Wind intermittency : lessons from overseas

IIt is well known that wind power is highly variable in output and that output from a single location cannot be a reliable source of electricity. However, it is, or has been, widely believed that the aggregated generation of a number of dispersed locations will have significantly more manageable properties due to the so-called “smoothing” effect. Simply, it is hoped that the variety of weather conditions across regions will result in a more constant and less sharply variable aggregate output. However, as Paul-Frederik Bach* notes in the following feature, the evidence from overseas is less than convincing.

In other countries with substantial wind power capacities the hourly wind energy output is published by the transmission system operators.

Denmark has published such data since 2000 and in Germany it has been required by statute since 2004. The Danish dataset is telemetrically reported from all generators, while the German data are estimates based on metered values for selected wind power plants.

Such information offers an opportunity to replace assumptions by observations and is highly desirable in the United Kingdom, for planning purposes, not least because its grid is less heavily interconnected than others and so it faces more critical system balancing problems, with both economic and physical aspects.

The spot price study

It was lack of UK market data that motivated the Renewable Energy Foundation (London) in 2008 to ask me to analyze the correlation between wind power and spot prices in the Danish price areas of the Nord Pool spot market for the years 2006 to 2008.

In the initial phases of the work it became obvious that the spot markets in Denmark and Germany were closely synchronised, even though the two countries have different market operators, that in Germany being operated by European Energy Exchange (EEX) in Frankfurt, and the Danish system by Nord Pool Spot in Oslo.

In view of this relationship it was decided to extend the study with wind power data for one of the four German control areas, which was then operated by E.on Netz (now Transpower).

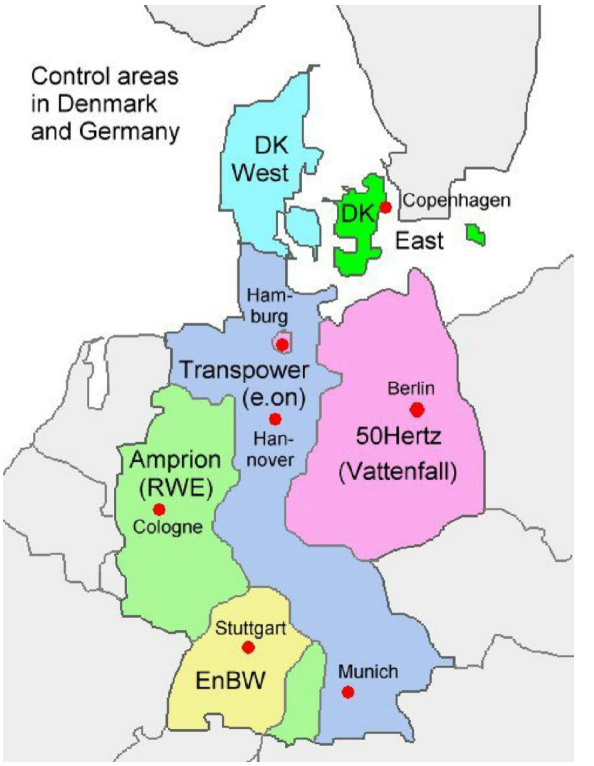
One main conclusion of the report, which was published in May 2008, was that the power markets in Germany and Denmark are so closely related that it is misleading to say that Denmark has successfully integrated 20% wind energy (by MWh) - instead we should say that the these two countries together have absorbed about 7% [1].

Another observation was that even the simultaneous wind power output in the two countries is positively correlated and the variability of the aggregate wind power is high. Crucially, there are frequent periods with very low and indeed very high, wind power output in both countries.

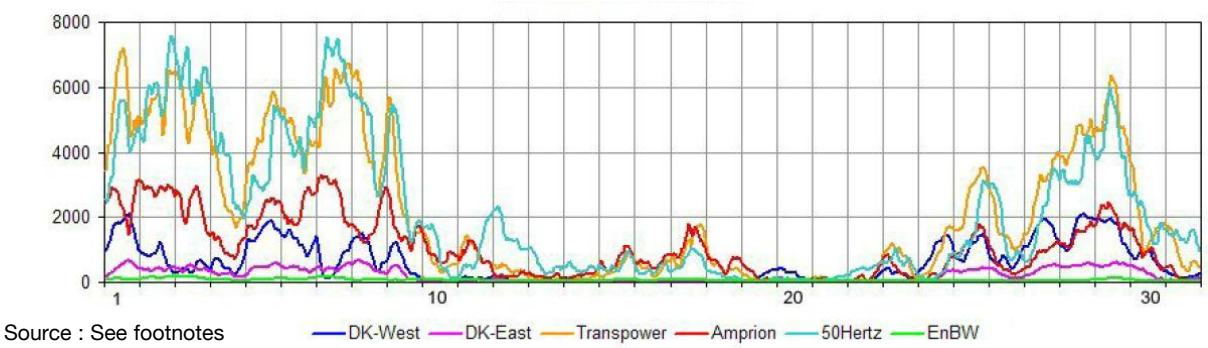
Low Winds in December 2007

The most significant calm period in the three year observation period occurred in December 2007, when wind power generation was low for two consecutive weeks. This combined with a high

Control areas in Denmark and Germany

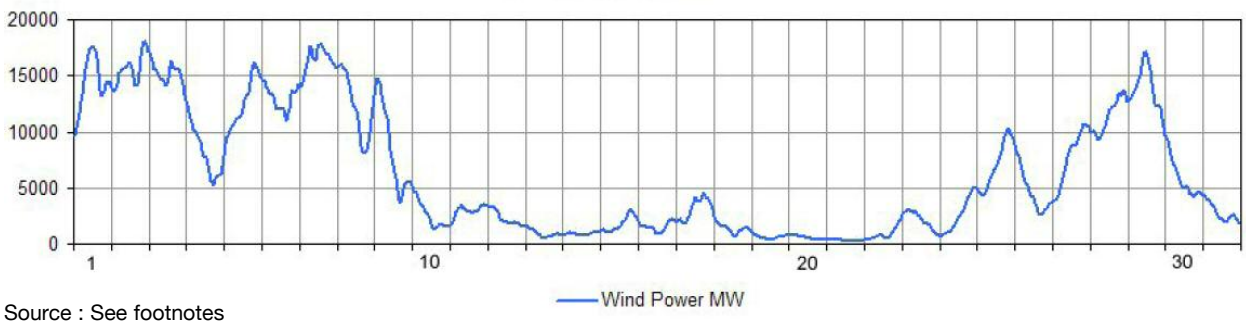


How wind output (MW) varied across regions in Denmark and Germany (Dec 2007)



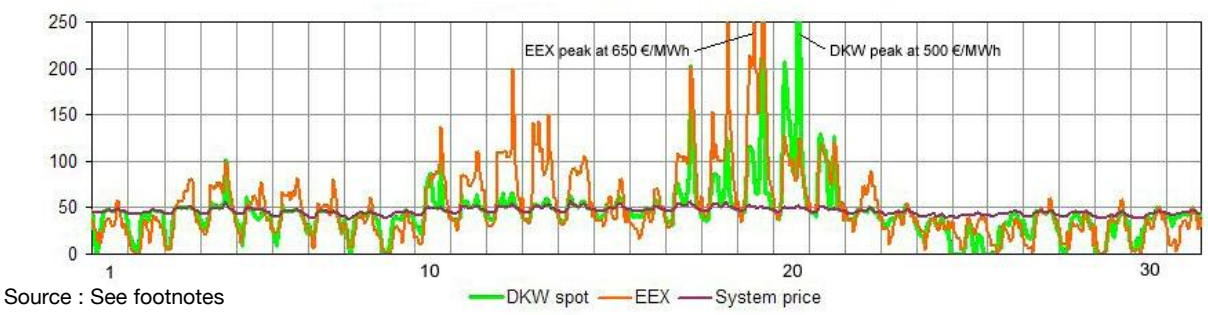
Source : See footnotes

How wind output (MW) varied in aggregate across Denmark and Germany (Dec 2007)



Source : See footnotes

How prices varied (DKW spot, EEX and system) (December 2007)



Source : See footnotes

demand for electricity and caused a power shortage with high spot prices in both Denmark and Germany.

It has been argued by some that the results of my study are irrelevant to the UK because "Britain and its seas are a huge area compared to Western Denmark"[2].

In order to test this argument data for December 2007 were downloaded for the remaining three German control areas, Amprion, EnBW and 50Hertz[3]. The extent of the two Danish and the four German control areas is about 600 km from west to east and 1,150 km from north to south.

The extent to which the conclusions from this extended area can be applied to the UK may depend to some degree on meteorological conditions beyond the scope of this article.

However, it seems reasonable to suppose that the behaviour of wind power in these countries will have some relevance to that anticipated in the United Kingdom.

It is obvious from the observations that the two week calm affected wind power in all 6 control areas.

Aggregating these outputs we can chart the simultaneous wind power generation in Denmark and Germany in December 2007 (*see charts above*).

While it is correct to observe that there is some smoothing, the degree is obviously limited in significance.

During this month the spot markets clearly responded to the wind power variations. Very low prices were recorded during periods with abundant wind power.

Conversely, German spot prices were high during both weeks with low wind power output, and in Denmark high spot prices were also observed, particularly during the second of the two weeks.

It should be noted that congestion on the interconnections between Sweden and Denmark and loss of a large thermal unit were contributing but not predominating factors.

The third chart (*see over*) shows the spot prices in West Denmark (DKW Spot[4] and Germany (EEX), and the system price for Nord Pool, and should be read in relation to the aggregate wind power chart above. Note that the peak prices (€650/MWh and €500/MWh) exceed the displayed vertical axis.

It is remarkable that the Nord Pool system price is much more stable than the spot prices in West Denmark and Germany. One conclusion that can be drawn is that wind power can have a significant effect on the spot markets in Germany and Denmark.

Capacity credit

The total installed wind power capacity in Germany and Denmark in December 2007 is estimated to have been between 23 and 26 GW. The sum of the individual wind power peak productions in the six control areas in December 2007 was 21,042 MW. However, the simultaneous or aggregate production peak was 18,028 MW, or 14% lower than the sum of the peaks in the individual areas.

The recorded minimum simultaneous, aggregate, wind power production was 252 MW, or about 1% of the installed capacity.

It is generally assumed, in Germany at least (UK sources are sometimes more optimistic), that the magnitude of capacity credit for wind power is about 6% of the installed capacity.

Such an assumption is not necessarily in conflict with the observations reported here, since capacity credit is a statistical term. Although the capacity credit of a thermal power plant can be much higher than 6%, the power system must be prepared for operation without this particular unit at any time according to the so called N-1 principle. Thus, the system should be ready for the loss of the largest single generating unit in the portfolio. The basic condition of such a precautionary reasoning is that outages of thermal units are stochastically independent; the failure of one does not indicate an increased likelihood that another will fail.

However, wind power plants do not operate in a stochastically independent manner, because they all depend on a common and related source, the wind.

Consequently, for planning and analytic purposes the entire fleet of wind power plants should be considered as one unit. Therefore while a 6% capacity credit for wind power might be reasonable, nevertheless the power system must be prepared for operation without any contribution from wind power, even in large areas such as Germany and Denmark combined.

Paving the way for additional wind power

Some might consider that the presentation of these observations is just fault-finding. My own view is that, on the contrary, it is only by facing possible problems following a high penetration of wind power that we can hope to inspire the development of solutions for a successful utilisation of renewable energy.

A straightforward solution to the wind power variability problem would be to install thermal reserve capacity for all the wind power, with reference to the N-1 principle. However, while engineerable and available, this approach would be very expensive and inefficient, perhaps unacceptably so.

Alternatively, when an increasing share of the generating capacity cannot be controlled by a dispatcher, new flexible elements, both in generation and demand, could be introduced in order to maintain the necessary balance between the consumption and production of electricity.

The new power system architectures being designed for this purpose, the so-called “smart grids”, are supposed to mobilise flexibility in our energy systems and provide innovative services to all users and better overall efficiency. Various promising options have been identified, and both the EU and several national governments support the development of smart grids. An example is the Ecogrid project in Denmark, on which the present author worked [5].

However, while environmental problems and shrinking supplies of fossil energy call for new energy solutions, the difficulties presented by renewable generators are not trivial.

Doubtless, wind power will make a contribution but it must be supported by other measures, some of which are yet to be conceived or engineered.

Ignoring the fundamental character of this problem would be both irresponsible and counterproductive; no solutions will be forthcoming unless we admit that they must be found.

An ongoing debate

The ready availability of empirical data in Germany and Denmark has allowed this paper to demonstrate and discuss an instance of sustained low wind power output in those countries, and much further data is available to researchers minded to study the wind power properties in greater depth.

While this material is drawn from an area of the same extent as the UK, and has probable relevance to the British case, it is regrettable that the discussion of wind power integration in the United Kingdom cannot be based on empirical observations made in that specific geographical area.

It would be of enormous assistance to researchers, and clearly in the public interest, if the relevant UK authorities were to publish time series data of observed wind energy output, from both the transmission and distribution connected installations.

Footnotes

1 Paul-Frederik Bach, Wind Power and Spot Prices: German & Danish Experience 2006-2008 (Renewable Energy Foundation: London, 2009).

2 Ed Owen, “Wind farm research triggers CO2 row”, New Civil Engineer (10-12 Dec. 2009), 8-9.

3 Danish data was obtained from: http://www.energinet.dk/en/menu/Market/Download+of+Market+Data/Download+of+Market+Data.htm.
German data from the following sources: http://www.transpower.de/pages/tso_en/Transparency/Publications/Network_figures/Actual_and_forecast_wind_energy_feed-in/index.htm; http://www.50hertz-transmission.net/cps/rde/xchg/trm_de/hs.xsl/SetWebsiteLanguage.xml?languagevariantid=ENG&lang=en&targetPage=153.htm; http://www.amprion.de/en/wind-data-according-to-17-stromnzv; http://www.enbw.com/content/de/netznutzer/strom/download_center/eeg/windprognose/index.jsp

4 The spot price in East Denmark is not shown because it was practically the same as the price in West Denmark during December 2007.

5 See: www.ecogrid.dk

About the author

Paul-Frederik Bach has more than 40 years experience in power system planning. He worked with grid and generation planning at ELSAM, the coordinating office for west Danish power stations, until 1997. As Planning Director at Eltra, Transmission System Operator in West Denmark, he was in charge of West Denmark's affiliation to the Nordic spot market for electricity, Nord Pool, in 1999. Until retirement in 2005 his main responsibility was the integra-tion of large amounts of wind power into the power grid in Denmark. He is still active as a consultant with interest in safe and efficient integration of wind power, particularly preven-tion of disturbances by advanced system control measures.

GENERATION

IP reveals Eggborough stake

International Power has revealed that it has exercised an option to take a 10% stake in the 1,962 MW Eggborough coal-fired power station.

The option had been acquired in 2006 and is currently being exercised, the company told *New Power*.

News of the option emerged in the latest set of IP’s results which showed that the company has written down its Eggborough investment by £25 million to reflect current UK dark spreads. In the last year or so power prices have fallen substantially while coal prices have remained reasonably robust so squeezing dark spreads. The exercising of the option will be completed by the end of March.