Outline for an uninterruptible/renewable power system

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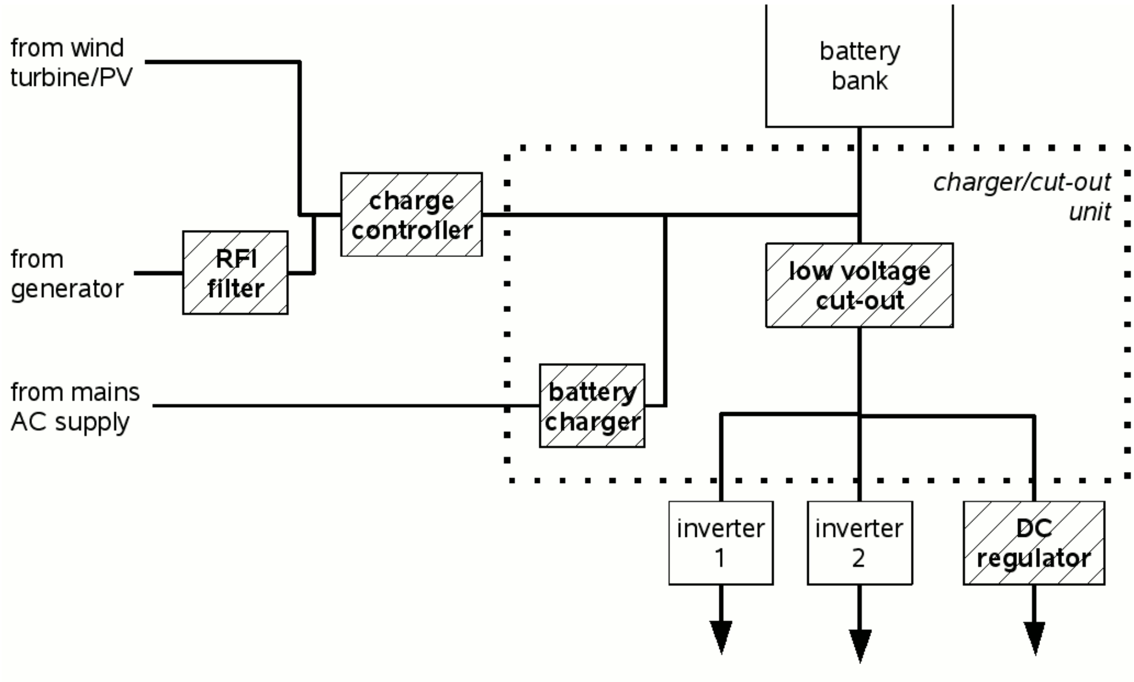
Here's an outline of the uninterruptible/renewable power supply (both uninterruptible and renewable power supplies use battery-based power storage systems, so they are essentially the same thing).

We'll begin at the end...



Inverters

An inverter converts the battery DC voltage into AC mains. To ensure that you don't over-stress the inverter it's best to get one that provides about 50% more power than the continuous load that your devices draw – this ensures that the short-term surge loads can be supplied without damaging/tripping the inverter. You could just have one inverter, but from an engineering safety point of view the system would then have a single point of failure (if the inverter stopped working, then nothing works!). For this reason it's better (albeit a little more expensive) to get two or more inverters. This means that if one fails, you can still run the most important devices from the remaining good one.

DC regulator

For devices that don't work from the mains we usually use a mains adapter. Converting DC to AC for the adapter and back to DC again is wasteful of the power contained in the batteries. For this reason if the device uses low voltage DC it's more efficient to use a DC voltage regulator. This reduces (or boosts) the DC battery voltage to the level required by the device. As with inverters, it's a good idea to size the capacity of the regulator at about two-thirds the continuous power load so that it can supply any short-term power spikes without damage/overheating.

Low voltage cut-out

Operating the inverter(s) discharges the batteries, and if allowed to continue it will discharge the batteries to a level where they are damaged. To prevent this we use a low voltage cut-out. This is a voltage controlled switch – when the battery voltage falls to a pre-determined level it sounds an alarm (which tells you you need to turn off the inverter). If it falls further then it disconnects the inverter(s) from the battery bank to prevent damage to the batteries. Note that the system I have developed gives the option of “latching” the cut-out – it disconnects the batteries and does not allow re-connection until the battery bank has been recharged to a level where the batteries can be used again without developing a prolonged discharge period (this improves the operational lifetime of the batteries).

Battery bank

The battery bank has to be sized to meet the need for power, for a certain period of time, without excessively discharging the batteries. This determines how many batteries you need. Although automotive batteries may appear cheap compared to proper lead-acid cells designed for power systems, that's not the case when you look at them in terms of their usable capacity. Ordinary automotive batteries could be used but they can only supply 5% to 10% of their rated capacity before they become excessively discharged. Sealed lead-acid cells are better, but they can only supply 20% to 25% of their rated capacity before they become excessively discharged. “Deep cycle” lead-acid cells are designed for deep discharge, and can supply 40% to 50% of their rated capacity without damage. What this means is that, for the same capacity of battery, one deep cycle battery is equivalent to two or three standard lead-acid batteries, or five to ten automotive batteries.

At desktop computer system can draw between 600 (for a tower and plasma screen) and 1500 (for a tower and CRT screen) Watts. On average it might draw between 300 and 750 Watts (let's call it 500 Watts for the sake of calculation). At 12 volts and inverter might draw 40 to 45 Amps of current. For an hour's operation you have to provide 40 to 45 Amp-hours (Ah) of battery charge. If you used deep cycle batteries, that would require 80 to 100Ah of battery capacity (deep cycle batteries come in various sizes, so how many batteries this would be depends upon the capacity). The largest standard size of lead-acid cell is around 65Ah, so you'd need five to six large lead-acid cells. Standard automotive batteries have a capacity of around 40Ah, so you'd need 22 to 23 batteries to supply the same amount of power! Note that a laptop consumes about a quarter to a fifth of the power of a desktop, so it requires a quarter to a fifth of the capacity.

The number of batteries isn't just an issue of cost, space and weight – it also presents a safety issue. If you accidentally short circuit the battery bank it can cause an intense electrical arc. A single deep cycle battery will generate a short-circuit current of 500 amps. A single automotive battery will develop a current of 200 amps, but as a single deep cycle battery is equivalent to up to ten automotive batteries, the total short-circuit current will be 2,000 amps – that will quite easily melt wires/metal bus bars in a fraction of a second and burn/blind anyone standing next to it! Another obvious difference is that “sealed” batteries are sealed – they don't leak acid, or give off potentially explosive/flammable hydrogen gas whilst on charge.

In short – ideally you need to use deep-cycle batteries because for a given amount of supplied electrical power they are a more efficient use of money, storage space, require less engineering to safely support the weight of the batteries and they are safer in use.

Charge controller

As you can damage a battery by over-discharging it, it is equally easy to damage a battery by over-charging it. At the simplest level, a charge controller is a voltage controlled switch that cuts off the charging current if the battery bank reaches a set maximum voltage. The more complex types of charge controller use pulse width modulation of the charging current to progressively reduce the level of charge until it finally cuts-off at the maximum battery voltage.

Where PV cells are used to provide power the charge controller can literally “switch off” the PV panels without damaging them. If you did this with a wind turbine you would remove the resistance the turbine blades offer to the wind and the turbine would “run away” – speeding up until it damages the blades. For this reason a charge controller (or, to give it its proper name, a “shunt regulator”) for use with wind turbines has to divert the charge into a “dump load” (a large, high-capacity resistor) rather than cutting-off the turbine.

If you use a low-voltage DC generator, such as a car engine or a small motor and automotive alternator, these can be disconnected. However the greatest problem with low voltage DC generators is that they generate a lot of electrical noise which could damage the charge controller. For this reason low voltage DC generators must have an RFI filter (essentially this is just one or more inductive coils and capacitors which together for a “low-pass filter” to block the noise from flowing down the wire) fitted before the charge controller to smooth the noise from the supply current.

Note that if you are using the mains supply to charge the battery/run the equipment you bypass the charge controller. This is because the battery charger incorporates the same electronics as the charge controller to prevent over-charging. If you were to run the battery charger through the charge controller it would most likely interfere with the limiting circuits of the battery charger – and in the worst case you charge controller would dump the current from the charger into the dump load, and you would be needlessly wasting mains power!

Charging sources – mains AC, generators and PV/wind turbines

The amount of equipment you need to provide the power for your system depends upon the amount of power that you use, but also whether that power has to be stored in the battery bank for later use. Charging a battery and then releasing the power for use is only 60% to 70% efficient. This means that if you must store most of the power you require in the battery bank (this is usually the case for wind- and PV-base systems) you have to provide up to 40% more capacity than you actually use to make-up for the loss in the charging cycle.

The source of charge has a significant effect upon the amount of battery storage that you need. If you are using a generator you only need a very small battery bank because most of the time the power will pass straight through to the inverter/regulator without charging the batteries. Likewise, if using the mains supply you only need a battery bank that provides enough power to bridge the periods when the supply is cut/interrupted. If you are using only renewable energy sources then you need a large battery bank in order to store the energy for use when the renewable sources are not available.

Sizing the system

In the schematic diagram the boxes that are hatched are the elements of the system that I can put together for you. I recommend that you source the batteries and inverters locally. These are heavy items, and given that they are relatively easily available around the world it's unlikely that they'd cost significantly more locally than they would to buy in the UK and then ship to the location of the project.

Ideally you should use laptops. These use a quarter to a fifth of the power of a comparable desktop system. If we assume that you have two Apple Power Books they're likely to draw around 300 Watts between them. I've never connected an Apple laptop using a DC regulator (I'm not sure whether Apple laptops use additional control electronics or just have a straight positive/negative power supply – but I could check with an Apple geek that I know) but if they would connect without a problem then if we would be far better off using a 24V system, we could probably do without one of the inverters, and save some money on the charger because of the additional load saved.

Let's assume you use the mains adapters plugged into an inverter. For a 300W load you're ideally looking for a 500W inverter. I'm assuming that you might have another 200W to 300W of other equipment (routers, etc.), so that's another 500W inverter. So, we need 2 x 500W inverters (in fact, you'll have to get 600W inverters as this is the standard size they are usually supplied in). In the UK these retail at around £75 each (for modified sine wave versions – if these create problems for the equipment because of the electrical noise they generate then you'll have to get full sine wave versions which are twice the costs).

You're proposing to run the system from the mains using the battery bank to cover for the interruptions in the supply. Let's assume that you're going to need, at most, 4 hours capacity to run (very roughly) 2 x 300W of load – let's call it half a kilo-Watt (500 Watts). If we assume that you're running at 12 volts then 500W of load for 4 hours is [(500 / 12) x 4 =] 170 Amp-hours of battery capacity. Assuming a 60% rather than 50% discharge level in order to prolong the life of the batteries, you're going to need about 456Ah (based on 38Ah deep-cycle batteries, that's 12 x 38Ah) battery bank. The price of lead-acid batteries is very variable. You can often pick then up second hand in clearance sales (often they are used in uninterruptible power supplies in industry for a year and then sold off) for half the price, or less, of new batteries. If you can buy large capacity batteries this will also work out cheaper. In the UK a new 38Ah deep cycle battery retails for around £80 (less if you buy ten or more), but you can buy second hand 50Ah batteries for as little as £50 (plus carriage). So 456Ah of deep-cycle battery will cost between £450 and £960 (plus carriage, which is dependent upon the supplier).

You're also going to have to choose a system voltage. 12 volts is a general standard, and it's easy to get 12 volt equipment. 24 volts is more efficient, but it's harder to get hold of 24 volt equipment – for example, if you wanted to rig up a couple of lights to work with the system, it's very difficult to find 24 volt fluorescent lighting units. For practicality, I suggest that you use 12 volts.

A low voltage cut-out to supply 500W will cost about £80. This would utilise automotive fuses and relays. If you wanted industrial quality components (they last longer, but cost more and would be difficult to replace outside of western countries) then it would cost around £200 to £250. A battery charger capable of supply 50 to 60 amps at 12 volts (it must supply this in order to run the equipment and charge the batteries simultaneously) would cost between £150 and £200, depending on the cost of the components that can be obtained from different suppliers. As this is for a specific operation I suggest these are built into a single box to make it easier to wire up. However, for the purposes of reliability, I suggest that the system is divided into two – one unit to run one inverter, and a second to run the other. This would mean, in the event of one failing, you could still run an skeleton system from one unit/inverter/battery bank whilst the other unit is repaired.

On top of these costs you will have to add the costs of cable, fuses and fuse holders to wire together the batteries. A reasonable estimate would be £60 to £80 for the whole system (unless you have an especially long run of cable between the battery bank and the point of use – ideally it shouldn't be more than 20 metres).

Renewable energy

The solar potential in Jamaica is about five times than in the UK, and in Guyana it's about 4 times. So the same PV unit will produce five or four times more power in these locations than in the UK. Theoretically, producing 500 Watts of power in Jamaica with an ideally angled PV panel can be achieved with a 100 Watt PV panel. However, this represents ideal conditions, and we have to add up to 40% for the losses when charging the battery bank, and so it would be wise to have perhaps 150 to 200 watts of installed capacity. At UK prices, two 100 watt polycrystalline 12 volt PV panels would cost around £1,200.

Wind is a little more trickey. It's very location specific (unlike PV, which you can just point at the sky) – and it doesn't work hardly at all within a few degrees of the equator. The tower for the turbine, which can be made from something as simple as a long scaffold pole tethered with steel cable, would have to be manufactured locally. There are various small wind turbines available, but the cheapest are types manufactured for yachts and sailing boats (e.g., the Rutland 913, which is manufactured in the UK but is sold around the world). However, any small wind turbine rated at 12 (or 24) volts would do provided that it's in the 200W to 500W range.

If you wish to use the system with renewable energy sources then this would be easier to organise if the charge controller/shunt regulator were provided as a separate unit (in any case, a lot of wind turbines and PV installations come with their own charge controllers/shunt regulators built-in, and so you may not need this element if it is already built-into the PV/wind generator system). However these would need to be designed to work with a specific capacity of installation. Charge controllers for PV installations up to half a kilo-Watt are relatively inexpensive (£80 to £100), but shunt regulators for wind turbines are more expensive (£100 to £200, depending on the size) because they are more complex to design. In use, these units would fit between the PV array/wind turbine and the charger/low voltage cut-out unit.

As with the batteries and inverters, it would make sense to try and source these locally as the cost of transporting these heavy/bulky items is likely to add significantly to the cost.

System cost

Putting this all together, to run two Apple Power Book laptops and another 200 to 300W of associated equipment from batteries for up to 4 hours to cover for mains interruptions, and with the potential to incorporate renewable energy source as an when you might develop them:

- Elements to be sourced at the project end –
    - Two 12 volt/600watt modified sine wave inverters (UK prices, inc. VAT), £150
    - 340Ah deep cycle lead-acid battery bank, based on 12 x 38Ah batteries, £1,000 (UK “new” prices, inc. VAT, with an additional 15% cost to cover carriage)
    - Optional – 200W/12 volt polycrystalline solar PV array, £1,200 (UK prices, inc. VAT)
    - Optional – 250W to 300W/12 volt (e.g., Rutland 913 marine) wind turbine, £490 (UK price, inc. VAT)
- Elements to be supplied from the UK –
    - Combined low voltage cut-out/battery charger unit(s), £230 to £280;
    - Cables pre-cut to the required length with connectors and fuse holders, £60 to £80 (fuse holders and connectors fitted to allow immediate connection)
    - Optional – 1,000W/80 amp solar charge controller for PV system (if required), £100
    - Optional – 500W/40 amp shunt regulator for small wind turbine system (if required), £150
    - Optional – RFI filter for use with low voltage DC generators/alternators (if required), £40
    - Multimeters and basic tools (crimp connectors, etc) to assist with maintenance, £40

Cost for basic system (battery, charger/cut-out unit, inverters, cable, tools) – £1,550

Additional cost for 200W solar PV system (PV panel/charge controller) – £1,300

Additional cost for 200-300W wind turbine system (turbine/shunt regulator) – £640

Additional cost for RFI filter for use with low voltage DC generator - £40

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