Wind Power and Variability

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Although wind power is often described as intermittent, that description is incorrect. Intermittent means "on or off." Wind power output varies around the country as a whole but rarely disappears completely.

An individual wind turbine will generate electricity for 70-85% of the time and its electricity output varies between zero and its full, "rated" output in accordance with the wind speed. However, the combined output of the UK's entire wind power portfolio shows less variability, as there are always differences in wind speed across the country as a whole. Whilst the amount of wind power varies, it rarely (if ever) goes completely to zero.[1]

This briefing sheet addresses some of the most common questions associated with the variability of wind. It examines issues that arise as the contribution of variable renewables rises to the point where they provide up to 40% of the electricity supply. This is not a ceiling and many suggest higher amounts can be accommodated. The aim is to clarify the short to medium-term issues, drawing upon the considerable body of analysis that has been carried out during the past 30 years. This is followed by a selection of findings from Parliamentary Select Committees and other authoritative bodies who have examined the variability issue.

Managing the electricity system

In order to maintain security of supplies, a second-by-second balance between generation and demand must be achieved. Any excess of generation causes the system frequency to rise whilst an excess of demand causes the system frequency to fall. The electricity system is designed and operated in such a way as to cope with large and small fluctuations in supply and demand.

No power station is totally reliable; coal, gas and nuclear plants can, and do, disconnect without warning, due to mechanical, electrical or instrumentation faults. Consumer demands are also uncertain, although reasonably predictable. The system operator procures reserves that enable the system to be balanced over various timescales, taking into account the uncertainties in demand and generation. When wind is operating in an electricity network, this introduces extra uncertainty, but the additional uncertainty, due to the variability of wind generation, is what matters. This additional uncertainty is quite small although it rises as the amount of wind power on the system increases. The uncertainty needs to be set in context and so the reserve needs of electricity systems without wind are discussed first.

Operational reserves

Large electricity systems have a number of robust defences against unexpected changes in the balance between demand and generation, including:

- Inertia of the generating plant. The mechanical and thermal inertia in the boilers and turbines of coal and nuclear power stations help keep the power system stable. The contribution is small, passive, and is the first line of defence.
- "Frequency response" plant – responds to frequency changes, automatically increasing output when the frequency falls, or vice-versa.
- Reserve plant – This refers to various types of plant. Some is operating at part-load; some is off-line, but able to start up within a short time.

In Great Britain, the amounts of reserve that are scheduled depend on the total system demand and on the "worst-case" power station trip that is likely at any given time. Around 2000MW of frequency response plant is typically available and the total reserve requirement at the winter peak is around 3850MW.

Wind variations

The short-term variations of wind generation (second-to-second or minute-to-minute) are generally small compared to the corresponding variations in demand. In addition, it is very unlikely that the national portfolio of wind generation would give rise to instantaneous power changes as large as those currently managed. When large power stations 'trip', up to 1200MW of generation can be lost – instantaneously. Wind generation is not like that. As more wind plant is built it will be widely spread over the country and so the power swings will be generally quite modest. Moreover, they can be quantified. Data from the wind power plant operating in Denmark,[2] for example, show that the average hour-by-hour variation in output is about 3%. Other data from wind plants in Denmark and Germany show that the maximum power swings within an hour rarely exceed about 20% of the installed wind capacity. So with 5000MW of wind on the system, the maximum hourly change (which will occur once or twice a year) will be about 1000MW. This is of a similar order to existing reserve holdings, and, while there may be a need to increase reserve holdings somewhat, it is unlikely to give rise to unmanageable requirements. Studies of wind power changes in Germany, Denmark and Finland[3] also show that for 90% of the time, power swings of dispersed wind generation within one hour are less than 5% of the installed wind capacity.[4] These studies (and others) estimate that additional reserves required on the system are only a few percent of the installed wind capacity. They increase with the amount of wind, reaching around 20% of the wind capacity when 30GW of wind is connected to the GB system.[5]

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The evidence in this area is fairly robust. Utilities first started looking at the issues surrounding variability about 30 years ago.[6] Since then numerous studies have been published, and they all reach very similar conclusions. A comprehensive list of these studies is included in the DTI/Carbon Trust *Renewable Energy Network Impacts Study*.[7] Another recent review identified over 150 references.[8] Parliamentary Select Committees that have looked at the question in some detail have concluded that variability is unlikely to cause any significant problems. The GB system operator, National Grid Transco, is confident that wind variations can be managed, as quoted overleaf.

Standby capacity

There is much interest in "what happens when the wind stops blowing" – particularly on cold days in the winter. There is, as far as we are aware, no evidence to demonstrate that windless days regularly coincide with peak demands on the UK electricity network. That is what matters, as the risks of power shortfalls are highest on days of peak demand. Several studies have shown that, more often than not,[9] wind power is usually available on days of peak demand. However, the System Operator does not rely on all the wind being available, any more than they rely on all the conventional plant being available. On average, at times of peak demand, roughly 85% of the conventional plant operates and about 35% of wind capacity. In each case, more will be available on some occasions, less on others. Operating power systems is all about managing risks and what matters is the overall risk.

It is a fallacy to assume that more standby plant will need to be built if the amount of wind on the system increases. If a new nuclear power station is built, there will be occasions when it will shut down, but it is not suggested that additional plant is built to cope with this eventuality. Instead, electricity systems operate with a common pool of spare plant that is typically a little over 20% of the peak demand. The GB system has a peak demand of around 60GW and the desirable margin is about 14GW. Statistical calculations show that this ensures that the lights will stay on with a high degree of reliability.

There is some debate as to whether any thermal plant can be retired with the introduction of wind, but there is strong evidence that this is possible and studies have suggested 8GW of wind, for example, can displace 3GW of thermal plant. It is important to note this "capacity credit" is a statistical concept. However even if this evidence is discounted, when wind is introduced into an electricity network, no additional backup needs to be built – it already exists. However, modest costs are incurred by wind as the existing thermal plant – particularly at high penetration levels – operates at a lower load factor. Its capital costs therefore need to be recovered from a lower number of electricity units and this can be referred to as "the cost of backup."

The costs of variability

The total costs of variability arise partly from the cost of backup, defined in the previous paragraph, and partly from the costs of the additional reserves that need to be scheduled to cope with the additional uncertainty. Using data from National Grid and other sources, it has been estimated that the additional cost to the electricity consumer may be between £1.5-2/MWh with 20% wind, rising to around £5-7/MWh with 40% wind.[10] The latter corresponds to around 5% on domestic electricity bills.

There are numerous technical innovations at various stages of development that can mitigate the extra costs associated with variability. Improved methods of wind prediction are under development worldwide and could potentially reduce the costs of additional reserve by around 30%. Most mitigation measures also reduce the costs of managing the electricity network as a whole. 'Smart grids', for example, cover a range of technologies that may reduce the costs of short-term reserves; additional interconnections with continental Europe, including 'Supergrids' also deliver system-wide benefits and aid the assimilation of variable renewables. Electric cars hold out the prospect of reduced emissions for the transport network as a whole and could act as a form of storage for the electricity network – for which the electricity generator would not have to pay.

Summary statements from key bodies

Welsh Affairs Committee (Commons), Session 1993-94, 'Wind Energy'
"The routine variations in demand within the grid and the need to protect against the failure of conventional power sources together require a flexibility far greater than that demanded by wind energy either at present or in the foreseeable future."

Trade and Industry Committee (Commons), Session 2001-02, 'Security of Energy Supply'
"We take comfort from the assurances given by the National Grid Company and others that the intermittency of certain types of renewable power – principally wind, but also wave and solar -would not cause supply or balancing problems for the transmission and distribution systems at the 10% level.

The GB System Operator, National Grid Transco, 'Seven Year Statement', May 2005
"…based on recent analysis of the incidence and variation of wind speed, the expected intermittency of wind does not appear to pose major problems for stability…"

Science and Technology Committee (Lords), Session 2003-04, 'Renewable Energy: Practicalities'
"The amount of standby capacity that is needed reflects the aggregated uncertainty of the power supplies, not the marginal uncertainty of wind power alone. The consequence is that for relatively low penetrations of wind power (up to 10% of total demand) the additional standby capacity required is small".

"There is no technical limitation within the foreseeable future on the amount of wind power that can be introduced onto the system."

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