Wind for Electricity Generation

Introduction

Modern wind turbine generators are highly sophisticated machines which take full advantage of state-of-the-art technology. Led by improvements in aerodynamic and structural design, materials technology, and mechanical, electrical and control engineering, they are capable of producing several megawatts of electricity. During the 1980s, installed capacity costs dropped considerably. Wind power has since become an economically attractive option for commercial electricity generation. Large wind farms or wind power stations have become a common sight in many western countries.

To a lesser degree, there has been a parallel development in small-scale wind generators for supplying electricity for battery charging, for stand-alone applications and for connection to small grids. Table 1 shows the classification system for wind turbines:

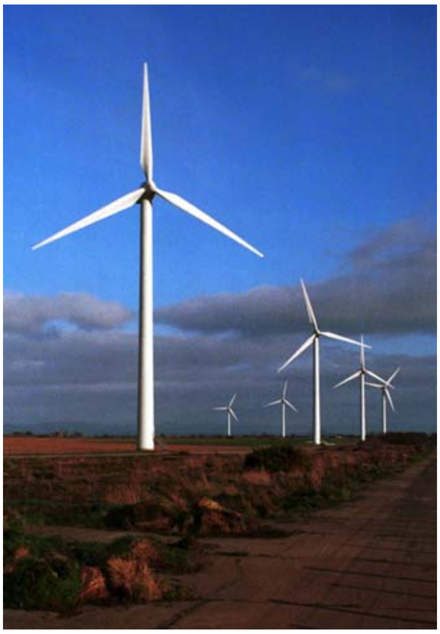

Figure 1 : Wind turbines are getting bigger and wind farms are more common. Great Orton Windcluster. Photo: Wind Prospect / Cumbria Wind Farm

Table 1 : The classification system for wind turbines
Source: Spera (1994) and Gipe (1999)

Scale	Rotor diameter	Power rating
Micro	Less than 3 m	50 W to 2 kW
Small	3 m to 12 m	2 kW to 40 kW
Medium	12 m to 45 m	40 kW to 999 kW
Large	46 m and larger	More than 1.0 MW

Wind generation for developing countries

Unlike the trend toward large-scale grid connected wind turbines seen in the West, the more immediate demand for rural energy supply in developing countries is for smaller machines of up to about 60 kW. These can be connected to small, localised micro-grid systems and used in conjunction with diesel generating sets and/or solar photo-voltaic systems.

Figure 2 : Small wind turbines can play an important role in rural areas of developing countries.
Photo: Practical Action Sri Lanka

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Currently, the use of wind power for electricity production in developing countries is small, the main area of growth being for very small battery charging wind turbines (50 – 500 Watts). Other applications for small wind machines include water pumping, telecommunication power supplies and irrigation.

Wind into watts

Power in the wind is explained in the Practical Action technical brief *Energy from the Wind.* Although the power equation in that Brief gives us the power in the wind, the actual power that we can extract from the wind is significantly less than this figure suggests. The actual power will depend on several factors, such as the type of machine and rotor used, or the sophistication of blade design. In reality, this figure is usually around 45% (maximum) for a large electricity producing turbine and around 30% to 40% for a wind pump, (see the section on coefficient of performance below). So, modifying the formula for 'Power in the wind' we can say that the power which is produced by the wind machine can be given by this equation:

$$P_M = ½.C_p.\rho.A.V^3$$

where, P_M is power (in watts) available from the machine
C_p is the coefficient of performance of the wind machine

There are a variety of important wind speeds to consider:

- ***Start-up wind speed :*** the wind speed that will turn an unloaded rotor
- ***Cut-in wind speed :*** the wind speed at which the rotor can be loaded
- ***Rated wind speed :*** the wind speed at which the machine is designed to run (this is at optimum tip-speed ratio
- ***Furling wind speed :*** the wind speed at which the machine will be turned out of the wind to prevent damage
- ***Maximum design wind speed :*** the wind speed above which damage could occur to the machine

The choice of rotor is largely dictated by the characteristic of the load, and hence of the end use. Slow machines - such as multiple-blade designs – are used for pumping water, while fast machines are used for electricity generation, such as the horizontal axis design with two or three blades.

Grid connected or battery charging

Depending on the circumstances, the distribution of electricity from a wind machine can be carried out in one of various ways.

Larger machines are connected to a grid distribution network. This can be the main national network, in which case electricity can be sold to the electricity utility when an excess is produced, then purchased back when the wind is low, this providing an agreement can be made between the producer and the grid. Using the national grid helps provide flexibility to the system and does away with the need for a back-up system when wind speeds are low. *See Grid Connection Technical Brief.*

Micro-grids distribute electricity to smaller areas, typically a village or town. When wind is used for supplying electricity to such a grid, a hybrid system consisting of a diesel generator set is often used as a backup for when wind speeds are low. Alternatively, electricity storage can be used but this is an expensive and impractical option.

Hybrid systems use a combination of two or more energy sources to provide electricity in all weather conditions. The capital cost for such a system is high but subsequent running costs will be low compared with a pure diesel system.

In areas where households are widely dispersed, or where grid costs are very high, battery charging is an option. In rural areas, a few tens of watts of power are usually sufficient as a source of lighting and of power for a radio or television. The preferable option for such turbines is the use of family units (one unit per family), but in some cases battery charging stations may also used, although this is not common. The use of rechargeable batteries reduces the inconvenience of intermittent supply due to fluctuating wind speeds.
12- and 24-volt direct current wind generators are suitable for battery charging applications, and are commercially available. Smaller turbines (50 -150 Watts) are available for individual household connection. Practical Action has developed low-cost small scale wind turbines for battery charging.

Wind generator system

A typical small wind generator has a rotor directly coupled to the generator, producing AC (alternating current) electricity at 120 / 240 volts. This is then rectified to 12 / 24 volts of DC (direct current) for domestic use or battery charging.

1 turbine & tower
2 charge controller
3 regulator
4 fuse boxes
5 dump load resister
6 battery
7 Inverter (optional, for AC appliances)
8 electrical socket

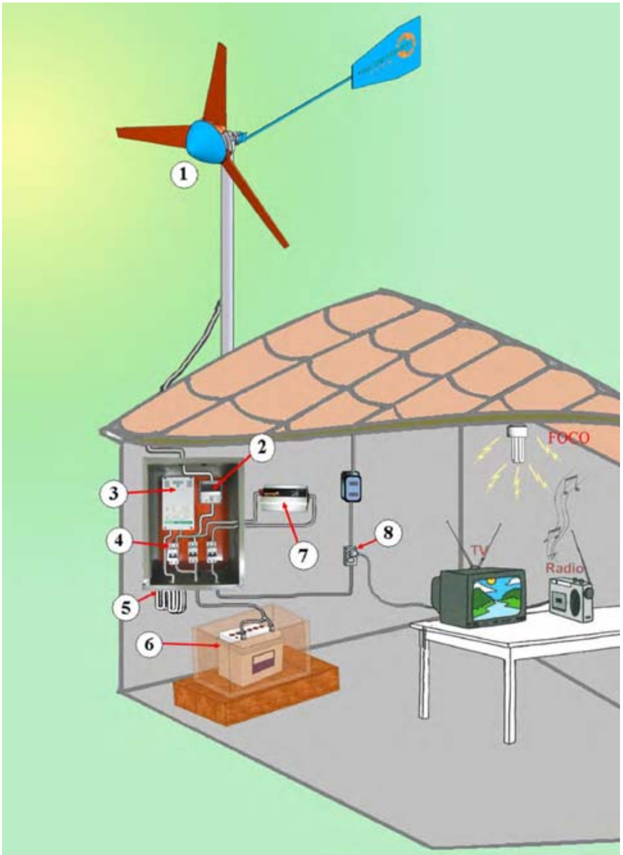

Figure 3 : The components of a small wind energy system.
Illustration: Soluciones Prácticas.

When devising any renewable energy system, the energy demand should be carefully considered. Small-scale wind turbines are suitable for low-energy light bulbs, radios, mobile phone charging and occasional television use, whilst highly demanding appliances such as electric heaters, toasters and irons are not suitable, as their energy consumption is too great.

Turbine

Local production of existing designs is simpler than developing a new machines, but the design will have to suit the local manufacturing capabilities and availability of materials which means that turbines in developing countries may need to be different to mass produced products.

The production of small- and medium-sized machines locally is generally much cheaper than imported machines. It also enables manufacturers to make minor modifications during the production process, allowing them to suit systems to their desired end-uses and to the conditions under which they are expected to operate.

Whilst most components can be made by small engineering workshops, some parts - such as magnets or electrical equipment - may have to be imported.

Towers can be made of welded steel, preferably galvanised, which can be manufactured in a local engineering works. The foundations can be cast from reinforced concrete on site.

The specifications for one of Practical Action's small-scale wind turbines are shown below.

(Please bear in mind that model design varies considerably.)

Type	2/3 blade upwind
Rotor diameter	1.7 metres
Drive	Direct
Rated Power	100 Watts
Start-up wind speed	3.5 m/s
Cut-in wind speed	3.5 m/s
Rated wind speed	8.0 m/s
Furling wind speed	14.0 m/s
Generator	Permanent Magnet Alternator
Max. Power Output	200 Watts

Table 2 : Small Wind Energy System for Battery Charging Turbine Specifications

Blades

Depending on the availability of materials, blades can be made locally from laminated wood, steel, aluminium, fibre glass or combinations of these materials.

Fibre glass blades use a mould, which can be used to make multiple blades.
Two halves of the fibre-glassed mould is shown in the photograph.

Once constructed, the rotor blade is subjected to a process of dynamic and static balancing.

Wind Rotor Blade Construction PDF

Fibre glass wind turbine blade: manufacturing guide. Version 1.4

Figure 4 : Mr. W.A. Fernando of the Dinusha Marine Works in Panadura manufacturing blades for small wind systems. Photo: Practical Action South Asia.

Generator

This part of the turbine converts the rotational motion of the blades and the axle into electrical energy.

The Practical Action Permanent Magnet Generator, (PMG) produces low voltage, 'three-phase' AC, and then changes it into 'direct current' (DC) for charging 12 volt batteries.

The permanent magnet generator is also referred to as an '*alternator*' because it generates alternating current (AC) but does not generate 'mains voltage' or 'utility power' AC.

Rectifiers are connected to the stator to produce direct current.

The design of the PMG is suitable for low volume manufacture in developing countries. More information on how to make a permanent magnet generator can be found in the document *The Permanent Magnet Generator (PMG): A manual for manufacturers and developers.*

Small Wind Energy Systems for Battery Charging (PMG Manual) PDF NB: large file 930K

Figure 5 : making a PMG in Sri Lanka. Photo: Practical Action South Asia.

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Tail Vane
There is often a tail vane which keeps the rotor orientated into the wind. Most small-scale wind-machines have a tail vane which is designed for automatic furling, pivoting the blades out of the wind on its yaw bearing at high wind speeds – over 15m/s - in order to prevent damage to the turbine. There are several mechanisms that can be used which depend on gravity or on springs that counter the force of the wind.

Larger machines have pitch-controlled blades: the angle at which the blades meet the wind is controlled. This achieve the same function.

Tower
The tower is of low solidity (thin), to minimise wind interference. Towers are often guyed for extra support. For small towers, guy cables can be anchored with a piece of scaffold or pipe which has been driven into the ground.

Auxiliary system

Charge controller / regulator
The function of the charge controller is to prevent damage to the batteries. If the batteries are fully charged then the charging current is diverted. The controller then diverts the excess charge to the dump load. Different types of battery require different types or charge controller settings.

Fuse boxes & circuit breakers
To protect the appliances from high currents, fuses or circuit brakes should be installed into the system. Such safety features are important for all electrical systems.

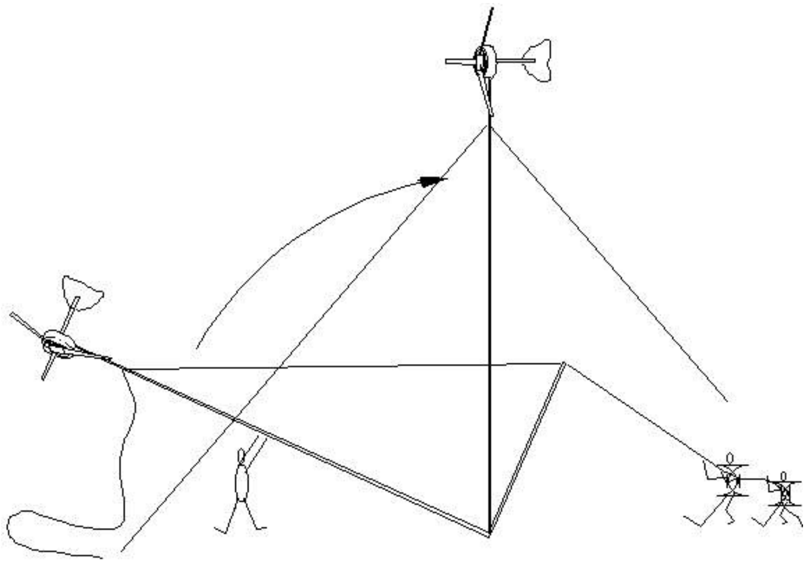
Dump resistor
In the simplest systems, the dump load is consumed by directing the excess current to a set of light bulbs or a heating element which can heat air or a tank of water.

Inverter
The inverter is used if the appliances are designed for alternating current.

Battery
Deep-charge batteries specifically designed for renewable energy systems do exist. However, they are expensive and only available in certain locations. Car batteries are often used instead, therefore. A battery can be damaged if excessively discharged, so a low-voltage disconnect device is often used to protect it.

More information on battery use and maintenance is in the Practical Acton *Technical Brief: Batteries*.

Installation
Small-scale wind turbines can be installed without heavy lifting equipment. The tower is pivoted at its base so it can be winched up with the aid of a lifting pole.



Planning permission may be required in some locations, and considerations should be taken of any possible legal restrictions.

Environmental concerns

Wind power is a clean, renewable energy source. There are, however, some environmental considerations to keep in mind when planning a wind power scheme. They include the following:

- *Electromagnetic interference.* Some television frequency bands are susceptible to interference from wind generators.
- *Noise.* Wind rotors, gearboxes and generators create acoustic noise when functioning, something to be considered when choosing a site for the machine.
- ***Visual impact***. Modern wind machines are large objects, and therefore have a significant visual impact on their surroundings. Some argue that it is a positive visual impact, others to the contrary.

Cost / economics

The cost of producing electricity from the wind depends on the local wind regime. As mentioned earlier, the power output from the wind machine is proportional to cube of the wind speed, and so a slight increase in wind speed will mean a significant increase in power and a subsequent reduction in unit costs. Capital costs for wind power are high, but running costs are low and so access to initial funds, subsidies or low interest loans are an obvious advantage when considering a wind-electric system. If a hybrid system is used, a thorough cost-benefit analysis needs to be carried out. A careful matching of load and energy supply options should be made in order to maximise the use of the power from the wind. (A load which accepts a variable input is ideally matched to the intermittent nature of wind power.)

References and resources

Energy from the Wind Technical Brief
This Technical Brief gives an overview of how to wind energy. Wind power can play a useful role in water supply and irrigation pumps, as well as in electrical generators.

Energy for rural communities Technical Brief
Nearly a third of the world's population do not have access to grid electricity. Households can use renewable energy systems to provide electricity.

Grid Connection Technical Brief
The potential for grid connection and its alternatives for providing electricity in rural areas are considered in this Technical Brief.

Batteries Technical Brief
There are a wide range of batteries available. This Technical Brief gives an introduction to the pros and cons of the different types of batteries.

Small Wind Systems for Rural Energy Services
S Khennas, S Dunnett & H Piggott: ITDG Publishing, 2003, ISBN 1 85339 5552

Windpower Workshop : *building your own wind turbine*.
Hugh Piggot: Centre for Alternative Technology, 1997

Small Wind Energy Systems for Battery Charging (PMG Manual) PDF NB: large file 930K

Wind Rotor Blade Construction PDF 332K

Fibre glass wind turbine blade: manufacturing guide. Version 1.4
A practical guide designed to show the process of producing a wind turbine blade from fibre-glass.

Energy Research Findings: Small Wind Energy Systems

Wind Turbine Technology : *fundamental concepts of wind turbine engineering.*
David, A. Spera: ASME Press, 1994

Wind Energy Basics : *a guide to small and micro wind systems.*
Paul Gipe, Chelsea Green Publishing Company, 1999

Microaerogeneradores de 100 y 500 W : *Modelos IT-PE 100 y SP-500*
http://www.solucionespracticas.org.pe/publicaciones/pdf/Microaerogeneradores%20de%20100%20y%20500%20W.pdf

Microaerogenerador IT-PE-100 para la electrificación rural
http://www.solucionespracticas.org.pe/publicaciones/pdf/Microaerogenerador%20IT%20PE%20100%20para%20electrificacion%20rural.pdf

Video: ***Renewable Energy in Sri Lanka*** 2 min 15 sec *modem 565k* | *broadband 1.6Mb*

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Enterprise Works was formally Appropriate Technology International ATI and were started as part of the US Government's response to Schumacher. They have undertaken wind energy projects in West Africa.

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Internet addresses

Home Power Magazine
http://www.homepower.com/

Wind Prospect Ltd.
http://www.windprospect.com/
Wind farm developer based in the United Kingdom.

Energy Source Guide

http://energy.sourceguides.com/

Renewable energy suppliers for wind, solar thermal & photovoltaic, hydro, tidal, etc

Fieldlines
http://www.fieldlines.com/section/wind
A discussion site for renewable energy DIY

African Windpower
http://www.power.co.zw/windpower/

Centre for Renewable Energy and Sustainable Technology
http://www.solstice.crest.org

Institute for Global Communications.
http://www.igc.apc.org/energy/wind.html
A good source for wind energy links

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