Wind Energy

Price 40p

A fast expanding industry

Wind energy has come a long way since interest was renewed in the ‘70s following the oil price rises. Installed capacity reached over 175,000 Megawatts* (MW) worldwide by June 2010 following increases of 31%, 29% and 27% in 2009, ’08 and ‘07 respectively. Average new turbine size has increased with most now being of 1.5-3 MW capacity though some 5 MW turbines have been installed and larger prototypes developed. Early small turbines have been replaced by larger, more efficient ones. Turbines are being installed successfully off shore and in more countries. Germany, which has made astonishing progress since 1990, had 26,400 MW installed capacity by mid 2010 but lost its lead to the USA which had 36,300 MW by the same date with both being overtaken by China with 41,800 MW installed by end 2010. Spain is now 4th and India, with 12,100 MW in mid 2010, 5th. The UK leads in offshore capacity with 1341 MW at end 2010. Wind technology and its market are ‘mature’.

Limitations of wind power

This heady progress should not obscure the simple fact that wind power is unreliable. The wind does not always blow, nor blow at the same strength, all the time. The more turbines one has and the more widely spaced they are across the country, the more chance there is of wind occurring *somewhere*, but there can still be little or no wind for a week or more as happened at the beginning of both 2009 and 2010 when electricity demand was very high. A study in Germany concluded that wind output was less than 11% of full capacity for over half the year with average utilisation (the percentage of electricity *actually* generated compared to the potential if working flat out) as low as 17.2%. This means that though one might have 10,000 MW of wind turbines installed one still requires 10,000 MW of gas or coal fired stations available to fill the gap when the wind drops. In Germany these provide 82.8% of the power in an average year. (The UK is more favoured. The split would be 28%:72%) Happily, because forecasts of wind output are improving, the fossil stations do not actually have to be ‘spinning’ and immediately available. Wind energy saves some fossil fuel (which is good) but not the *capital cost or all of the running cost* of the standby plant. In addition the low ‘load factor’ and far flung location of many wind farms means grid connections costs more *per unit of electricity* than for fossil or nuclear plants.

Integrating wind energy into the grid

Clearly if the wind is blowing one should use the electricity generated. In the UK electricity is fed into a high voltage national grid from nuclear, gas, coal, and oil fired power stations with smaller sources such as hydro, CHP and energy from waste plants fed into local, lower voltage, networks.

Ideally nuclear reactors should not be stopped and started though modern reactors can follow the load to a certain extent. As the UK has only a small number of dams providing hydroelectric power any variation between electricity supply and demand is taken up by adjusting the output from fossil stations. Forecasts take into account previous patterns of demand, temperature and factors like national events such as royal weddings and cup finals when demand leaps as kettles are switched on at half times and other breaks. Electricity generators, including wind farms, contract (right up to one hour before the electricity is required) with electricity supply companies to provide agreed amounts of electricity for each 30 minute ‘slot’ in a day. Because supply and demand never match exactly, the national grid operator also contracts with ‘fast reacting’ suppliers based on a statistical estimate of variations in demand and supply. Currently the ‘margin’ is 2,500 MW, all or none of which may be used.

1.5 MW wind turbine at Swaffam, Norfolk

The grid operator must also provide for a sudden failure either of a power station or power line linking to the grid. This is not a problem with single turbines but could be with large offshore farms where under water

An ALDES Briefing Note

Last updated January 2011

This briefing note has been prepared for ALDES by Richard Balmer, but the opinions expressed are his own. If you see errors or have comments, please contact Richard Balmer at richardbalmer162@btinternet.com

cables could be damaged. Currently the Dinorwig pumped storage hydro plant provides rapid response against these failures. Water is pumped from a low reservoir to a high one when electricity demand is low so it is available for any sudden increase in demand of up to 1800 MW for 5 hours. A scheme at Ben Cruachan in Scotland can supply 400 MW for 18 hours and there is keen interest in developing more.

Practical limits for wind energy

Denmark has gone furthest in exploiting wind energy. Around 20% of its electricity comes from wind but this is only practical because it can balance its supply by taking and dumping to the Scandinavian and German grids which have large hydro electric back up. Even so a problem arose in January 2005 when a hurricane hit Scandinavia. The grid tripped under the surge of power and left large areas without electricity for 3 days. Poor 'quality' (ie variable and unreliable) electricity is a concern to Danish users as well as the price they pay which is the highest in the EU. Most countries believe they could take 20% of electricity from wind at *peak* without problems, that is 5-6% on *average*. In 2008 wind generated almost 6.5% of Germany's electricity but the rate of installing new capacity is slowing both there and in the US, so it is extraordinarily ambitious for the UK Government to be proposing that wind capacity rise to around 40,000 MW (33,000 MW off shore) and granting licences for 25,000 MW off shore in January 2010. In theory this would mean wind supplying more electricity than we actually need at some times. One study[1], drawing on Danish experience, suggests anything over 10,000 MW (6-7% of total electricity) is impractical although another study[2] implies the limit is 10%.

This second study analysed wind speed data from around the UK and postulated an 'ideal case' where wind farms were sited so that whatever wind was present could be used. The findings were interesting. First about twice as much wind occurred on average in the 3 winter months, when electricity demand is high, than summer. Second there was more wind between the hours of 8 am to 8 pm than 8 pm to 8 am which, again, is when it is most needed. On the other hand the study found much variation hour to hour.

Wind turbines aim to optimise performance at particular sites. The turbine in the study produced no electricity in winds of less than 4 metres/sec (9 mph) and shut down at 25 m/s (speeds in excess of this are rare). From 4 to 14 m/s output increased by the *cube* of the wind speed. From 14 to 25 m/s output was constant. A 2010 study by Durham University concluded that the best sites should have a wind regime, not with exceptional winds, but with those commonly of 7-14 m/s. Operational failures and downtime increased if turbines were exposed to great variation. Even so a relatively modest change in wind speed from 8 to 10 m/s *doubles* output and vice-versa. This rapid variation presents severe problems where wind is a major source for a local community.

Storage and managing demand

There are 2 ways to overcome the variation problem. One is to find ways of 'storing' electricity: the other to manage demand. Storage would assist the introduction of solar and tidal energy as well as wind. Small turbines can use batteries but something better is required as amounts increase. Pumped storage has been mentioned above but sites are limited. Surplus wind electricity could produce hydrogen which can be re-converted back to electricity when the wind drops or, alternatively, used for transport fuel, opening up a huge new market. Since 2004 a number of trials have begun around the Baltic, Faroes and elsewhere. A further option is to develop a European super grid in the hope that there will be a renewable source somewhere (wind in the north, solar in the south, etc) to meet demand. The main obstacle to both is cost rather than technology. The problem with wind is that the 'storage' needs to cover a whole week, rather than a few hours for, for example, tidal.

The other option of 'managing' demand is already here to a limited extent. Industry can choose 'interruptible contracts' and 'Economy 7' tariffs are used to feed storage heaters at night and switch on dishwashers and washing machines. However Economy 7 is a predictable system which domestic consumers can get used to whereas a wind related supply is not. Consumers will be frustrated if appliances go off without warning. For the time being it seems that wind energy will have to be used in harness with fast reacting coal or gas which will actually be used most (around 72%) of the time. Unless these stations are fitted with carbon capture (which is not yet ready) a wind-gas system is not very green.

Costs of wind energy

It is not easy to estimate the real cost of generating wind energy. There are good and less good sites. Much of the UK's best wind energy is in the north and west while most demand is in the south east, so allowances for the extra cost of overhead power lines should be made. The best sites in the UK will struggle to get much below 3.5p/kWh (BERR put the average at 6.0 p/kWh) and perhaps 1p/kWh should be added for the capital cost of standby plant and extra cost of grid connection.

Surveys have shown the majority of people would pay more for 'green' energy but when asked 'how much' interest tails off at 10%. Worse, suppliers have been dishonest and tainted the market. Government has had to *impose* a requirement that suppliers take a minimum amount of renewable energy under the 'Renewables Obligation'. This is 11.1% in the year ending 31.3.11 with the amount rising to 15.4% in 2015/16. Every unit not bought in 2008/09 cost 3.699p. This 'penalty' money is redistributed to suppliers who did buy units.

Because the *total* quantity of renewable electricity is below the obligation, wind generators obtained around 5p/unit extra last year over fossil electricity**.

Opposition to wind energy

For many years progress in the UK was dogged by the difficulty of obtaining planning permission. Only 409 MW capacity had been installed by 2000 even though subsidies had been promised for over 2000 MW. Wind farms need 1 km^2 for every 10 MW capacity. Though many find turbines elegant, they are prominent with the tip of the blades often 100 m above ground. Many are unhappy about turbines especially in scenic countryside and raise concerns about bird kills, low flying aircraft, deaths to maintenance workers (about 44 so far worldwide, most due to falls), noise, interference to radio, TV and radar, and fears of ice being thrown from blades (in one reported case by 200 metres: blade tips can move at 200 mph). Some years ago a judge decided a wind turbine 500 metres away reduced a property's value by 20%. Nor is the problem just the turbines. There was great opposition to the 220 km long power line bringing wind generated electricity across the Scottish Highlands. Underground lines are some 20 times more expensive than overhead ones and have problems dissipating the heat from the transmission losses, as well as being a hazard to farmers and others.

Planning approval is still not straightforward. Wind farms can make a lot of money, which incurs suspicion. Nonetheless 5213 MW capacity is now installed with 1341 MW of that offshore making the UK the 8th largest. A new problem is the global shortage of manufacturing capacity and installation barges and the fall in the value of the pound leading to higher costs.

Offshore wind farms

An important decision occurred in July 2003 when the Government agreed turbines could be built off shore. Offshore turbines avoid the aesthetic objections to those on land and have 2 advantages. First there are more sites near centres of demand such as London. Second the wind, though weaker, is steadier. 11 offshore farms now feed electricity into the grid and bigger ones like Gwynt y Mor (750 MW), the London Array (1000 MW) and Barrow-in-Furness (500 MW), have been approved. The recent 25,000 MW licences could see massive farms in the North Sea as well as smaller ones off North Wales, in the Bristol Channel, and off Dorset. The London Array would comprise 341 turbines and be spread over 90 sq miles in the Thames Estuary 12 miles off the coast between Margate and Clacton. Investor confidence weakened when the original estimate of £1.5 bn doubled but promises of larger subsidies have brought them back.

Even so the sea remains a hostile place. If a turbine breaks down repairs can be delayed and will certainly be more expensive. The major turbine manufacturer Vesta faced bankruptcy when it had to retrieve all 80 turbines from the Horns Rev field to replace gearboxes, leaving Siemens the dominant offshore supplier. Whereas onshore turbines will be down 2-5% of the time, offshore could reach 20%. There are other problems too. Shipping lanes, oil platforms and fishing grounds must be avoided. Vibration may be affecting dolphins and other marine life. Originally it was thought the extra cost of going offshore would be 2-3p/kWh but it could be more. From 1st April 2009 offshore wind earnt 1.5 ROC's/unit (a subsidy of c. 7.5p/kWh). From 2011 to 2014, to encourage new build, this will rise to 2 ROC's (subsidy 10p/kWh).

Local generation

A further development has been to encourage local (so called micro or embedded) generation of power. Small turbines, which can be sited above roof level on simple poles, are on the market and can be plugged straight into a house electric circuit. From 1st April 1910 electricity produced receives 36.5p/unit and any exported to the grid 5p more. This is an enormous subsidy designed to kick start a market but early results in urban areas, where other buildings 'get in the way' and disturb the wind, have been so poor they are no longer encouraged.

Conclusions

Though late in the field the UK is at last beginning to exploit its excellent wind resources. The *extra* cost of wind generated electricity over fossil stations depends on the mix of on- and off-shore and seems to be going up. Assuming a long term extra cost of 5p/kWh and 10% of electricity coming from wind, consumers will pay about £2 bn/year more for their electricity - a sizeable sum.

The real challenge however is to find a non-fossil way to balance out the wild variations in wind electricity generated. It is reasonable to double the present capacity but dangerous to go much further until we can be confident this 'balancing' can be achieved at some kind of reasonable cost. If not we will lock ourselves into long term dependency on coal or gas.

** Example: Suppose the number of renewable units the government wants is 300 and the number generated is only 200. Suppose the penalty is 4p/unit so the total penalty money is 100 x 4p=400p. This is passed from companies who didn't buy enough to those who did. They now receive a refund worth 2p/unit (400p/200). This means it is worth buying renewable units at 6p over the fossil price (4p + 2p). Also that the extra cost of renewables is born equally by all companies

References

1: Sharman Hugh "Why UK wind power should not exceed 10 GW" Civil Engineering 158 Nov 2005 pages 161-169

2: Environmental Change Institute, University of Oxford "Windpower and the UK wind resource" 2005