LESSONS FROM THE DENA GRID STUDY

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Although the 'dena grid study' does not aim to address the question whether introducing wind power into an electrical system saves fossil fuels, it nevertheless provides clues. These confirm the indications from South Australia and Denmark that there is a limit — at about 13% of electrical supply — at which it becomes difficult to increase the wind infeed. The shortened English version of the dena grid study, that we look at here, does not attempt to assess the *energy cost* of introducing wind power into the electrical system to cover 13% of total supply. But what the present paper points out is that the energy cost is determined by the need to provide 29% of total supply from the DIB (dominant in-harness backup), to counterbalance the variable 13% from wind. As long as the loss of efficiency occasioned by running the DIB remains in doubt, so long will it remain an open question whether introducing wind into an electrical system saves fossil fuels.

This paper draws material from the shortened English version of the German Energy Agency (dena) grid study, published in 2005, which is available on the web at:
http://www.ewea.org/documents/Dena%20Grid%20Study_Summary_2005-03-16_denapdf [494 kB]
The present paper attempts to extract, from the dena grid study, lessons relating to the potential of wind power to reduce the use of fossil fuels. However, that was not the purpose of the dena grid study. Its purpose is enshrined in the full title of the report, *Planning of the Grid Integration of Wind Energy in Germany On-shore and Offshore up to the Year 2020*.

Because the dena grid study is focused on deciding whether it is technically possible to integrate wind power into the grid, so as to provide 13% of Germany's electricity, it hardly touches on the more fundamental question, namely whether there is any advantage in attempting to integrate wind power into the grid. Despite that, it gives some incidental clues. Combining them with information from other sources — mainly the E.ON Netz *Wind Report 2004*,[1] the report from South Australia, and data from Denmark — useful indications emerge. We start with some extracts from the dena grid study. My comments are interjected, in square brackets.

Annotated quotations (numbers are page numbers)

4. "The technical characteristics of the conventional power plants have to be adapted to the fluctuating feed-in from wind power, which has to be accepted with priority."
5. "The German Energy Agency (dena) has commissioned the study 'Planning of the Grid Integration of Wind Energy in Germany On-shore and Offshore up to the Year 2020' (dena grid study)." [But see next two items: this Part I goes only up to 2015.]
6. "During the preparation of the study it became clear that within the given framework conditions of the study it would only be possible to draft technical solutions for the integration of renewable energy sources into the existing power system up to a share of approx. 20% in electric power generation (5% off-shore wind, 7.5% on-shore wind, 7.5% other renewable resources). A further major increase in geographically concentrated off-shore wind farms in northern Germany, as is planned after 2015, would require a more extensive investigation to develop viable technical solutions." [i.e. the viability is still uncertain.]

6. "The present report on Part I covers the time period up to 2015, with a share of renewable energy sources in power generation of 20%, while the planned Part II of the dena grid study will examine the time period up to 2020.

8. "The average full-load-hour figure for wind turbines is calculated to be

   1650 h/a in 2007 [= 1650 / 8760 = 19% load factor.] rising to

   1960 h/a in 2010 [= 1960 / 8760 = 22% load factor.] and to

   2150 h/a in 2015 [= 2150 / 8760 = 25% load factor.]. The reason for the increase by about 30% is increase in replacement of old by more efficient wind turbines, and the use of productive sites in the North and Baltic seas." [In view of a current 16% infeed factor in the E.ON Netz area and in Germany as a whole, and in view of Denmark having mainly modern wind turbines and achieving only 17.5% infeed factor, the above figures — if we take them to be infeed factors which they need to be to be relevant — look somewhat optimistic for Germany[2]]

8. "With the on-shore and off-shore extension of wind power under the EEG, [EEG = Renewable Energy Act.] the average energy production is projected to rise from 23.5 TWh in 2003 to 77.2 TWh in 2015, some 42% of that would come from off-shore wind farms." [77.2 TWh/yr = 8.8 GW, which is about 8.8 / 66 =13% of present electricity supply, which ties up well enough with the statement above of aiming to achieve, "5% off-shore wind, 7.5% on-shore wind" by 2015]

Being economical with the truth about wind power

The power density of wind farms is good in comparison to biomass. That is true on both metrics which may be applied. The power density of wind is about 1 W_e/m^2 (10 kW_e/ha) based on the 'protected' space needed around the wind turbines, and in the region of 30 W_e/m^2 based on the land 'monopolized'. These compare to 0.5 W/m^2 for biomass. The problem with wind power is variability (also termed 'intermittency'). The substantial problem introduced by wind is the need to compensate for variability. Thus it is being 'economical with the truth' to describe what wind power can *provide* without also describing what the use of wind power *entails*, namely dealing with that variability.

Where the study is weak (although admittedly it appears to be outside its terms of reference) is that it fails to estimate what the *peak* infeed factor is likely to be. Without knowing that, it is impossible to determine how much of the 'block' of electricity covered by wind will be provided by wind, and how much by the DIB (dominant in-harness backup) which has to compensate for the variability of wind.[3] We can make good that omission, as we have a *peak* infeed figure, 80%, from E.ON Netz area (extending over 800 km), and can use that datum to make the calculation. Taking the optimistic 25% load factor that the dena grid study assumes for 2015 (also presuming it to be an infeed factor) that means that 25 / 80 = 31% of the 'block' would be provided by wind, with the remaining 69% by the DIB. The study fails to assess this, and only states loosely that, "The technical characteristics of the conventional power plants have to be adapted to the fluctuating feed-in from wind power." *How much extra fossil fuel will be used thereby is not addressed*.

The study does look at the need for keeping spinning reserve, and concludes with this somewhat opaque conclusion: "The wind-related regulation and reserve capacities can be covered by conventional power station park and its operating method as developed in this study. No additional power stations need to be installed or operated for this purpose." It would appear to be saying that the available plant is sufficient to provide spinning reserve, but it does not attempt to assess the energy cost of this or, *what is almost certainly a more important factor*, the energy cost that results from the aforementioned need to make use of plant of a type which can "be adapted to the fluctuating feed-in from wind power." Note that the loss to be incurred could be an ‘opportunity’ loss rather than a ‘direct’ loss: that is to say the opportunity to install the most efficient plant would be lost because of the need to use plant that could adapt to the fluctuating feed-in from wind power. The effect is dramatic with gas-fired plant because CCGT plant can run at 60% efficiency when allowed to operate unmolested by wind infeed. The exact situation, with regard to the degradation of efficiency of otherwise highly efficient coal-fired plant, e.g. second generation pressurized fluidized bed combustion (PFBC) plant, remains uncertain.

In summary, this 24 page English ‘shortened version’ of the dena grid study sticks closely to its brief; that is to determine whether it will be technically possible to incorporate sufficient wind power to cover 13% of total electrical supply; it does not ask the question whether this will save a significant amount of fossil fuel, or indeed if it will save *any* fossil fuel, *after making proper allowance for the need to operate the DIB*. While no reference to that question appears in this ‘shortened version’, if the long version has been reported correctly, then it would appear that there has been some recognition that the use of more efficient fossil fuel plant may save more fossil fuel than introducing wind turbines. We must not lose sight of the fact that were the wind able to supply 13% of total supply, that would entail the DIB supplying (13 / 0.31) x 0.69 = 29% of total electrical supply. It is obvious that one cannot know whether fossil fuel is being saved without knowing how seriously efficiency is impaired in the process of supplying that 29% of total supply *from plant that is capable of continuously varying its output*. “Impaired” refers to the extra fuel needed in comparison to the fuel used when plant could operate unmolested by wind.

It cannot be stressed strongly enough that failure to deal with this aspect of wind power is the great hole in the thinking of those who have otherwise expended a great deal of time and paper on analysing wind power. The existence of the hole is especially surprising when it is considered that, taking this case as an example, the DIB has to ‘cover’ 13 / 0.31 = 42% of electrical supply, and it has to do so varying its output fairly continuously. For a substantial part of the time, the DIB will be producing at a high proportion of its capacity: E.ON Netz, in *Wind Report 2004*, stated that for over half the year, i.e. 4380 hours, wind infeed was less that 11% of capacity, that is 11 / 80 = 14% of *peak* infeed. At other times, the wind infeed will be close to *peak* infeed, making the DIB largely idle. It is usually recognized that failure to forecast the wind accurately is a problem. Where there is a lacuna in thinking is in not recognizing the problem that remains even with perfect forecasting, namely having to use plant which is, to use the dena grid report’s anodyne phrase, “adapted to the fluctuating feed-in from wind power”

Comparison with South Australia and Denmark

South Australia has just released an extensive report into its problems with winds. A back-of-the-envelope calculation indicates that they are having to call a halt to wind expansion with wind supplying 12% of electricity. They only surmise that with improvements to the interconnectors they *might* increase that.

Denmark is in a rather special situation for two reasons, (a) it has such good interconnectors to Norway and Sweden that they could carry the greater part of its total electrical supply; and those nations have ample hydro storage which can be shut off to allow priority to wind power; (b) it has made extensive use of Combined Heat and Power (CHP), which is effectively another intermittent electrical source, and thus diminishes the scope to use wind power.

Despite these confusing (and conflicting) factors, there is perhaps some loose indication of limits, in that when Denmark increased its ability to feed wind power electricity into the grid to about 21% of its total electricity supply, it had to export about 40% of that. In other words, it could only directly use 21 x 0.60 = 13%. There thus appears some tenuous evidence that 13% may be pushing the limit with systems which are primarily being powered by coal. Incidentally, the upper limit in a gas-fired system, with no nuclear or CHP to interfere, is approximately 20%.

What remains unresolved is whether introducing 13% into a primarily coal-fired system increases or decreases the use of fossil fuel. With primarily gas-fired systems it appears highly probable that introducing wind power *increases* the use of fossil fuels, but whether that applies to primarily coal-fired systems is unresolved.

Endnotes

1 I have had several reports of difficulties in getting the English version of *Wind Report 2004* off the E.ON Netz website, and found them myself This address does work (and the file can be saved): http://www.members.aol.com/optjournal4/eon04pdf.pdf

2 There is normally considerable ambiguity about the terms capacity factor and load factor. These are the meanings I use (introducing the further term 'infeed factor'):

Definitions

Infeed factor. (IF) is the amount of electricity that is measured by a transmission system operator as having been fed into the grid, by one or more wind turbines, divided by the amount of electricity that would be produced were those turbines to operate continuously at their rated capacity. N.B. the wind turbines must be only feeding the grid, with output not being partly used in an adjacent building.

Capacity factor (CF) is a figure which is usually about 30% higher than the infeed factor, and it is the amount of electricity that is reported by wind associations, or by *Windstats*, as having been produced, by one or more wind turbines, divided by the amount of electricity that would be produced were those turbines to operate continuously at their rated capacity.[a]

Load factor (LF) is intentionally ambiguous, allowing the reader to infer from the context if the reference is to 'capacity factor' or 'infeed factor'. 'Load factor' is useful when quoting figures from a source which has failed to be precise about meaning.

Notes

a The extent to which the CF exceeds the IF has been established, with fair certainty, with data from Germany (IF 16%, CF 21%), Denmark (IF 17.5%, CF 23%) and the UK (IF 24%, CF 29%). Uncertainty still dogs the load factors emanating from the USA for which Howard Hayden (*The Solar Fraud*) reported load factors of 23.5% in 1998 and 30% in 2002 A possible explanation is that the first is an infeed factor and the second a capacity factor, but clarification is awaited.

3 Note that the DIB (dominant in-harness backup) is a concept rather than a defined group of generating plant That is because, although it would be possible to allocate a specified amount of plant to even out the variable input of wind, there is no need to operate that way. More likely, the task of the DIB will be spread across all the remaining plant. That is the essential reason that it is so hard to establish the loss of efficiency incurred by having to operate the DIB (even when the situation is essentially simple, with wind infeed being chaotic, and hence no use for demand following).