Wind Turbine Technology

BWEA Briefing Sheet

THE BRITISH WIND ENERGY ASSOCIATION

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Since earliest times, man has harnessed the power of the wind, with the first mill recorded as long ago as 6AD. The technology has diversified over the years to include pumping water, grinding grain and powering sawmills. By the middle of the nineteenth century there were over 10,000 windmills in operation in England alone. The latest diversification came in the 1880's when the turning action of the sails was converted to drive an electrical generator.

The technology continued to develop, but the real commercial impetus came around the time of the 1970's oil crisis with the rekindling of interest in sustainable and secure power production. This led directly to the establishment of wind power as the fastest growing energy source worldwide, with the market in Europe alone expanding at an average 30% per annum, a rate of growth equalled only by the telecommunications and computing industries. Now, climate change and security issues provide a further drive for the creation of sustainable, non-polluting diverse energy supplies.

Wind energy technology has developed rapidly in recent years and Europe is at the hub of this high-tech industry. Turbines are becoming cheaper and more powerful, with larger blade lengths which can utilise more wind and therefore produce more electricity, bringing down the cost of renewable generation.

The first commercial wind farm in the UK, built in 1991 at Delabole in Cornwall, used 400 kilowatt (kW) turbines, while the latest trials have involved turbines ten times more powerful, of four megawatts (MW) plus.

After an average working life of 20-25 years, wind turbines have a scrap value which can be sold on.

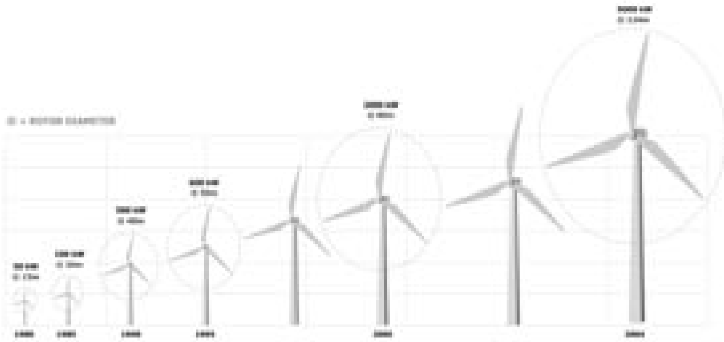

Figure 1: Growth in size of commercial wind turbine design Based on EWEA's Wind Energy - The Facts[1]

How Does a Wind Turbine Work

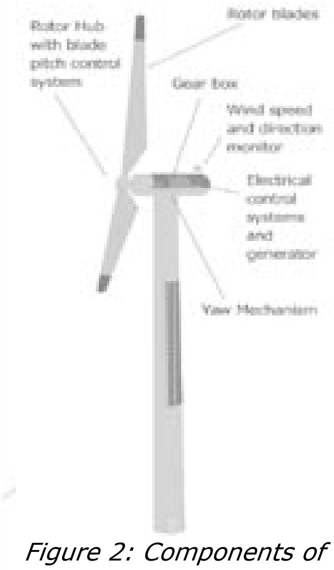

Figure 2: Components of a typical wind turbine

Wind turbines produce electricity by using the natural power of the wind to drive a generator. The wind is a clean and sustainable fuel source, it does not create emissions and it will never run out as it is constantly replenished by energy from the sun.

In many ways, wind turbines are the natural evolution of traditional windmills, but now typically have three blades which rotate around a horizontal hub connected to the power electronics, located in the nacelle at the top of a steel tower.

Most wind turbines start generating electricity at wind speeds of around 3-4 metres per second (m/s), generate maximum 'rated' power at around 15 m/s and shut down to prevent storm damage at 25 m/s or above.

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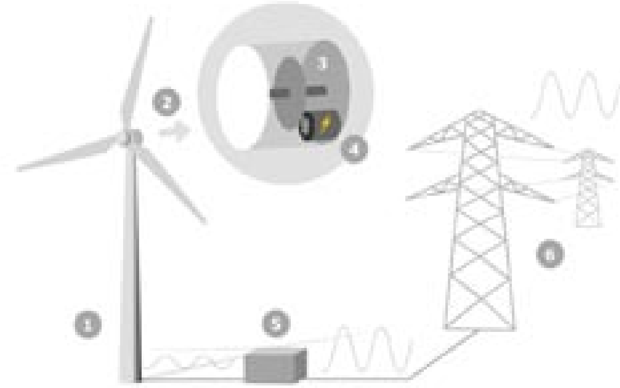

Figure 3: How a wind turbine converts the kinetic energy of the wind to electrical energy for the grid

Wind passes over the blades exerting a turning force (1). The rotating blades (2) turn a shaft inside the nacelle, which goes into a gearbox (3). The gearbox increases the rotation speed for the generator (4), which uses magnetic fields to convert the rotational energy into electrical energy. The power output goes to a transformer (5), which converts the electricity from the generator at around 700 Volts (V) to the right voltage for the distribution system, typically 33,000 V (33kV). The regional electricity distribution networks or the National Grid (6) transmit the electricity around the country.

Offshore Technology

Offshore technology is based on the same principles as onshore technology. Piles (1) are driven into the seabed and erosion protection, similar to sea defences, is placed at the base to prevent damage to the sea floor. The top of the foundation is painted a bright colour to make it visible to ships and has an access platform to allow maintenance teams to dock. The aerodynamically shaped blades (2) rotate around a horizontal hub, which is connected to the nacelle (3). Subsea cables (4) take the power to a transformer (5) which converts the electricity to a high voltage (33kV) before running it back to connect to the grid at a substation on land (6).

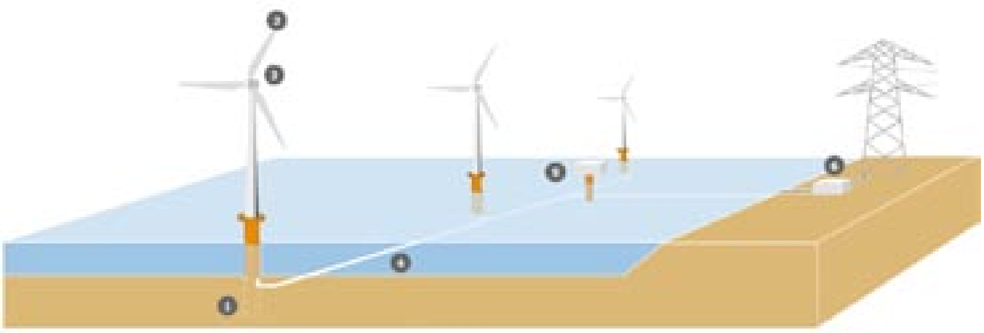

Figure 4: Installation of wind turbines at sea. Please note that as the UK offshore industry is still in the early stages of development, this is an indicative illustration only

Operation and Maintenance

Both onshore and offshore wind turbines have instruments on top of the nacelle, an anemometer and a wind vane, which respectively measure wind speed and direction. When the wind changes direction, motors turn the nacelle, and the blades along with it, around to face the wind. All this information is recorded by computers and transmitted to a control centre, which can be many miles away, meaning that wind turbines are not phsyically staffed, although each will have periodic mechanical checks, often carried out by local firms. The onnboard computers also monitor the performance of each turbine component, especially the blades, and will automatically shut the turbine down if any problems are detected, alerting an engineer that an onsite visit is required. In reality, the situation is more complicated, with many wind turbines, more voltages, different types of generators and safety systems, but this is a good guide to the basics.

The amount of electricity produced from a wind turbine depends on three factors:

- **Windiness of the site**

The power available from the wind is a function of the cube of the wind speed. Therefore if the wind blows at twice the speed, its energy content will increase eight-fold. Turbines at a site where the wind speed averages 8 m/s produce around 75-100% more electricity than those where the average wind speed is 6 m/s, as not all the extra energy can be harvested.

- **Wind turbine availability**

This is the capability to operate when the wind is blowing, i.e. the turbine is available to work. This is typically 98% or above for modern European machines.

- **The way the turbines are arranged**

Turbines in wind farms are laid out so that one turbine doesn't take the wind away from another. There are also landscape issues to consider. It is generally agreed that the ideal position for a wind turbine generator is a smooth hill top, with a flat clear fetch, at least in the prevailing wind direction.

How Electricity from a Wind Turbine Gets to Homes and Businesses

Whether the wind turbine is located onshore or offshore, the electricity it produces needs to be taken to the end user, i.e. to the customer.

The UK electricity system consists of five main parts. Generators (1) generate the electricity with many contributors, both nuclear and fossil fuel plants. The National Grid (2) is the core of the system, distributing electricity for long distances around the country. Once transported, the National Grid hands over the power to distribution companies (3), which own and operate the local electricity distribution networks. In the middle of this are the supply companies (4 - not shown) who sell electricity to consumers (5).

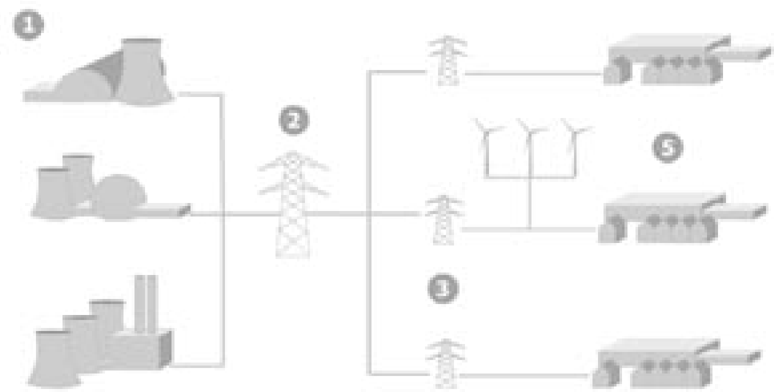

Figure 5: UK electricity supply system

Can we Rely on the Wind?

Wind energy is often criticised for being unreliable, with concerns over what will happen when the wind stops blowing and whether we can rely on the wind. The simple answer is yes, wind energy can be relied upon, even although the wind does not blow constantly. Wind turbines generate electricity for approximately 80% of the time, although not always at full output.

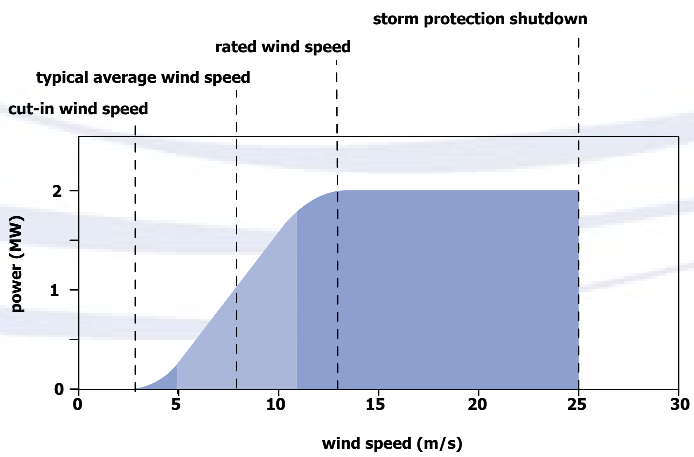

Figure 6: Wind turbine power curve

The proportion of time that a wind turbine is generating below maximum output depends on the average wind speed at the site. Most sites where wind turbines are installed in the UK have wind speeds in the range 7.5-9 m/s and so generate electricity for 70-85% of the time.

In fact, no energy technology can be relied upon 100% of the time and all power plants are unavailable at certain times, whether for routine maintenance or for unexpected reasons, such as component failure or if lightning strikes a power line.

For any type of a power plant it is possible to calculate the probability of it not being able to supply the expected load. Load factor is not the same as efficiency. In fact, very few machines operate at their theoretical maximum load factor, for example a kettle is not on all the time, nor are cars driven constantly at 70 miles per hour.

$$\text{LOAD FACTOR} = 100\% \times \frac{\text{ENERGY GENERATED (MWh)}}{\text{MAXIMUM POWER (MW)} \times 24\text{h} \times 365 \text{ days}}$$

At any one point in time, wind turbines in the UK have a load factor of around 30-40%, i.e. the average output from a 2 MW turbine is about 5,000 MW hours annually. To put this in context, the average annual domestic electricity consumption is 4.7 MW hours[2], meaning that single turbine generates the equivalent of the electricity requirements of over a thousand homes each year.

Figure 7: Load factors of different electricity generating technologies

Energy Technology	Load Factor
Sewage Gas	90%
Farmyard Waste	90%
Energy Crops	85%
Landfill Gas	70-90%
Combined Cycle Gas Turbine (CCGT)	70-85%
Waste Combustion	60-90%
Coal	25-85%
Nuclear Power	65-85%
Hydro Power	30-50% in UK*
Wind Energy	30-40%
Wave Power	30-40%
Solar Power	8-10%

*can be higher elsewhere

A load factor of 30% does not mean that wind turbines are idle for two thirds of the time nor is it necessary to keep extra power plants on stand-by to accommodate changes in the wind. For wind to provide 10% of the UK's electricity needs, only a small amount of conventional back-up supply will be required, adding only 0.2p/kWh to the generation cost of wind energy and will not in any way threaten the security of the grid[3]. In fact, this is unlikely to become a significant issue until wind generation reaches levels above 20% of electricity supplied[3]. Over 700 MW of wind energy is already operating in the UK with a capacity credit of over 200 MW, replacing or avoiding the need to build an equivalent amount of thermal or nuclear capacity.

The average wind farm in the UK will pay back the energy used in its manufacture within three to five months[4], comparing favourably with coal or nuclear power stations. Furthermore as a free fuel source, wind energy does not suffer from erratic fluctuations in global fossil fuel prices.

Today's wind turbine technology already demonstrates how harnessing the power of the wind can make a significant contribution to our energy system.

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1 EWEA (2004), Wind Energy - The Facts. An Analysis of Wind Energy in the EU-25, Executive Summary, available at www.ewea.org/documents/Facts_Summary.pdf
2 Based on 115.3TWh for domestic consumption (Digest of UK Energy Statistics, 2002. pp15) and 24.48 million households as established by the 2001 Census. See www.bwea.com/edu/calcs.html
3 The Carbon Trust and DTI (2004), Renewables Network Impact Study, www.carbontrust.org.uk/carbontrust/about/publications/Renewables Network Impact Study Final.pdf; National Grid (2004), Seven Year Statement, www.nationalgrid.com/uk/library/documents/sys_04/default.asp?sNode=SYS&action=&Exp=Y
4 Millborrow, D (1998), Dispelling the Myths of Energy Payback Time, as published in Windstats, vol 11, no 2 (Spring 1998)

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