Why wind power works in Denmark

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[editor's note, by Super G] The following is a guest post from Cry Wolf.

This post is based on an excellent report titled "Why Wind Power Works in Denmark" by Hugh Sharman, which can be found here.

The main problem with most oceanic and climatic forms of renewable energy—wind, tidal, wave and ocean currents—is that electricity generation is sporadic and may not be linked to the times that power is needed. Hydroelectric power alone provides a means of storing this oceanic/climatic renewable energy for use when it is most needed making Hydro an invaluable source of electricity.

The current absence of a means of storing wind energy leaves electricity grids at the mercy of the weather and critics have long since pointed out that wind energy cannot provide a grid base-load. Furthermore, it cannot be relied upon to provide peak electricity production. So what is the point in having wind energy? It has seemed to me that wind's primary purpose has been to provide politicians with a feel good factor and grounds for claiming green credentials.

Sharman reports wind energy production data for Denmark for the whole of 2003 and shows how shockingly unreliable wind energy production is. But he also shows how the Danes and their Scandinavian neighbours have made wind energy work productively by balancing Danish wind energy output against Norwegian and Swedish Hydro generation and here in lies the main message of this post. But first, a summary of the findings.

Denmark

Denmark lies on the eastern margin of the North Sea where it is quite windy. The population is around 5.5 million and the country produces the highest per capita amount of wind energy in the World. There is 0.88kW installed wind capacity per capita in Denmark compared with 0.18 kW per capita in Germany and 0.01 kW per capita in the UK. Wind supplies 16% of Denmark's electricity.

The Danish wind carpet

Denmark has 5500 wind turbines including two large off-shore wind farms. A total capacity of 2374 MW was installed by the end of 2003. The Danish grid is split in two (there are some large islands) and Sharman's report deals only with the west Danish grid, representing 80% of the total. Crucially, the west Danish grid was already connected to Norwegian, Swedish and German grids before the wind carpet was built.

A fine day at Horns Rev, the World's largest offshore wind farm

Load factor

The load factor of the Danish wind carpet is only 20%. In other words, for every 5 MW of installed capacity the wind carpet on average produced 1 MW during 2003. Information on the cost of installing wind power is given here.

On average 1kW of installed wind power costs $1000. Therefore, to get 1 MW return, 5 MW costing $5million needs to be installed.

Highly variable output

There were 9 occasions in 2003 when the wind carpet produced at > 2000 MW (>85% of installed capacity) but these periods of high output were short lived (Sharman, Figure 8). The output suffers from extreme high amplitude high frequency variance - in other words it is very spiky. "Sometimes the Danish wind carpet produces maximum output when there is little demand. On other occasions it delivers no energy when demand is high". On one day during 2003, the wind carpet actually consumed more energy than it produced.

I find the high variance in output surprising as I'd always assumed that wind in one location would compensate for no wind at another and this should result in some smoothing of output. In Denmark it seems that the wind blows everywhere at once and this may be due to the flat topography and relatively small area. In larger, topographically more variable countries it might be expected that greater smoothing of output will occur.

How the Danish grid is balanced

The west Danish grid is connected to the Norwegian, Swedish and German grids. The inter connectors were built as export lines of Norwegian and Swedish hydroelectric power to Germany but have found a new use in helping to balance the highly variable wind output from Denmark.

Figure 13 (Sharman) shows the hourly output from the Danish wind carpet in December compared with energy exchange over the interconnectors. This shows quite amazingly that essentially all Danish wind power is exported to Norway and Sweden. These countries dynamically balance the interconnected grid using their extensive hydroelectric generating capacity that can be adjusted rapidly to compensate for the highly variable input from Danish wind. In essence, water is conserved in Norway and Sweden when the wind blows in Denmark. This conserved water can be used to produce power when it is needed. This to my mind is a brilliant scheme that essentially provides a means of storing wind power through conserving hydro power.

Energy sinks

Sharman also points out that some of the variance in Danish wind energy output gets sunk into the massive German grid that lies to the South. The variance in the Danish wind supply is only a problem for Denmark because wind energy represents a significant proportion of the total grid supply—16%. Any country wanting to rival the Danish wind model will have to either develop a grid balancing system or develop energy sinks within the grid or both.

A few weeks back some TOD engineers were throwing around ideas about using the batteries of electric cars as sinks for wind energy. This sounded a great idea. Would it also be possible to develop water-heating systems in public buildings to store heat when the wind blows? Would it be possible to use wind energy to actually pump water back into hydro dams using existing pump storage schemes?

Conclusion

Denmark has no indigenous hydroelectric power but has managed to negotiate a power balancing agreement with Scandinavian cousins to make their wind carpet work. Larger countries such as the US and the UK that have extensive hydroelectric capacity must surely manage to engineer a power balancing act between their wind and hydro generators.

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