FACT SHEET 7: WIND ENERGY

Windmills have been used for centuries to pump water and grind grain and, more recently, to generate electricity. Small systems, which can produce a few kW of power, are frequently used as part of remote area power supplies. Larger systems (50 kW – 3 MW) have been integrated with the main power grid in several countries. For example there are about 18 000 systems in California, which together have nearly the same peak generating capacity as the South Western Australian Electricity Grid. The economic analysis of wind energy systems is complex but there is growing confidence that wind energy can make a significant and cost effective contribution to grid electricity supplies.

How Do Wind Turbines Work?

Wind energy conversion systems (wind turbines) are designed to convert the energy of wind movement (kinetic energy) into mechanical energy (ie the movement of a machine). In wind turbine generators this mechanical energy is converted into electricity and in windmills this energy is used to do work, such as pumping water, milling grains or driving machinery. The electricity generated can be either stored in batteries or used directly.

ENERGY AVAILABLE FROM THE WIND

There are three principles governing the amount of energy available from the wind.

1. The power generated by the turbine is proportional to the wind speed cubed. For example, if the wind speed doubles the power available increases by a factor of eight and if the wind speed triples then twenty seven times more power is available! Conversely, there is very little power in the wind at low speed. This means that accurate and detailed local wind speed data are necessary to determine the likely energy yield from a given site. Generators should be designed for that particular site. Average wind speed information alone is not enough.
2. The power available is directly proportional to the swept area of the blades. That is the power is proportional to the blade length squared. For example, doubling the blade length will increase the power output by four times and tripling the blade length will increase it by nine times.
3. The maximum theoretical efficiency of wind generators is 59%. In practice, most wind turbines are much less efficient than this and different types are designed to have maximum efficiency at different wind speeds. The best wind generators have efficiencies of about 35 – 40%

Practical wind turbines are designed to work between certain wind speeds. The lower speed, called the **‘cut in speed’**, is generally 4 - 5 m/s. At this speed the energy produced from the wind will not be greater than the amount of energy lost in friction and electrical losses. The **‘cut out speed’** is the highest speed the machine can safely stand without being damaged. The **‘rated speed’** is the wind speed at which the particular machine achieves its maximum output. Above this speed there may be mechanical reasons why the output stays constant even though the wind speed is increasing (Figure 1).

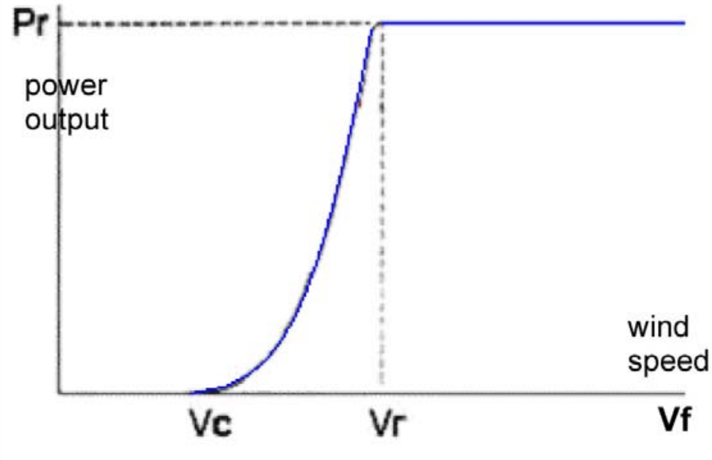

Figure 1.
Power Output from a Wind Turbine as a function of Wind Speed (Pryor, 2003).

Vc is the cut in speed at which the turbine starts to produce electricity, Vr is the rated speed at which the turbine reaches its maximum output and Vf is the furling speed, which is the wind speed at which the machine shuts down to avoid damage. Pr is the rated output of the turbine.

This curve would be typical of an optimally designed horizontal two or three bladed machine. The machine output follows the peak power available from the wind as the wind speed increases until it reaches the generator capacity. Then the output is regulated to maintain a steady output until the windmill is eventually shut down at the furling speed.

PARTS OF A WIND TURBINE

A wind turbine usually comprises:

Rotor: The blades of the rotor are designed to spin in the wind, driving the turbine generator. Sometimes gearing is used to obtain the right frequency for electricity generation (Figure 2).

Generator: This generates the electricity when there is sufficient wind to rotate the blades. There are now many designs of generator, including some with new powerful permanent magnets. The electricity is either stored, exported to the grid or used directly.

Directional system: Horizontal axis machines require a mechanism to swing them into line with the wind. Small machines usually have a tail assembly. Large machines usually have a 'servo mechanism' that orients them to the direction of maximum output.

Protection system: Modern wind turbines are usually equipped with mechanisms to prevent damage in excessively high winds. Large machines may have complex arrangements to shut down generation at high wind speeds. The angle of the blades is usually changed in smaller systems so that the blades present a smaller surface area to the wind and this reduces the speed of rotation. They may also use mechanical brakes.

Tower: The tower holds the turbine's assembly above the ground. This allows the windmill to use the higher wind speeds found away from turbulent air currents close to the ground. Tower design is particularly critical as the tower must be as tall as economically possible, robust and enable access to the turbine for maintenance. Yet it should not add unnecessarily to the cost of the system. It is particularly important when designing a tower to make sure there is no resonance between the frequency range of the rotating blades and the natural movement frequency of the tower.

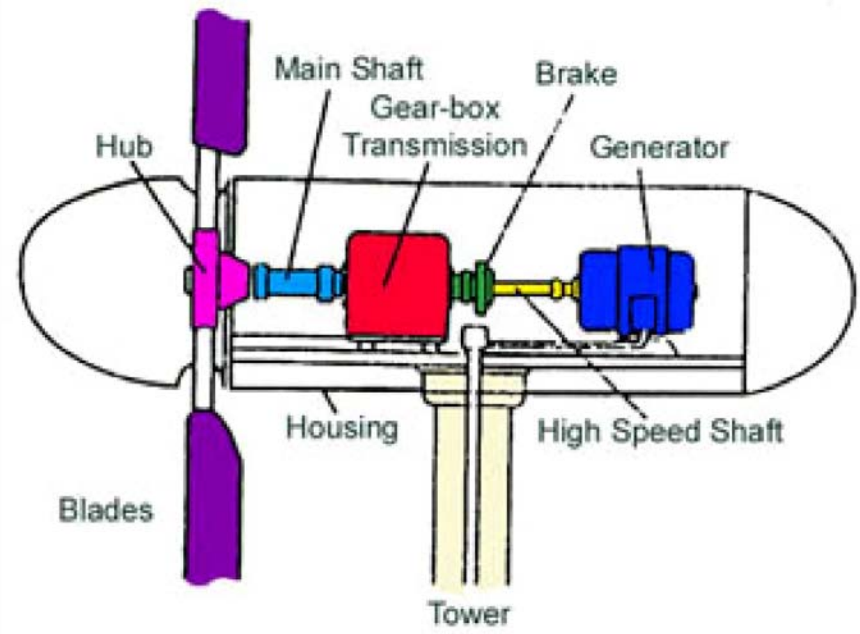

Figure 2.
Components of a large-scale wind generator

Wind turbines are rated according to the power output they produce. They range from a few kW up to a few MW. The size of turbines has increased over the last few years and it is not uncommon for a single turbine to be rated over 1 MW.

SMALL SCALE WIND TURBINES

Wind turbines that have a rated capacity of less than 10kW are usually classified as small-scale turbines. These turbines can also be connected to the grid, but more commonly are used to generate electricity as part of a Remote Area Power Supply (RAPS) system in regions where the grid is unavailable.

Windmills have been used in Australia to pump water from underground bores for nearly a century, and are a common site in rural Australia. They are designed to operate at lower wind speeds than wind turbines for electricity generation. Windmills 'store' the energy they produce in water tanks so that water is available for feeding livestock or irrigation in times where there is no wind.

MANAGING VARIABILITY IN WIND TURBINE SYSTEMS

The greatest challenge to the economic use of wind energy is the variability of the wind's speed. There are very few areas on the Earth where wind is constant throughout the day or the year. Energy storage, or a backup electricity system, is therefore required for windless or extremely windy periods, and also to give an even supply when the wind is blowing.

For small systems (up to a few kW) this generally comprises lead-acid batteries with possibly a petrol or diesel generator for back up. In hybrid generation systems, wind turbine generators are often coupled with an array of photovoltaic cells and a traditional generator.

For larger systems, the problem of variable wind speed and therefore power output is more complex. One possible solution is to build an interconnected grid with wind turbines at different locations. So while one windmill is not producing a great deal of power another in windier conditions will be. Proposals have also been made to couple wind generators to hydro storage.

Studies have shown that large grids can directly absorb about 10% wind contribution without affecting the management of the grid system, although Western Power Corporation's Denham wind project is providing about 40% of the electricity to that small grid. This is made possible by using Low Load Diesel generators to supply electricity when there is no wind blowing and then reducing the electricity produced by the diesels as the wind begins to blow and the turbines start to produce electricity (Whale 2003).

Wind speed variability is not a problem when the supply of energy does not have to be continuous, for example, water storage tanks with wind powered water pumps. In special cases energy may be stored directly in the form of heat for water or space heating, as purified water (with reverse osmosis machines), or even in the form of ice for refrigeration.

Wind Power in Australia

WIND FARMS

A number of large wind farms have been commissioned since the introduction of the Mandatory Renewable Energy Target. Locations and specifications for large turbine installations in Australia can be seen in Table 1. New wind farms can be identified by browsing the register of the Renewable Energy Regulator.

Figure 3.
Wind turbines at WA's Albany Wind Farm (by courtesy of C. Creagh 2004).

Location	State	Capacity
Challicum Hills	Victoria	52.5 MW
Starfish Hill	South Australia	34.5 MW
Albany	Western Australia	21.6 MW
Toora	Victoria	21 MW
Codrington	Victoria	18.2 MW
Windy Hill	Queensland	12 MW
Woolnorth Stage 1	Tasmania	10.5 MW
Blayney	New South Wales	9.9 MW
Crookwell	New South Wales	4.8 MW
Ten Mile Lagoon, Esperance	Western Australia	2.02.MW
Hampton	New South Wales	1.32 MW
Huxley Hill, King Island	Tasmania	750 kW
Kooragang Island	New South Wales	600 kW
Thursday Island	Queensland	450 kW
Denham	Western Australia	690 kW
Mawson Base	Aust, Antarctic Division	600 kW
Flinders Island 2	Tasmania	250 kW
Coober Pedy	South Australia	150 kW
Epenarry	Northern Territory	80 kW
Breamlea, Geelong	Victoria	60 kW
Flinders Island 1	Tasmania	55 kW
Armadale, Perth	Western Australia	30 kW
Murdoch	Western Australia	28 kW 48 kW

Table 1.
Summary of wind installations with a capacity of greater than 25kW
(Australian Wind Energy Association)

INDUSTRY

Australia has a flourishing wind energy industry. It is involved in the research and development of small wind turbines as well as sales, service and manufacturing. Some of the main firms involved are Westwind, Powercorp and WD Moore and Co. Large wind turbines, greater than 60 kW, are not manufactured in Australia. They are imported from Europe and the USA.

The major electricity utilities in Australia are also involved in demonstrating and testing the applications of wind power. Those with active research and development wind power programs include Western Power, Country Energy (formerly Great Southern Energy), Energy Australia, Pacific Hydro, Stanwell and Hydro Tasmania.

Australia is active in small wind power research with major activity occurring at the University of Newcastle, the University of Technology Sydney, the Northern Territory University and Murdoch University.

Why use wind power

ADVANTAGES OF WIND POWER

- Wind power is a local, renewable resource.
- No carbon dioxide or other greenhouse gas is emitted as a result of wind power.
- Wind power has low operating costs as it requires no fuel.
- The technology for wind turbines is improving and the capital cost per MW generated is decreasing.

CONSTRAINTS ON WIND POWER

- Wind power is limited to those places where the wind blows strongly most of the year.
- Some people consider that wind turbines are unsightly. They create some noise and can kill birds if built in a flight path.
- Because winds vary so much power from wind is not always available when people want extra electricity.

The Future

Wind power systems have been encouraged by governments as clean alternatives to fossil fuels. The future looks optimistic following the development of large scale systems in both Europe and the United States. Improved sub-system technologies, the move towards mass production and increased experience in installation are all reducing costs. Wind turbines have become competitive with conventional systems in some areas.

For small scale power generation in remote areas, the main way of producing electricity until recently was liquid fuelled systems (diesel or petrol). Many remote area power supplies (RAPS) systems, which combine wind and photovoltaics with diesel backup, are now being installed. If the cost of photovoltaics decreases in the future, they may displace wind at lower power output levels.

The outlook for large grid-connected wind farms in Australia is promising, with many electricity utilities conducting wind monitoring in likely areas.

Abbreviations

MW – mega watts

kw – kilowatts

GWh – gigawatt hours

m/s – metres per second

References

Whale J., 27/11/2003, personal communication at Murdoch University.

Pryor, T. (2003). M390/M492 Energy Systems Unit Reader. Perth Australia, Murdoch University.

Creagh C. (2002), personal photograph, Murdoch University, Perth, Australia.

Further information

For more information on "Where Wind Energy Comes From" and "A Brief History of Wind Energy" visit the RE-Files

Australian Cooperative Research Centre for Renewable Energy

National Renewable Energy Laboratory (USA)

Western Power Corporation

Country Energy (formerly Great Southern Energy & Advance Energy)

Energy Australia

Pacific Power

University of Newcastle

Northern Territory University

Westwind Turbines

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