 1500 watt pure sine wave inverter to run most of the household. To overcome the problems associated with the standby current of the inverter, I would have a second low power (DC) system to run my portable computer and other items which are always on. I would still have a second smaller modified sine wave inverter running from this circuit in the knowledge it could be used as a back up if the other fails.

I would use proper 2 volt solar batteries with a capacity to give me 2 full days power.

I would still have a large capacity generator, running on gas.

Most importantly I would put the stress on the panels. These would be 6, 120 watt panels not 85 watt as we have at present. To install more would provide more power than we need for summer. In mid winter even these extra panels, put in the best possible location would not cover our power needs . Thus we would always need to use the generator, but to a lesser extent.

In terms of appliances, the current washing machine is suitable. Our fridge freezer was not the model we wanted, which was not in stock. It was a much more expensive model offered at the same price as the one we had ordered. At the time I did not think the difference in consumption about 300wh was important. Now I know that that difference is important and would find a model that is A++ rated. Even so I would continue to use timers.

The other big change I would make is my working computer. I would seek a portable or at least a model with a comparable power consumption.

How do we feel now?
Have we learnt to live with solar energy? Yes, but with a degree of ambivalence.

We cannot afford the type of solar system that would supply all our power needs. Thus we have to compromise. The compromise involves a hybrid system which involves a degree of “hands on”. To maximise the systems potential we need to change the position of the panels during the day, which is not always possible. When running some appliances we have to switch on the generator and make decisions about the best combination of appliances to run. Each evening I check the battery voltages and switch on the generator to top up the system.

Given the repeated problems and the subsequent anxieties, security of supply has been a big issue. Our supply seems secure in that most components are duplicated. One reason for purchasing the modified sine wave inverter is that it could easily run most of our system if the main unit failed.

We have been able to cut the costs of gas considerably through this hands on approach to the system. I cannot say my wife is happy with the system which she feels is overcomplicated but (she says) she is adapting to he situation. Thankfully, reading this paper has helped.

When this system was planned I simply did not know enough to ask the right questions and therefore we ordered a system which appeared good on paper but, even if it had worked, did not really fit our needs. The only consolation I have is that many people seem to be in the same boat. I hope this article will help others to ask the right questions and discover better ways to live with solar energy.