The Wind Power Electrification of Vulumanu Community High School

Pentecost Island
Republic of Vanuatu

Summary

Energy services play a fundamental role in human development. They are essential not only for basic human needs like cooking, moving water, and lighting, but also for improving life and helping to alleviate poverty by permitting new productive activities. In fact, there are links between energy and many other sectors including: health, education, nutrition, communications, transportation, economic development (both macro and micro levels) to name but a few.

Without improved energy services (particularly electricity) income generating opportunities are very limited and consequently the prospects for employment remain poor. Schools, health centers, administrations, etc. all have a vital need for electricity to be able to function properly and to serve their respective communities.

However, the majority of the rural population of Vanuatu depends on energy inputs which are largely limited to human (such as gathering and hauling firewood and water), kerosene, batteries (typically disposable, an environmental and economic nightmare itself), and biomass (firewood, etc.) Ironically, energy resources are plentiful and inexpensive (one might even say free) in Vanuatu if one considers renewable energies such as those from the sun, wind, flowing water, and the earth.

This project will demonstrate the effectiveness of small, de-centralized wind generators to provide electric power to the remote, rural population of Vanuatu.

Background Information

Wind power has been a viable source of energy for much of recent human history. Windmills have been used to grind grain and pump water and are still in use today in many parts of the world. Wind generators (also called wind turbines) produce electricity by spinning a magnet inside a coil of wire, much like the way an automobile alternator produces electricity.

In the 1930's in the United States, wind generators were widely used as an economical source of electricity in rural and farming areas. Today, 16% of Denmark's electricity comes from wind power. In Europe, 13000 Megawatts of wind generated electricity provide 7,000,000 people with their electrical needs. There are over 18,000 Megawatts of wind generated power installed world wide. Wind energy is the fastest growing energy source in the world!

A wind generator's rotor (the blades) changes the lateral kinetic energy of the wind into rotational energy. The rotational energy is then turned into electrical energy by the generator, which is located behind the rotor. The electric power passes through a charge controller and several other monitoring devices and then is stored in batteries until needed.

Why wind power?

- Wind power is inexpensive.
- Wind is an abundant and renewable energy resource.
- Wind power is reliable.
- Wind power is safe.
- Wind power is clean.

Project description

A 600 watt wind turbine will be installed at Vulumanu Community High School, North Pentecost Island, by project staff and school and community members. The wind turbine will provide for the bulk of the school's electricity needs. These needs include office machines such as computers, printers, fax, and photocopier; classroom, study hall, and library needs such as lighting and AV equipment (TV, VCR, etc.); lighting in dormitories and ablutions; kitchen and dining hall needs such as lighting and running appliances like a freezer and refrigerator; and any other miscellaneous needs for electricity the school may have. Additionally, any surplus power the school produces could be sold to the surrounding communities as an income generating activity.

This will be a hybrid installation. The wind generator and the school's existing diesel generator will charge a common battery bank. A hybrid electrical generating system maximizes the strengths of the two sources of power while minimizing their weaknesses. The school will draw its electric power from the battery bank. Typically, the battery bank will be charged by the wind generator. During times of low wind (very rare) the battery bank will be charged by the generator. Generator run time will decrease dramatically which will greatly reduce fuel consumption and increase generator life. The net result is that the school will have a reliable source of power that is extremely economical to operate.

This should serve as a model for all generator installations in Vanuatu. Generators that power an electrical load directly are notoriously expensive and inefficient to operate (see Appendix A.)

Vanuatu Renewable Energy and Power Association will produce a users manual in English and Bislama. VANREPA will also conduct hands on training sessions for the operation of the system with key project participants. VANREPA will design an appropriate maintenance regimen and produce a maintenance manual in English and Bislama.

VANREPA will visit the school quarterly for one year. These visits will allow VANREPA to monitor the performance of the equipment and survey the users and make any appropriate adjustments to operation and/or maintenance procedures.

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Goals and Objectives

- To demonstrate the effectiveness and viability of wind power as an energy resource in Vanuatu.
- To demonstrate a hybrid electrical generating system.
- To demonstrate a rural, decentralized mini-grid and charging station.
- To trial a community based electrical cooperative.
- To decrease the operating expenses at Vulumanu Community High School.
- To improve the quality of life in the rural areas through rural electrification.
- To build reliance on our own renewable energy resources rather than to rely on expensive, imported fossil fuels (which are both economically and environmentally disastrous) for energy.
- To compliment the global environmental agenda

Beneficiaries

The entire country will benefit from this project through education and awareness raising. The Vulumanu school community will benefit directly from improved energy services. Villagers living near the school and other institutions in close proximity (Haulua Youth Centre, Dispensary, Provincial sub-center) will also benefit from improved access to electricity.

Sustainability

These wind turbines are very robust and they require very little maintenance. In my considered opinion, it is one of the only small wind turbines that is able to stand up to the environment of Vanuatu. The blades are polypropylene, an excellent long-life plastic, and they are painted black to provide UV protection. The turbine can withstand cyclone-force winds. However, in serious weather situations the entire apparatus can be readily disassembled due to the unique tilt up tower. This machine has a life of more than twenty years. The only maintenance required is periodic (annual) lubrication.

Renewable Energy Utility

VANREPA is in the process of establishing a Renewable Energy Utility (REU) that will provide support to this and other renewable energy projects in Tafae Province. The purpose of the REU is to maintain the technology installed at Vulumanu School to ensure long term sustainability. The REU will be financially supported by the sale of battery recharge tokens to households in Vulumanu. As the success of any given project is often determined by the strength of its management and support rather than by the strength of its technology, this utility is deemed an essential component of the project.

This project incorporates a small income generation component which is outlined below that will provide additional financial support to the REU for the ongoing maintenance of the wind turbine system.

Included in the budget is two maintenance visits to the Vulumanu site to be undertaken six months and one year after installation.

Income Generation
Households will have the opportunity to purchase an efficient household lighting kit including a rechargeable battery that will provide up to 3 days lighting. The kit will include components to enable it to be recharged at the wind system battery storage site. These components include a portable combined charge controller and 12V 6.5Ah battery and two 1.5W white led lights. The system will provide approximately 3 days of light before recharging the battery is necessary. The efficient lighting package will be available for purchase from VANREPA for 12,000 Vatu.

Community members will be able to purchase "battery re-charge tokens" from the local community store or direct from the REU for 30 Vatu enabling them to recharge their batteries at the school. The average rural household in Vanuatu spends 350 Vatu per week on kerosene for lighting. This recharge cost is less expensive than kerosene. Often there are availability issues associated with kerosene, this project provides a more reliable energy source for households.
The small amount of funds generated through this component of the project will be managed by the REU to support the ongoing maintenance of the wind system.

Benefits to Women
Women are most affected by the lack of energy services. Improved energy services (particularly access to electricity) reduce the burden of daily tasks for women. Caring for her family is the primary responsibility of women in rural communities. Access to electricity can provide a woman with adequate lighting for her children to study in. It can improve her family's nutrition through refrigeration. It can improve her family's health by providing lighting and vaccine refrigeration in health centres. Electricity can also provide lighting for community centres for meetings, evening classes, and other activities. These are just a few examples of how electricity can improve a woman's life. There are links between improved energy services and many sectors of life including: gender, health, nutrition, education, environment, and enterprise development, to name but a few.

Replicibility
There are numerous windy sites across Tafae Province that would benefit from the installation of a wind power system. There are additional windy sites in other Vanuatu provinces, which are generally situated on the eastern coastline. Thus, it is technically possible to replicate this project at many locations.

The capital cost of wind turbine systems is not a barrier to replication as this cost compares favorably with those of alternative systems. Over the lifecycle of the technology, costs are significantly more economical than that of a diesel generator at suitable sites.

The REU will enable wind power technology operation, maintenance and implementation training to be delivered to REU personnel and relevant community members. This will enable the provincially managed REU to replicate the project at other sites where the necessary natural features exist.

Replication will be supported by the REU which will cooperate with the Vanuatu government Energy Unit in the dissemination of information about wind power technology and the REU program.

Vulumanu Wind Power Project Budget

Aid-in-Kind

Wind Generator

600 watt wind turbine, tilt-up tower, controller, batteries, monitors.

Overseas Crating and Shipping

Total Aid-in-kind **1,171,273 vatu**

Donor Costs

Technical Assistance and Support 1,280,000 vatu

In Country Travel

Airfares	6 x vila/sara/vila	(25,040 vatu) = 150,240 vatu	
Per Diems and lodging		25 x 3000 vatu = 75,000 vatu	
Total In Country Travel			225,240 vatu

Materials

Inverter, monitor, battery 647,031 vatu

Supplies

Cement, cable, tools, etc. 67,100 vatu

Domestic Shipping and Transport 60,000 vatu

Administrative Support 345,000 vatu

Maintenance Inspections

Airfares 2 x vila/sara/vila	(25,040 vatu) = 50,080 vatu	
Per diems and lodging	6 x 3000 vatu = 18,000 vatu	
Technical assistance and support	240,000 vatu	
Total Maintenance Inspections		308,080 vatu

Total Donor Costs **2,932,451 vatu**

Total Project Cost 4,103,724 vatu

APPENDIX A

Hybrid Energy Systems in Remote Area Power Supplies

(Information courtesy of the Murdoch University Energy Research Institute)

Remote Area Power Systems (RAPS)

Introduction

Outside of the major centres of Vanuatu, villages are not connected to the electricity grid. Where these villages have power systems, they are generally independent power systems generating power for one or two buildings. These power systems are known as Remote Area Power Supplies (RAPS). For the purpose of the following, RAPS systems are small scale(<50kW) self-contained units, providing electricity independent of the main electricity grid network.

Main Components

RAPS systems range from small petrol generators, able to power appliances directly, to more complex installations using only renewable energy, with a combination of both also being possible. A RAPS system that has a combination of energy sources is termed a hybrid RAPS system. Figure 1 illustrates a hybrid RAPS system using a combination of a wind generator, solar panels, petrol or diesel generator, battery charge control system, battery storage and inverter. The system chosen is dependant on each user's needs, availability of renewable resources, their preferences and often, most importantly, their budget!

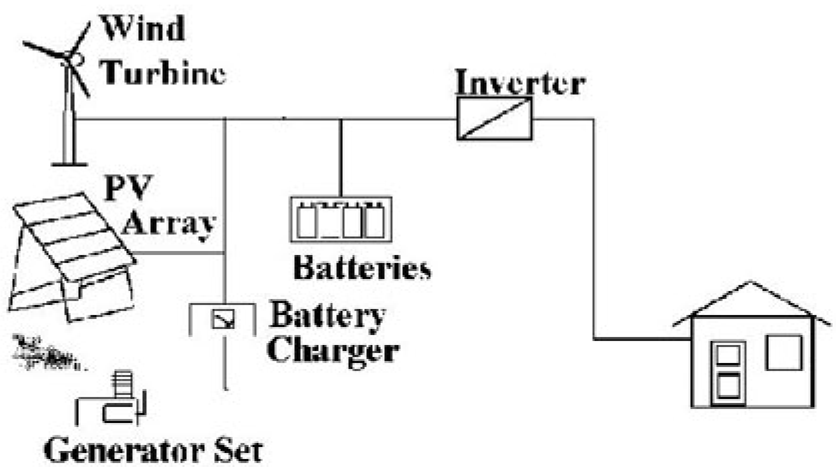

Figure 1 A Hybrid RAPS system
(Image courtesy of MUERI)

The main components can be grouped into 3 categories; components that supply power (generation equipment), components that store energy for later use (energy storage equipment) and components that convert from one form of power to another or control the flow of power in a system (power conditioning and control equipment). For information on the energy storage, power conditioning and control equipment refer to the information later in this information file.

Generation Equipment

Traditional Fuels

Stand alone generator sets, using petrol or diesel, are typical of most RAPS systems. These generator sets can vary from small portable units to larger units installed in a dedicated power shed. The larger units will often incorporate auxiliary control equipment to automatically start the generator on demand. Some generator sets will produce DC electricity for charging batteries directly. More commonly a generator will produce AC electricity for running appliances and electrical equipment directly.

Generator units perform best when operated near their rated output. As the load on the generator decreases so does the efficiency of the unit. If a generator set runs for long periods at very low loads significant maintenance problems can occur. In a RAPS application there are often periods of quite low load. The traditional solution to this has been to only run the diesel during high load periods and concentrate all usage of electricity into these periods. However with developments in communication and other technologies it is often desirable to have a 24 hour power supply in remote locations to keep the equipment available and running.

Rising fuel costs and the impracticality of running generators for long periods at low loads has led to the introduction of renewable energy equipment, batteries and inverter technologies, which reduce fuel costs and maintenance and provide a 24-hour power supply. The diesel (see figure 6) or petrol generators can still be used as a backup system to meet the load directly or to charge the batteries when there is insufficient sun or wind. The level of generator usage will depend on the size of the load demand and the available renewable energy resources and equipment.

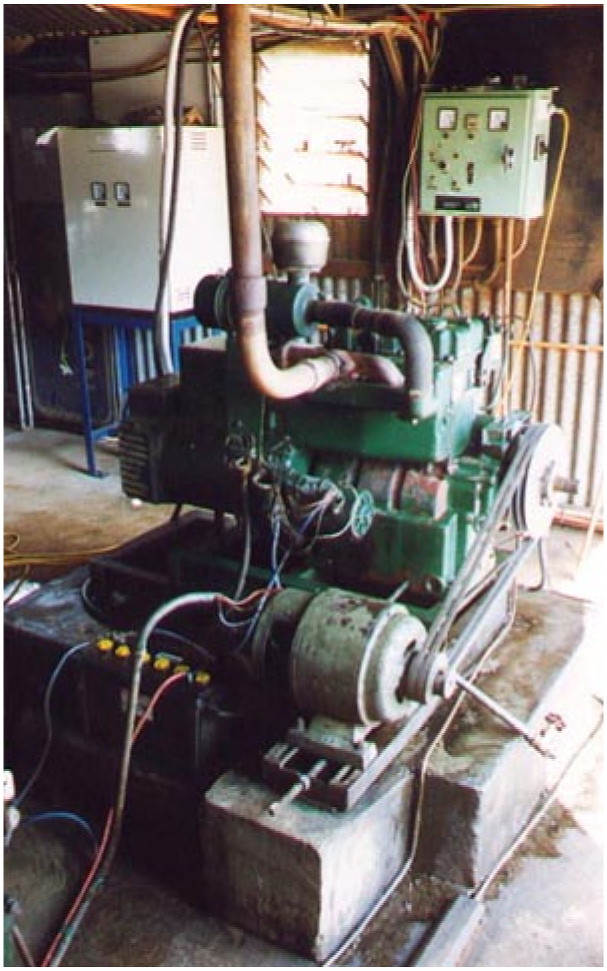

Figure 2 A Diesel Generator with control system and inverter in background (about 15 kVA) (Courtesy of MUERI).

Solar

Photovoltaic modules convert solar energy (sunlight) directly into electrical energy. Throughout Vanuatu a reasonable level of solar energy is received year-round and accurate data on solar radiation is available for many areas. The amount of energy received from the sun is quite predictable and can be used to predict the ouptut of solar modules.

A small array, as in figure 5, which has four solar modules, can produce up to 300 watts in peak sunlight conditions.

Figure 3 Small solar array
(Image courtesy of ACRE)

Wind

The output from wind generators increases significantly as the wind speed increases, and wind speed increases as height above the ground increases. It is essential to obtain data for wind speed if the potential for using wind turbines at a proposed site is to be correctly assessed. Unfortunately, the required information on wind speeds is not available for many areas in Australia. In evaluating any available data the effect of the local topography/geography needs to be considered as it may cause uneven wind patterns that will affect the turbine's output.

A wind turbine installed in an area with a good wind resource can produce energy cost-effectively. However, the available wind resource typically varies from season to season, this creates a significant variation in the wind turbine output. Backup generation devices may be required to meet any shortfall of energy during these times of low wind speeds.

RAPS System Sizing

Correct sizing of RAPS systems is very important, particularly if wind or solar energy is used. If the system is too small, power shortages will be experienced and the batteries may be damaged by excessive discharge. If the system is too large it will be unnecessarily expensive. The size of the system is dependent on the electrical load. The availability of wind and solar energy will also determine the size and type of system used. Suppliers of RAPS systems generally have methods of designing a system to meet each user's specific needs.

Determining the Electrical Load

The electrical loads can be estimated if the power used by each appliance is known. The total energy required will depend on this power draw and the operating time of the appliance.

Overall electrical loads can be determined by drawing up a list of all items, their power use and their average operating time per day. The total will be used in determining the size and type of system required.

RAPS Simulation

In order to determine the most appropriate components, and, more importantly, component sizes for a RAPS system, computer simulations of the proposed system may first be undertaken. Numerous commercial software packages are available today, such as the software Hybrid2 and RAPSIM, which allow the user to select diesel generators, photovoltaics, wind turbines, inverters and battery banks, in any combination, to supply the load demand given the weather resources available at the site. By evaluating the results of several simulations, the user is able to select the optimal system size for highest efficiencies and/or lowest cost before physically purchasing the components.

Using A RAPS System

By using other non-electrical energy sources for cooking, hot water and heating, large savings can be made in electrical load and therefore the cost of the RAPS system. For cooking, gas or wood stoves can be used. Water can be heated using wood, gas or solar. For space heating, a wood fire or gas can be used along with good insulation to help keep the heat in. In construction of new buildings passive solar design techniques will help minimise energy requirements for heating and lighting.

The operating times of some large power consumption items may have to be scheduled because there may not be enough power available to operate them simultaneously. When replacing or buying new appliances, the effect on the RAPS system must be determined. Using energy efficient appliances can save on overall costs.

A Home Energy Use Calculation Sheet is available from MUERI.

RAPS Installation

A RAPS system needs to be designed to ensure it will meet the user's specific needs. Several companies with experience in RAPS systems should be approached for quotes. A preliminary site study is required to ensure that the chosen energy source will be suitable. For solar power, PV modules must not be shaded and trees must be checked for possible future shading. For wind power, data on local wind speeds should be collected to ensure enough energy is available from the wind year-round. The final electrical installation should be done by an electrician with experience in installing AC and DC electrical equipment according to the relevant standards.

Other System Technologies

Introduction

The amount of power produced by renewable energy devices such as photovoltaic cells and wind turbines varies significantly on an hourly, daily and seasonal basis due to the variation in the availability of the sun, wind and other renewable resources. This variation means that sometimes power is not available when it is required and on other occasions there is excess power. The variable output from renewable energy devices also means that power conditioning and control equipment is required to transform this output into a form (voltage, current & frequency) that can be used by electrical appliances. This information file looks at the devices used to store, condition and control the output from renewable energy systems including remote area power systems (RAPS) and grid-connected installations.

Battery Storage

Wind and sunshine are not always available when there is a demand for energy, so backup storage may be required when using renewable inputs especially in RAPS systems. The energy is usually stored in deep cycle lead-acid batteries that are similar to car batteries, but are better suited to the heavy charging and discharging typical of RAPS systems. When several batteries are connected, they are called a battery bank (see figure 5). There are Australian Standards for battery installations and safety regulations that need to be followed in a RAPS installation.

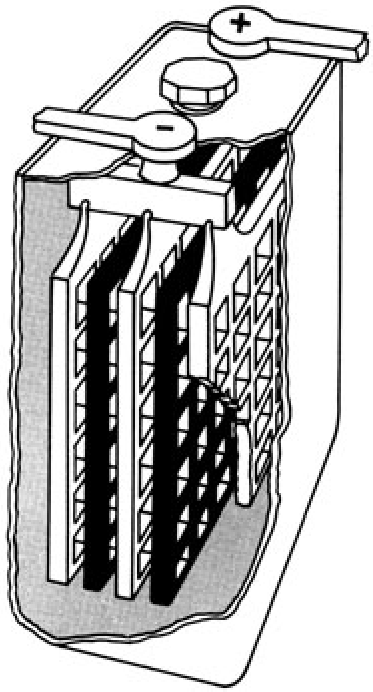

Figure 4 Schematic of a lead acid battery

Battery storage can provide all the storage in renewable RAPS systems that do not have a backup system. However, if a backup generator is available less battery storage is required.

Battery ratings are expressed using the voltage and the storage capacity of the battery. The storage capacity of a battery is the quantity of electricity that a fully charged battery can deliver under specified conditions. This capacity is expressed in Ampere-hours and is usually specified at 25°C. It is determined by the time taken to discharge the battery at a constant current until a specified cutoff or final voltage is reached, which is dependent on the battery type and manufacturer. The capacity is stated as an Ampere-hour value at a discharge rate, which is noted by a "C" followed by a number indicating the rated hours. An example of a typical rating is 2 volt battery with a capacity of 100 Ah @C100 rate.

Battery banks consist of many batteries connected in series to provide the correct voltage for a system. Typical system voltages are 12, 24, 48, 96, 110 & 120 Volts DC. These can consist of many individual batteries either 12, 6 or 2 volts connected in series. Occasionally batteries will be connected with 2 (or 3) parallel strings to increase the overall capacity of a battery bank.

Figure 5. 48V DC Battery Bank
(Photo courtesy of MUERI)

Either vented cell (wet cell) or sealed cell (gel cell) batteries can also be used to store electricity generated by renewable energy conversion devices. In sealed cell batteries there is a minimum amount of electrolyte absorbed in a gel. These batteries have the advantage of being low maintenance as compared to traditional wet cell batteries, as there is no need to add water. Batteries in a RAPS system must have good performance at low and high temperatures, a long cycle life in deep discharge applications and a high energy density.

Battery Charge Controllers (Regulators)

In all systems, to protect the battery bank from over-charging and over-discharging, a battery charge controller should be used. The simplest method used for charge control will turn off the energy source as the battery voltage reaches a maximum and will turn off the load when the battery voltage reaches a preset minimum. The battery charge controller for a system is more commonly referred to as a regulator. There are 3 main types of regulator; Shunt, Series and Pulse Width Modulated (PWM) regulators.

- **Shunt regulators:** when the batteries are fully charged the power from the renewable source is dissipated across a dump load. These are commonly used with wind turbines.
- **Series regulators:** when the batteries are fully charged the power from the renewable source will be switched off in the simplest series regulator(see figure 3). An improvement for this type is the proportional type, where the current is controlled by a variable component in series with the renewable source.

- **PWM Regulators:** These regulators use a high frequency switching technique. The regulator switches the control device on and off quickly. When the batteries are discharged the unit will be switched fully on. As the battery is reaching a fully charged state the unit will start switching the control device on and off in proportion to level of charging required. When the battery is fully charged no current will be allowed to flow to the battery. In solar systems the PWM technique is used in series with the solar modules. In wind turbine systems the PWM technique uses a shunt (dump) load to divert excess energy away from the batteries

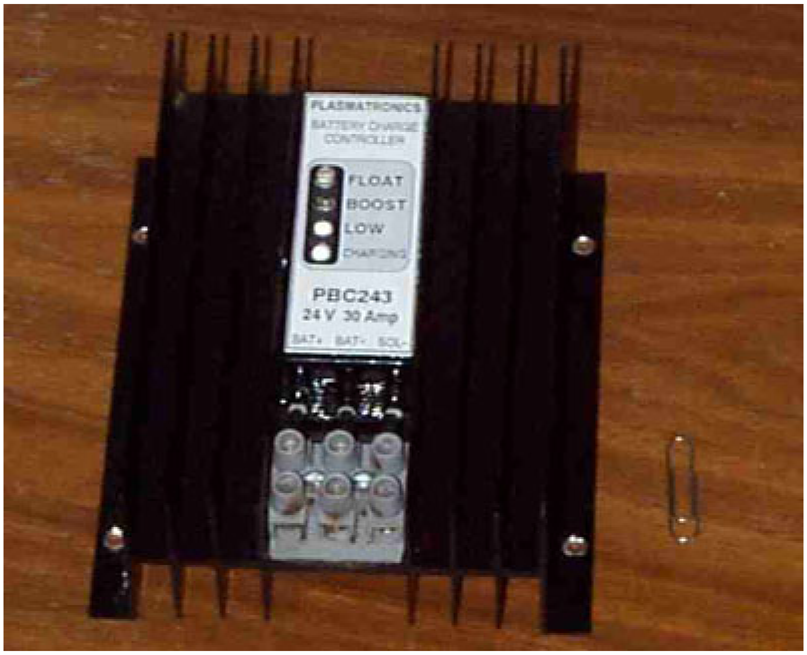

Figure 6. Plasmatronics series regulator
(Image courtesy of MUERI).

To stop the battery from being over discharged a load disconnector can be used. Quite often this can be through an auxiliary circuit in the battery charge controller or through a low voltage disconnect function built into the inverter.

Maximum Power Point Tracker

Another type of regulator is the Maximum Power Point Tracker (MPPT). This is used with photovoltaic modules to optimise the match between the panels and the battery bank. This technique uses a DC to DC converter with circuitry that measures the incoming power from the module and adjusts the voltage so that the maximum power is being sent to the battery bank independent of the battery bank voltage.

Inverters

Renewable energy systems often provide low voltage, direct current (DC) from batteries, solar panels or wind generators. To use this DC power directly requires special nonstandard appliances that may be available for camping and other portable or low power applications. Some appliances, such as fridges are relatively expensive. Electricity available from the main electricity grid is provided as alternating current (AC) at 240V in Australia, so most appliances are manufactured to suit this supply. The electrical energy used by the appliance is referred to as the load on the system.

An inverter is an electrical device that changes direct current (DC) into alternating current (AC). The inverter enables the use of standard appliances in RAPS systems. Inverters often incorporate extra electronic circuits that control battery charging and load management. Generally, Inverters used in most household systems now produce power of a similar quality to that in the main electricity grids, these are referred to as true sinewave inverters. Earlier model inverters produced lower quality power, which was adequate for most appliances. These are now only used in very small inexpensive systems. They are often referred to as modified square wave inverters and sometimes as modified sinewave inverters.

Figure 7 Photo of an inverter (Image courtesy of MUERI)

System Controllers

In systems with a number of power sources sophisticated system controllers are required. These controllers are usually computer controlled, with inputs indicating the state of the system being fed into the controller and then the microprocessor makes changes to the system operation if necessary.

The functions performed by system controllers include:

- Disconnecting or reconnecting renewable energy sources
- Disconnecting or reconnecting loads
- Implementing a load management strategy
- Starting diesel generators if battery voltage is too low or if load becomes too high
- Synchronising AC power sources (e.g. inverters and diesel generators)
- Shutting systems down if overload conditions occur
- Monitoring and recording of key system parameters

References

Remote Area Power Supplies by the Victorian Solar Energy Council.
Rural and Remote Area Power Supplies for Australia by the Department of Primary Industries and Energy.

Further Information

Murdoch University Energy Research Institute (MUERI)
Australian CRC for Renewable Energy (ACRE)
Department of Primary Industries

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