system components

There are some essential components required to build a system for producing home-generated, renewable electricity. Each of the components is necessary for the complete system to work and so every part is equally important. The equipment needs to be compatible in both voltage and current output. There must be a balance between the output over time of the solar panels or wind generators, the size of the batteries, and the amount of electricity that is being consumed. By this I mean that the batteries should be large enough to store sufficient power to keep your system working during low-generation periods. Also the system should produce, on average, more power per week than you use so that the batteries smooth out the variations from week to week. In effect the power you consume from your home generation needs to be tailored to the system output and may mean running certain parts of the system on mains power to achieve a workable balance between home-generated production and consumption.

We will keep returning to this subject, but understanding how to build a balanced system will help you avoid the major disappointments that occur when the uninitiated build a system based on extrapolating potential output figures given by manufacturers – which I consider to be fairy stories. It is worth noting that in lowland Britain to create reliable home generation of renewable electricity both wind turbines and solar panels will be needed, unless you are in the enviable position of having access to hydro-power.

quality

The perennial problem with buying equipment, whether it is new or second hand is always the price and the quality. Is it better to go for cheap new or quality second hand? Each person has their own ways of assessing this, but if the equipment is inexpensive then that's probably due to cost cutting in either labour or component quality; or most likely both. If you have the luxury of being able to afford more expensive equipment, then there is a good chance that the quality and reliability of the product will be superior. The renewable energy market currently seems to be flooded with unknown brands that have tempting prices, but I feel it is better to buy quality equipment once rather than buy lower quality twice, in which case you pay the same amount in the long run and end up with a worse deal. I'm a slightly paranoid type who always fears paying over the odds, particularly as renewable energy is a rapidly expanding industry that is likely to attract unscrupulous operators who are only in it for short-term gain (more later). You will find me using this 'more later' phrase from time to time: it's just that I don't want to go into too much detail just yet, but you will find more information on this subject leaping out at you as we cover other subjects related to this one. Many of the things we are covering have effects on and are related to other parts of the system, and my job is to try to show how they fit together.

batteries

Batteries are used to store the energy produced by most home-generation systems. A rechargeable battery is basically a reversible chemical method of storing electricity and consists of several 'cells'. There are various types based on different chemical reactions, for instance the nickel cadmium (alkaline cell) or the lead and sulphuric acid (acid cell); the lead and sulphuric acid battery is the type most commonly used for home-generation systems.

Each cell has a nominal voltage and the voltage will fluctuate around that value depending on the state of charge and whether the cell is being charged or discharged. The amount of electricity (current) that is flowing through the cell also has an effect on the cell voltage. All of which means that a lead acid (2 volt) or a Nickel cadmium (1.2 volt) cell does not have quite the finite voltage you might imagine.

wind turbines

The prices and outputs of turbines vary enormously. The main thing is that they have to be in the wind on top of a tall tower or pole. So, if you live in an area surrounded by thirty-metre trees or tall buildings then a wind turbine may not be appropriate because your access to clear, non-turbulent wind will be reduced or non-existent. The size of these machines varies enormously: the larger the output, the greater the diameter of the blades and the stronger the tower needs to be to support it, so it is more expensive to fit and maintain.

One of the main considerations for wind turbines – apart from that they have to be in the wind – is that they must be connected to a ‘load’ at all times or else the rotor (blades) will gather speed beyond their design specification, unless the machine is fitted with a blade-feathering system (more later, see page 41), and could potentially be damaged. What I mean by ‘load’ is that the electricity always has to have somewhere to go – so the turbine needs to be connected to something to complete the circuit. A load can either be the grid, through a synchronous grid inverter, the battery bank, or heating elements.

There is no point fitting a wind turbine to the structure of your house unless you live on your own and are deaf. The house acts like the sound board of a guitar and the only way to sleep would be to rip the thing off the wall in the middle of the night, which is not advisable. Having said all that a turbine in the right setting without turbulent air from obstructions has a rare beauty and is a veritable joy to behold as well as providing useable electrical energy. In the *research* chapter (page 151) there is loads of information about what you can reasonably expect to get from a turbine.

rectifier

Many modern turbines produce three-phase alternating current (AC) output; see the *electricity* chapter for an explanation of this term (page 109). To be able to charge a battery this form of electricity must be converted into direct current (DC). A rectifier enables this conversion by connecting the three AC cables from the turbine to the rectifier and the two DC output connections (positive + and negative -) from the rectifier are then connected to the battery. In many cases the rectifier is included in the turbine control box and so is not a separate component.

solar panels

Before we cover this subject it’s worth pointing out that two types of panel are referred to as solar panels. The first type are water-heating panels that have water running through them and are connected to the domestic hot water system and the second type are panels that produce electricity. These electrical panels are called photovoltaic panels, or PV panels for short, and this is the type discussed in depth in this book.
These are passive, flat panels that create electricity when facing the sun.

They are made of a very common element called silicon but the process of making them is energy intensive and so they are expensive. The price has come down dramatically over recent years with the development of more efficient manufacturing processes, and so demand has increased which helps with further unit-cost reductions. There are three types of panel material: monocrystalline, polycrystalline and amorphous silicon. The first two have similar properties and the last varies considerably, which I will explain in more detail, in the *solar panels* chapter (page 59). Unlike wind turbines, solar panels can be disconnected and left 'open circuit' and no harm will come to them. This is important to know because it has implications for battery-charge control systems.

charge controller

This does exactly what its name suggests and prevents the batteries from being damaged through severe overcharging. They are voltage sensitive and as the batteries charge up the charge controller's voltage rises. When the voltage reaches a level that indicates the batteries are fully charged then several things can happen depending on whether it is a solar panel or a wind turbine controller.

- for solar panels the controller just disconnects the panels from the battery until the battery voltage reduces because some electricity is being used.
- for a wind turbine the controller cannot just simply disconnect as this would leave the turbine without a load, which could result in damage to the turbine. In this case the controller switches on a 'load' (similar to an electric fire) that uses up some of the surplus electricity and so prevents overcharging.

inverter

The inverter is a clever piece of kit that takes direct current from the batteries and converts it into mains, alternating current electricity. Up until a few years ago it was accepted as common knowledge that most inverters were not reliable and so it was best to try to do without them. Along with being unreliable many inverters took a fair amount of power to run and so it was not practical to leave them running all the time. As an example, I had a 2 kilowatt data-power inverter that took 150 watts to run without any load, which equates to 3.6 kilowatt hours every twenty-four hours. This was more than the average daily output of the wind turbine. Things have changed now, and my current inverter has been left running since the day it was commissioned with a daily, twenty-four hours, off-load consumption of just 500 watt hours (0.5 kilowatt hours).

direct current (DC) load controller.

When you use an inverter to supply power from the battery bank, then the inverter will automatically switch off if the battery voltage falls below a certain level. This protects the battery from over-discharge and damage; see the *batteries* chapter (page 79). When, however, you are using a direct current (DC) circuit directly off the batteries then there is no over-discharge protection. This situation is relevant for DC lighting and maybe DC fridges. A DC load controller can be fitted between the batteries and the DC load so that when the volts are low the DC load controller disconnects the circuit. Just to remind you, standard incandescent lights (the type with elements) will run on alternating or direct current. You can get boxes of bulbs with various voltage ratings 12, 24, 50, 110 volts etc, all with either bayonet or Edison fittings.

ROCs meter

ROCs are Renewable Obligation Certificates and are related to the generation of renewable electricity. The home generator can claim payment for each kilowatt hour produced and recorded through a ROCs meter. The system needs to be registered with a licensed ROCs buyer, which could be the supplier of your National Grid electricity.

The meter is a standard electricity meter that can be bought for as little £10 as long as it is on the energy regulator OFGEM's accredited list. The list can be accessed via the OFGEM website, see *resources* for details (page 177). The meter is wired into the output of the inverter and so records the electricity used. The system can be independent of the grid and so if you are totally off-grid then you can still claim ROCs payments. See the *building a system* chapter (page 127) for a bit more detail about this

A ROC is equal to 1000 kilowatt hours and at the time of writing I am being paid £150 per ROC or 15 pence per kilowatt hour. I have given these figures as an example but, of course, they will be out of date by the time the book is in print.

fuses

It is important to know where the weak spot is in any system. Fuses are that weak spot and are deliberately fitted to prevent damage to the rest of the circuit from overload. They are easy to fit as they are wired in series with a power cable. Fuse boxes are basically a collection of fuses to individual circuits fed by power from one source. The value of each fuse depends on the load on each circuit, and each load will draw a certain current (amps). So fuses are calibrated by the maximum current they will carry before they melt and disconnect the circuit. These electrical terms like current are explained in the *electricity* chapter (page 109), and it is vitally important to have a good grasp of these concepts to be able to work with your own system.

If the fuse fitted is too large, or there is no fuse fitted, then when there is a fault and too much current is passing through the circuit the weak point could be the wire itself. The wire would heat up, just like an electric fire, and burn off the insulation, with a good chance of starting a fire. The fuse prevents all that damage and tells you, because it has failed, that there is an electrical problem or an overload.

electrical components

You don't need to know this stuff but it might be interesting to some. Years ago a mate of mine had the patience to teach me about some of the basic electronics components, and the information has been very useful over the years when trying to get around problems without spending any cash. This fits in with one of my basic rules, that if you don't spend it you don't have to earn it, and so can spend more time just messing around and learning by experiment.

diode: a component that behaves like a one-way valve and only allows electricity to flow one way. These are used in rectifiers, for changing alternating current to direct current, and as 'blocking diodes' to prevent batteries discharging through solar panels overnight so that electricity can flow from the panel to the battery, but not the other way.

The use of diodes in rectifiers is worth talking about, and it is probably easiest to look at the single-phase units that are found in battery chargers. The transformer (see page 131) is connected to the rectifier by 2 cables. On each of the 2 cables, there are 2 diodes. With alternating electricity each cable varies between positive and negative charge at fifty cycles per second. So let's just look at one of the transformer output cables. The electricity is moving between negative and positive and there are two diodes connected to it. One diode is connected so that only the positive electricity will flow through it, and this is then connected to the positive of the battery. The other diode is connected the other way round so that it effectively only allows negative through to the negative battery terminal. The other transformer output cable has two more diodes that are connected in exactly the same way. At this point the electricity is therefore split into positive and negative, becomes direct current and is sent down the different battery cables. This type of rectifier is called a bridge rectifier. The electrical symbol for a diode is an arrow pointing at a bar, see fig 1.

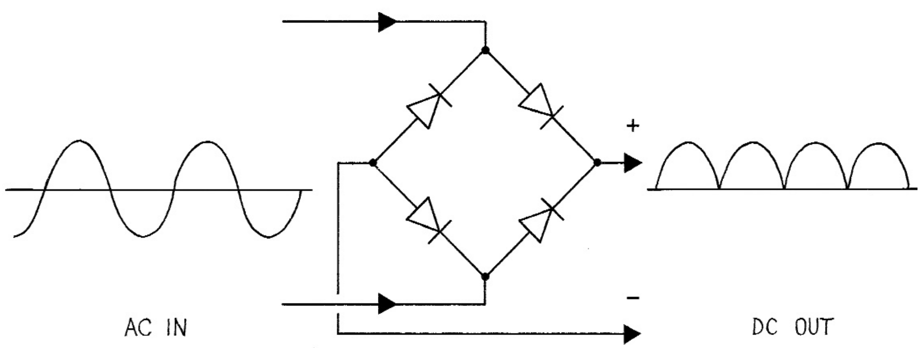

fig 1: bridge rectifier

zenner diode: is a component that acts like an electronic weir allowing only current with a voltage above its preset voltage to flow. These can be used in regulators or for changing the value of volt meters. I have a box of quality volt meters that go up to 40 volts. I have a 48-volt battery system and so these volt meters are useless to use in it. But if I put a 30-volt zenner diode in series with one of the meters, on 48 volts it reads 18 volts. Then its just a matter of renumbering the scale or just getting used to it as it is, so
18v = 48v, 20v = 50v etc.

relays: these are electro-mechanical switches where a small current can switch on a larger and independent supply. The small current energises an electromagnetic coil that then pulls the contacts together and so switches on the larger supply. The coils are wound for various voltages and the contacts are built to handle various currents. The switching is through contacts that either close or open when the coil is energised. In this way things can be switched off as well as on. The closed contacts that are opened by the energised coil are referred to as 'normally closed' contacts, and open ones that are closed when the coil is energised are called 'normally open'.

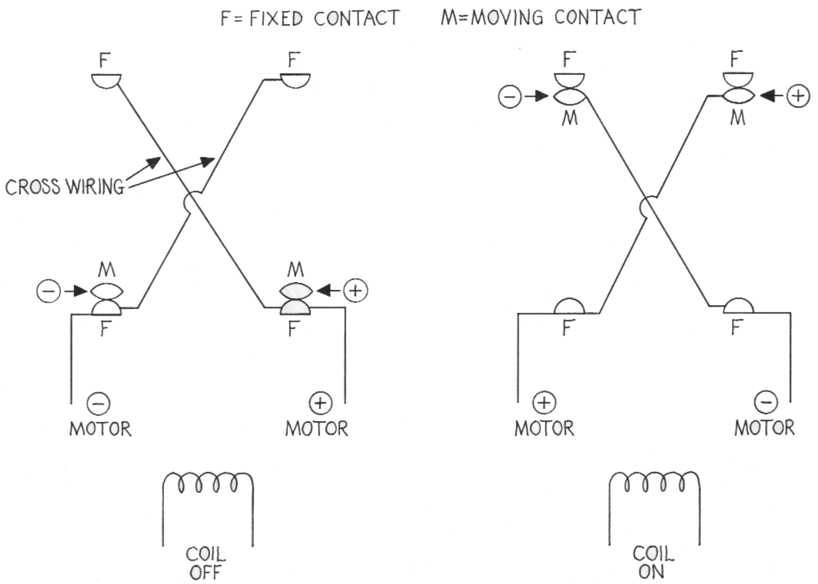

fig 2: reversing relay wiring

Relays can have one set of contacts or many sets and can be used to reverse direct-current motors by changing the polarity of the motor wires, i.e. swapping positive and negative over. In the *solar panels* chapter (page 59) we describe the use of relays with two sets of contacts for reversing. To make a reversing relay you have to cross-wire some of the contacts so that in one position positive and negative are reversed from the other position as in fig 2.

transistors: these are the solid-state version of the relay except it takes virtually no signal to switch them on. They are made of layers of silicon similar to solar panels and are in a large family of components called semi-conductors. Unlike relays that are either on or off, transistors can be slightly on or slightly off and so are used to amplify a varying signal. Enough of that; suffice it to say they can be sometimes used in place of small relays.

transformers: these only work on alternating current. In their simplest form they consist of two coils of wire wound around a laminated iron core. An alternating current flowing through coil A induces a current in coil B. The number of turns in coil B determines the voltage of the induced current. Battery chargers have transformers in them that change the voltage from mains, 240 volts, down to battery volts, 12, 24, 48 etc. volts. Transformers that have two distinct and electrically separate coils are called isolation transformers, because they isolate you from mains electricity. To explain the benefits of this type of transformer we must talk about the mains electricity system.

In Britain the domestic mains electricity supply is 240 volts, single phase. The wire colours are:

- brown: positive
- blue: negative
- yellow and green: earth

Within the supply infrastructure the earth and the negative are joined together, which means that you can receive a shock by just touching any part of the positive system. The electricity flows through you from positive to earth/negative, which you are standing on, unless you are insulated from earth by, for instance, wearing wellies. If there is an isolating transformer in place you have to touch both output cables before you get a shock because there is no direct connection to the mains supply.

There are other types of transformer where the two coils are joined together, which are called auto-transformers, and they do not isolate you from the mains. The most useful of these for the practical wind and solar 'backyard constructionist' is the variable auto-transformer (Variac). With these you put mains power in and by turning a control knob can vary the output volts. The practical consequence of this feature is that you can turn a common 12 volt battery charger into a 2 volt charger to boost individual 2 volt cells that are in a lower state of charge than the rest of the pack.

I'll just go through that to make sure all is clear: the Variac is plugged into the mains and turned right down, the 12 volt battery charger is plugged into the Variac and the battery charger cables are attached to a 2 volt cell. The Variac is then adjusted until the battery charger's amp meter shows a reasonable charge rate for the charger's capacity, to avoid burning the charger out. I appreciate that some modern battery chargers only have LED indicators, which makes things more complicated. I have a 24 volt forklift truck battery charger connected to a large Variac, which will happily charge a 2v cell at 30A. For more detail about charge rates and charging see the *batteries* chapter (page 79).

meters: These are electro-mechanical devices that show either the current flow or the voltage in a system.

A volt meter is wired across positive and negative to show the voltage of the whole system. On a battery system it can show battery volts and so indicate the state of the battery's charge, for more detail see the *batteries* chapter (page 79).

An amp meter is wired in series with the positive, to measure the flow of current into a battery.

These meters have an indicator needle that moves around a scale that must be correct for the current or voltage of the system they are being used on.

Amp meters have a full-scale deflection value, which may be quite small even though the meter scale shows a larger current. In this case there is a piece of resistance wire fitted across the meter terminals, called a shunt, so that only part of the current goes through the meter, the rest goes through the wire. This system is used in control panels and means it is unnecessary to run large power cables to the meter and back again. The shunt is fitted in line with the power cables and then small wires go up to the meter from either side of the shunt.

So if you are reclaiming meters from scrap equipment and there are small wires going to the meter make sure you find the shunt and reclaim that as well. You can make your own shunts with single strand copper wire, but you need to calibrate the shunt by wiring it into the low voltage side of a battery charger and battery. The meter with the shunt should read the same as the meter on the battery charger.

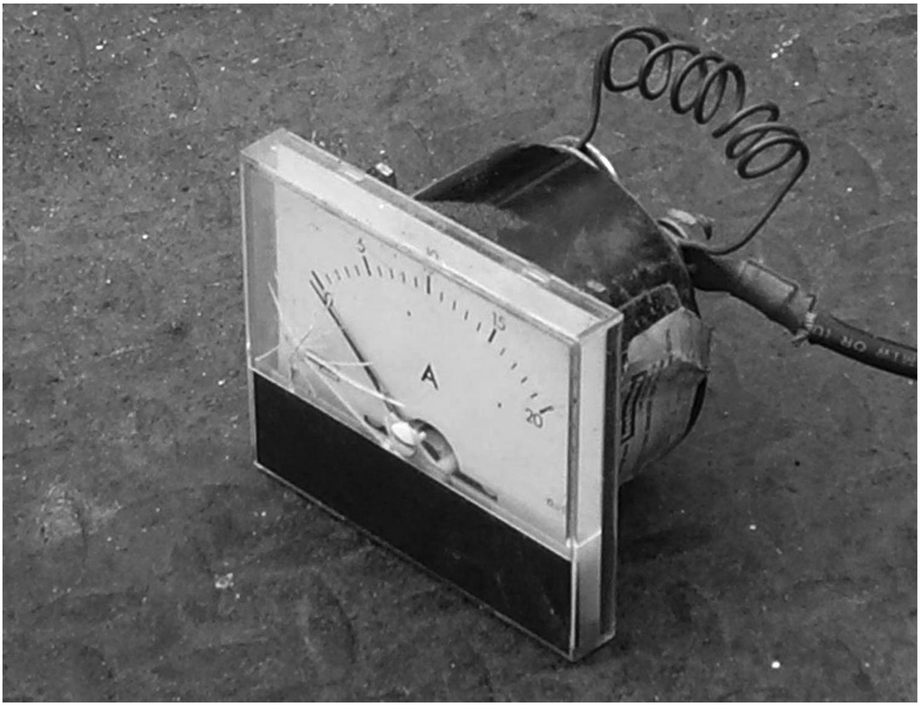

fig 3: amp meter and shunt

Volt meters also have a fixed scale. If the scale is too large I don't know any way of changing it, but if it is too small then a zenner diode can be used as described under the zenner diode section (page 29).

Having wrapped your mind around all this information, you will hopefully now have a good idea of the basic components of a home-generation system. In the following sections I will fill in more details about them, starting with wind turbines.