Intermittency of UK Wind Power Generation 2011 and 2012

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Executive Summary

This summary covers the principal findings of an analysis of electricity generation from all the UK wind turbine farms which are metered by National Grid, from January 2011 to December 2012.

The analysis shows:

- The total output of the monitored wind turbines (as measured by the National Grid) increased from 2,430MW to 5,705MW over the period
- The average capacity factor for all monitored wind turbines, onshore and offshore, across the whole of the UK was 33.2% and 30.7% in 2011 and 2012 respectively.
- The average capacity factor in any given month varied from 16.2% (July 2011) to 50.8% (December 2011) with 9 months having an average output of <25% of monitored capacity and 12 months <30%.
- The time during which the wind turbines produced <10% of their rated capacity totalled 3,165 hours or 131.9 days - 18% of the two year time span studied.
- The time during which the wind turbines produced <5% of their rated capacity totalled 1,200 hours or 50 days – almost 7% of the two year period.
- The output from wind turbines is extremely intermittent, with output varying by a factor of 10 over very short periods.

Three assertions are commonly used to support industrial wind turbine installations:

- Wind turbines generate on average 30% of their rated capacity over a year
- The wind is always blowing somewhere in the UK
- Periods of low wind across the UK are infrequent

However, the conclusions to be drawn from the evidence are:

- In windy years such as 2011 and 2012 turbines can, on average, produce over 30% of their rated capacity, but this is certainly not the case every year.
- The assumption that the wind is blowing somewhere in the UK at any given time is, in practical terms, false: there are regular periods when there is not enough wind to contribute to any meaningful power generation.
- Periods of low wind are so frequent that wind turbines cannot be relied on as a steady source of power, even given two-fold increase in installed capacity over the period studied. Wind turbines must be backed up by the equivalent capacity of conventional fossil-fired power stations, thus largely negating any fuel savings or reductions in CO_2 emissions.

Intermittency of UK Wind Power Generation 2011 and 2012

Introduction

The previous Secretary of State for Energy and Climate Change, Chris Huhne, asserted that he had no intention of seeing the power go out on his watch. He also said that without power derived from industrial wind turbines, energy bills would continue to rise. However, the official data collected by the National Grid shows that wind generation is so intermittent as to put energy security at risk without backup from an equivalent level of conventional generating capacity. The fact that backup capacity is needed inevitably raises electricity prices in any system with a significant percentage of wind generating capacity.

Similarly, the organisation representing the wind industry, renewableUK (www.renewableuk.com/), states on the Onshore Wind page of its website, "Onshore wind farms reduce CO_2 emissions, provide energy security, and contribute to the local and national economy." The page also states, "Onshore wind works well in the UK because of the excellent wind resource. It has also become one of the most cost effective forms of renewable energy, providing over 5,000MW of capacity. A modern 2.5MW (commercial scale) turbine, on a reasonable site, will generate 6.5 million units of electricity each year – enough to make 230 million cups of tea."

On 26 April 2013, the renewableUK home page gave these figures under the heading "Powered by Wind": Energy Produced 22,446,212 MWh, powering the equivalent of 5,261,653 homes and giving CO_2 reductions (pa) of 7,617,234 tonnes.

But what are the facts behind these statements – can we rely on wind turbines to power our homes and offset the annual release of carbon dioxide from conventional coal- and gas-burning power stations? This might be true if the wind blew consistently but it does not; it blows very intermittently.

This report aims to use published figures to test the following three assertions which are commonly used to justify industrial wind turbine installations:

- Wind turbines generate on average 30% of their rated capacity over a year
- The wind is always blowing somewhere in the UK
- Periods of low wind across the UK are infrequent

Based on this analysis, it is also possible to conclude whether wind turbines in the UK are making any significant contribution to a reduction in CO_2 emissions.

Installed and Monitored Capacity

During 2011, the installed nominal capacity of wind turbines in the UK increased from 5,190 MW to 5,772 MW. By the end of 2012 this had risen to 7,777 MW. The capacity monitored by the National Grid increased from 2,430 MW to 4,006 MW in 2011 and to 5,705 MW by the end of 2012.

Although not all wind generation is monitored by the Grid, there is no reason to suppose that the generating capacity not monitored behaves significantly differently from that which is recorded. From the data on the NETA (New Electricity Trading Arrangements) website (www.bmreports.com/bwx_reporting.htm), it is not possible to distinguish between onshore or offshore wind generation, or that from different parts of the UK. However, as this report seeks to look at the overall generation picture across the UK and not break it down by region, this is not seen as an issue.

Analysis

The National Grid publishes data on electricity generation by fuel type on its NETA website. This covers generation from all conventional industrial generators and from most of the industrial wind generation installations in UK.

This analysis given in this report takes the recorded data at half hourly intervals and uses it to show the intermittent output graphically over each month of 2011 and 2012.

Do wind turbines generate on average 30% of their rated capacity over a year?

The data points for each 30-minute period are averaged over the full month and a figure for output as a percentage of monitored installed capacity is calculated.

2011	**Monitored Capacity (averaged over the month) MW**	**Average Output (MW)**	**Average Output (%)**
January	2,490	758.1	30.4
February	2,662	973.2	36.6
March	2,862	709.0	24.8
April	3,226	917.7	28.4
May	3,317	1,416.7	42.7
June	3,402	701.0	20.6
July	3,402	551.2	16.2
August	3,544	738.6	20.8
September	3,702	1,310.7	35.4
October	3,731	1,588.4	42.6
November	3,731	1,621.0	43.4
December	3,971	2,015.5	50.8
Average 2011	**3,340**	**1,109.5**	**33.2**

The figures for 2011 show a significant variation in the average output from month to month. Monthly averages vary by a factor of more than 3, with the July output running at 16.2% and that of December 50.8%.

2012	**Monitored Capacity (MW)**	**Average Output (MW)**	**Average Output (%)**
January	4,006	1,723.0	43.0
February	4,079	1,633.6	40.0
March	4,304	1,150.9	26.7
April	4,454	1,081.0	24.3
May	4,604	948.1	20.6
June	4,686	1,099.7	23.5
July	4,686	804.3	17.2
August	4,686	999.4	21.3
September	5,041	1,940.5	38.5
October	5,066	1,311.4	25.9
November	5,270	2,057.3	39.0
December	5,314	2,500.6	47.1
Average 2012	**4,696**	**1,439.5**	**30.7**

For 2012, the figures again show a significant variation from month to month, the July output once more being lowest at 17.2% and December the highest at 47.1%.

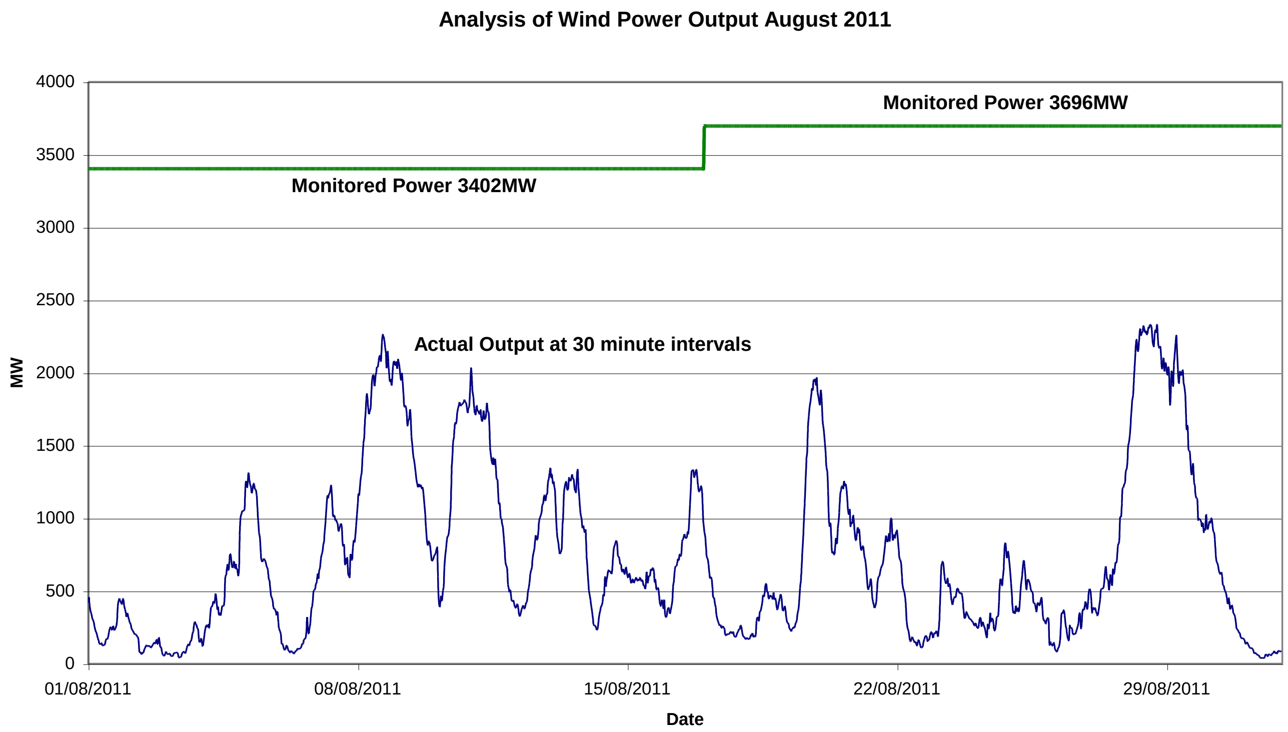
From the data analysed the answer is “Yes, wind turbines do, on average, generate more than 30% of their rated capacity” for both 2011 and 2012.

However, it should be noted that despite a 40% increase in (nominal) installed capacity from 2011 to 2012, the average output dropped. It is likely that the windiest sites for onshore wind farms have already been used, so that newer ones can be expected to have a lower capacity factor. For comparison, the average output during 2009 was 27.2% and during 2010, a low wind year, was 21.1%.[1]

(1) Analysis of UK Wind Power Generation, November 2008 to December 2010 – Stuart Young Consulting

Is the wind always blowing somewhere in the UK?

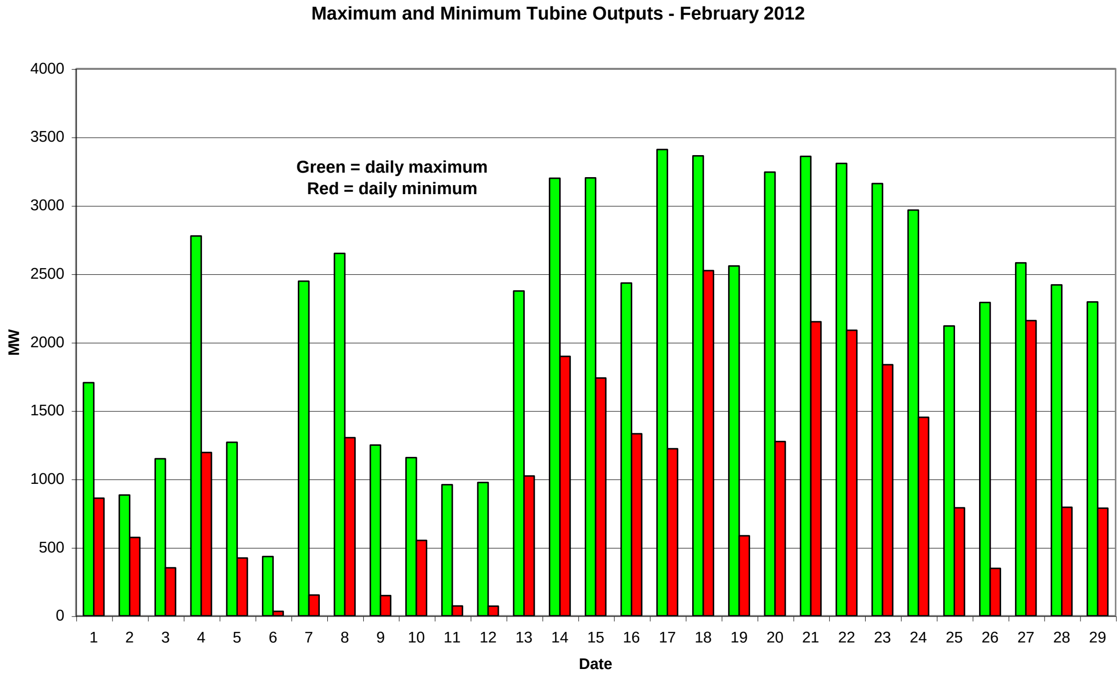
The graph below shows a typical month’s data, from August 2011.



It can be seen that, during August 2011, the wind was indeed always blowing somewhere in the UK as the output from all the wind turbines feeding the National Grid never fell to zero. However, the output varied dramatically from day to day, with 5 days in the month having a minimum output (averaged over 30 minutes) of under 100MW, of which 3 days recorded under 50MW.

This graph is quite typical and detailed graphs, with additional data, are given in the appendix for each of the 24 months analysed.

The data can also be presented as minima and maxima in any month as shown in the bar chart below for February 2012, when the average output was a higher than normal at 40%.



On four days of the month, the variation from minimum to maximum output is over 13-fold.

The following table gives the minimum output during each month over the 2 years for which the data was analysed.

2011	Minimum Output MW	As % of Monitored capacity	2012	Minimum Output MW	As % of Monitored capacity
January	81	3.3	January	122	3.0
February	129	4.8	February	32	0.8
March	9	0.3	March	50	1.2
April	106	3.3	April	60	1.3
May	0	0.0	May	0	0.0
June	36	1.1	June	34	0.7
July	21	0.6	July	63	1.3
August	38	1.1	August	14	0.3
September	23	0.6	September	164	3.3
October	58	1.6	October	71	1.4
November	85	2.3	November	152	2.9
December	237	6.0	December	78	1.5
Average	**69**	**2.1**	**Average**	**70**	**1.5**

Therefore the assumption that the wind is always blowing somewhere in the UK may be strictly correct, but often it is not blowing enough to generate a significant amount of electricity. It should also be noted from the above table that the minimum output levels have not significantly changed even with more wind turbines being installed and that further increases in wind generating capacity are likely to increase the maximum output but do nothing to increase the minima.

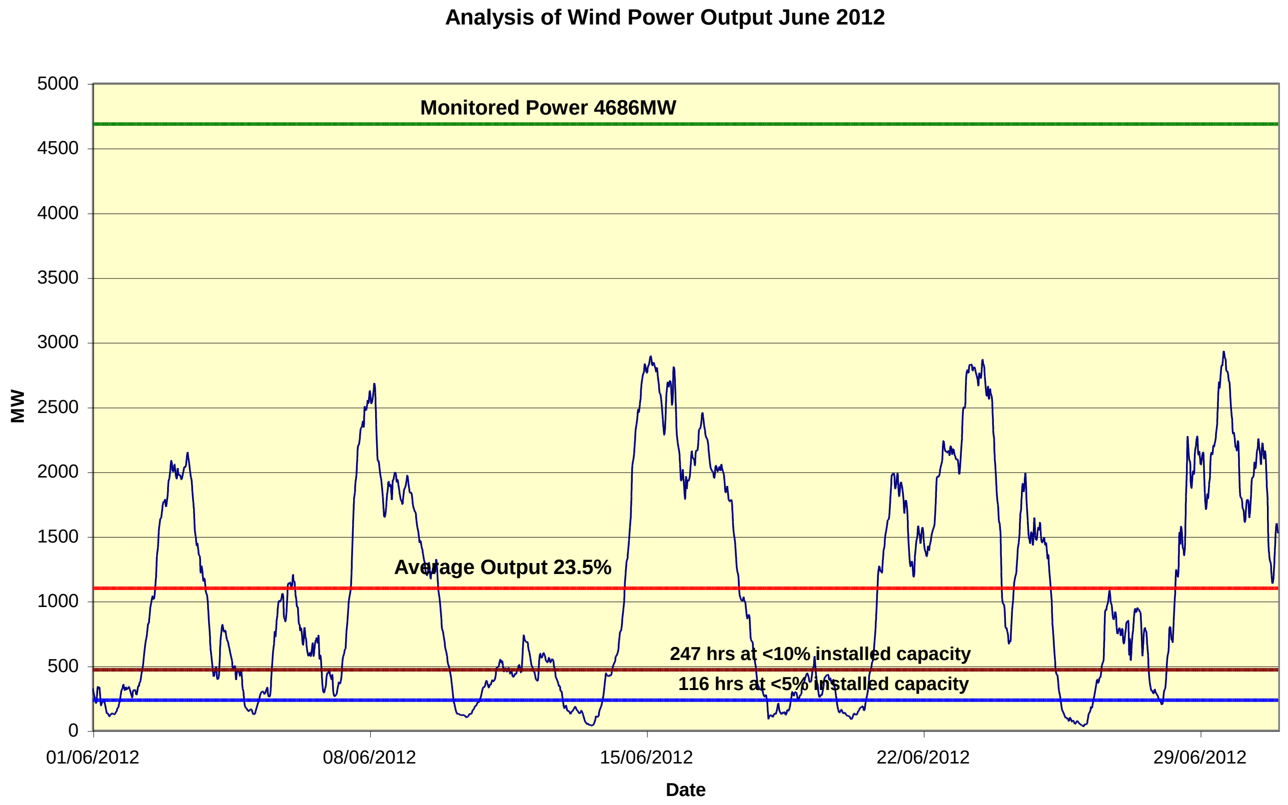
Are periods of low wind across the UK infrequent?

The minimum output figures in the previous section are useful up to a point, but a more detailed analysis of the data for each month tells us more about the frequency of low output or "low wind".

The graph from August 2011 on page 4 showed typical variations to be seen every month. However, in order to see the overall impact of "low wind" it was decided to quantify the total time when the output from all UK wind turbines was less than 5% of installed capacity. For comparison, periods where output was less than 10% were also reviewed.

Analysis of these data shows that not only does the wind blow very intermittently but that there are significant periods when the total output from wind turbines across the whole of the UK drops to less than 5% of their nominal capacity.

Another typical graph, for June 2012, is given below and includes lines showing 5% and 10% of monitored capacity.



This shows that there were 116 hours, or 4.8 days in total, when the output of all the wind turbines in the UK was less than 5% of their installed capacity. The equivalent figure for generation periods less than 10% of installed capacity is an astonishing 247 hours, or 10.3 days - one third of the total period.

The graphs given in the appendix show more data on how often output falls below 5% and 10% of installed capacity, together with average outputs.

The table below gives the total hours per month and per year for which total output fell to less than 5% and less than 10% of installed capacity.

2011	Hours Output <5% installed capacity	Hours Output <10% installed capacity	2012	Hours Output <5% installed capacity	Hours Output <10% installed capacity
January	20.0	118.5	January	35.0	65.0
February	1.0	40.5	February	42.5	69.5
March	77.5	194.5	March	75.0	181.0
April	28.0	150.0	April	36.5	200.5
May	1.0	4.0	May	126.0	243.0
June	31.5	122.0	June	116.5	247.5
July	152.5	341.0	July	76.0	266.5
August	107.0	238.5	August	126.5	238.5
September	22.0	64.0	September	5.0	49.5
October	32.5	62.0	October	54.0	146.5
November	12.5	28.5	November	8.0	41.5
December	0.0	6.5	December	13.5	46.5
Total hours	**485.5**	**1370.0**	**Total hours**	**714.5**	**1795.5**
Total days	**20.2**	**57.1**	**Total days**	**29.8**	**74.8**

It can be seen that there are significant deviations from month to month. In the "worst" month, July 2011, the output from the turbines was less than 5% of their installed capacity for over 152 hours, or 6.3 days. Over the 2-year period there was a total of 1200 hours, or 50 days, when the output was less than 5%. Between 2011 and 2012 there was an increase of almost 50% in the total time when output was less than 5% despite an increase in average installed capacity of over 40%. This clearly illustrates the total dependence of wind generation on the weather, however large the installed capacity is.

For comparison, output was less than 10% of installed capacity for 1,370 hours in 2011 and 1,795.5 hours in 2012, an increase of over 30%.

So the answer to the question "Are periods of low wind across the UK infrequent?" is a definite no. In fact, periods of low wind, as demonstrated by wind turbine output, are significant. Also, more than doubling the generating capacity over the study period actually resulted in an increase in the periods of low output.

Discussion

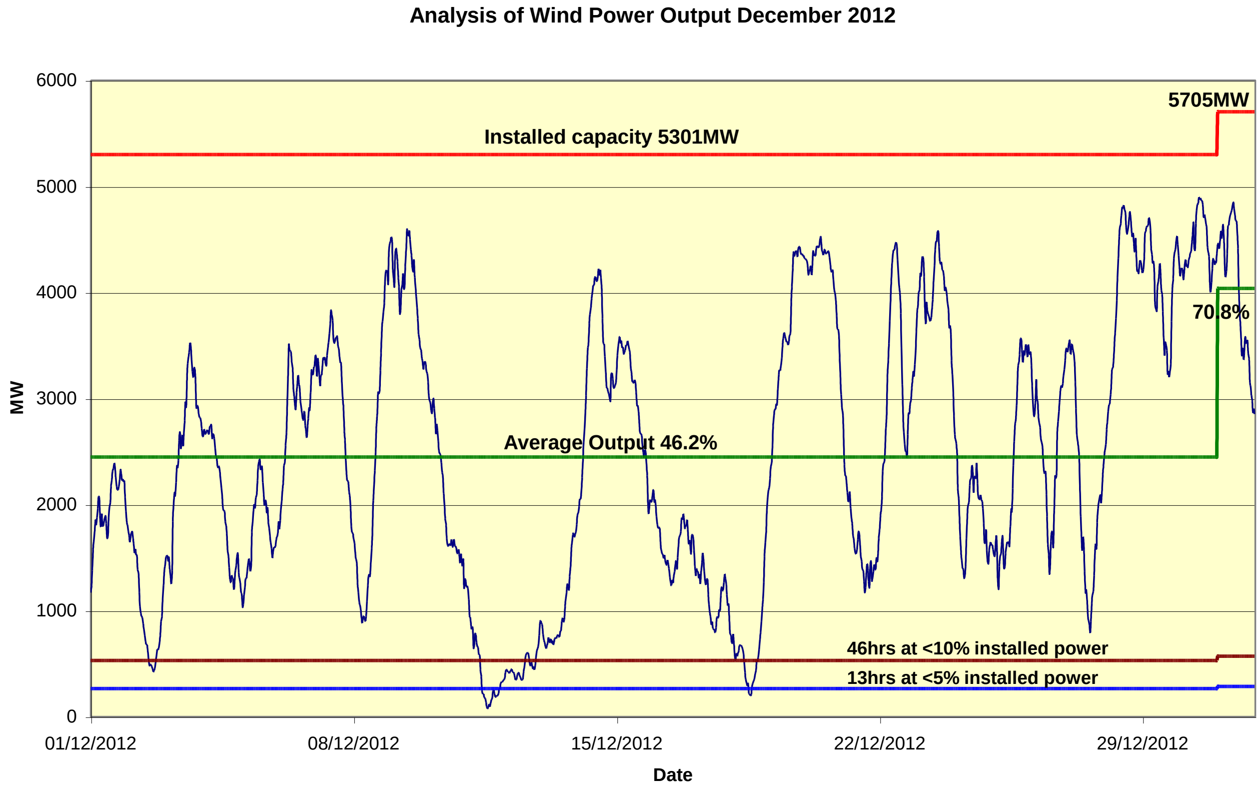
This report does not seek to compare wind turbine output with the power demand in the UK. However, it is well known that this power demand is cyclical and quite predictable on a daily basis. It is clear from the graphs that the output from wind turbines is very intermittent and unpredictable from month to month, day to day and even hour to hour. Full conventional backup capacity is needed however many wind turbines are installed.

The period studied covers only 24 months, but the results mirror what others have found in the analysis of wind turbine output from 2009 and 2010. For example, in the "low wind" year of 2010, UK wind turbines produced less than10% of their rated output for 38.6% of the time and less than 5% of their rated output for 20.8% of the time. The equivalent figures for 2009 were 29% and 15% respectively. So the figures analysed in this report may, on past evidence, be regarded as a best-case scenario unless the UK is to be subjected to a sustained increase in levels of strong winds in future years.

Having concluded earlier that wind turbines can, on average, produce 30% of their installed capacity (in a good year), we still need to ask what is the problem with installing wind turbines in significant numbers to fulfil the UK's commitment to reductions in CO_2 emissions?

The answer to this lies in the intrinsic intermittency of wind turbine operation. Because of this, wind turbines cannot be relied upon to supplant conventional power stations.

Take the most recent set of data analysed, for December 2012, as an example.



This was a month of very high winds, giving the second highest average output of the two years studied. However, there are massive variations from day to day and hour to hour. For example, over a 2-day period spanning 9th to 11th December, wind turbine output fell from a peak of 4,586MW to just 78 MW, a drop of over 4,500MW. This was followed by a rapid rise in output on 13th/14th December from 679MW to 4,224MW in slightly over 24 hours. After a further fall to 199MW on 18th December, output again surged to 4,377MW within 24 hours.

It is said that wind speeds can be predicted, but accurate predictions cannot be made with the intermittent and unpredictable nature of wind, as demonstrated by the turbine output above. This output, remember, is from all wind turbines monitored by the National Grid across the whole of the UK from the north of Scotland to the tip of Cornwall.

Even if accurate prediction of wind conditions was feasible, it will always be necessary to have an equivalent level of conventional generating backup to accommodate the intermittency demonstrated in this paper. This is provided by gas stations (some using the more efficient combined cycle, but to a large extent open cycle turbines which can be rapidly ramped up or down) or coal fired stations which operate with "spinning reserve". Spinning reserve is always required due to fluctuations in demand, but these can largely be predicted as demand is cyclic. However, the level of spinning reserve must be at higher level with the imposition of an erratic and largely unpredictable source of electricity being fed into the grid.

Power stations operating with spinning reserve are not operating at full efficiency as they are burning fuel as normal but are not generating at design capacity. Similarly, the open-cycle gas turbines needed for rapid reaction at times are one of the least efficient types of conventional generation.

Thus the need for conventional back up partly negates any CO_2 savings. As the total wind energy capacity increases, this will become a more and more significant issue. (Although the exact effect has yet to be established, there must clearly be a significant reduction in any carbon savings claimed at least).

As far as the author is aware, no-one within the Government or the wind industry has claimed that it has been possible to close down any conventional power station due to the contribution made by wind turbines in the UK. Hence how can their claims for reductions in CO_2 emissions be justified?

Conclusions

Returning to the statement made by the previous Secretary of State for Energy and Climate Change quoted in the introduction to this report.: "The power will not go out on my watch" is only true if wind turbines are backed up by an equivalent level of conventional, fossil-fuelled power station capacity.

He also said, "without power derived from industrial wind turbines, energy bills would continue to rise". This is factually correct but very misleading. Energy prices may be expected to rise whatever the source of power, but this analysis indicates that they will rise even more with power from wind turbines because of the need to retain conventional power station back-up.

This also means that the statements made on the renewableUK website, "Onshore wind farms reduce CO_2 emissions" and "Powered by Wind - giving CO_2 reductions (pa) of 7,617,234 tonnes" are incorrect if the need for back up generating capacity is taken into account.

It is incumbent upon the Government to ensure that the British consumer is getting value for money from industrial wind turbine installations and that they are not just paying subsidies to developers and operators (through ROCs) whilst getting nothing back in return in terms of CO_2 emission reductions through the supplanting of fossil-fuelled power generation.

The overall conclusion from this report is that wind turbines are not capable of making a meaningful contribution to a secure and affordable electricity supply for the UK. Nor will they be able to do so even if their numbers are increased many fold, because of the intermittency of wind across the whole of the UK.

About the Author

Derek Partington has a degree in Physics. He was formerly a Chartered Engineer and a member of both the Institute of Physics and the Institute of Measurement and Control.
He worked for British Steel for 30 years and Local Government for 10 years, in both cases as a Project Manager and Business Analyst.
He has been undertaking research into wind turbines for over 4 years.

Acknowledgement

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