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How much super grids could decrease wind power variability?

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INTRODUCTION – Super grids spreading over a whole continent have been discussed lately in Europe and in the US. Super grids could help to decrease the variability in the wind power production through the low correlation of wind power production over long distances. However, before constructing such grids, it is prudent to ask which is more economic: build large transmission networks or to deal with the variability within more regional power systems. The work outlined here presents some results in terms of the achievable reduction in wind power variability when going from local to continental scale wind power production.

SITING MODEL – In order to make a rough assessment, a simple model was created to site wind power across the continent according to the selected parameters (Table I). North America was divided into grid squares according to the division in the GEOS-5 re-analysis data. Annual electricity consumption was estimated for each grid square according to the consumption in each US state (consumption in Canada or Mexico was not considered). Then it was required that each grid square has to cover 50% of annual demand with wind power – either produced locally or transmitted through the power lines that had to build, if the model wanted to transmit the power from distant wind farms. Each grid square had a resource-cost curve for wind power based on processed GEOS-5 data. This meant that the more wind power was built in a grid square the more expensive it got.

Assumption/*Result*	Unit	Scenario			
		NoCost	Base	Trans+50	Spatial
Wind power annuity	$/kW	171	171	171	171
Transmission cost	$/kWh/km	0	8	12	8
Substation cost	$/MWh	0	3.4	5.1	3.4
Transmission loss	%/1000km	3 %	3 %	3 %	3 %
Site availability	% of area	100 %	50 %	50 %	12.5 %
Capacity	GW	532.1	581.3	611.9	670.6
Transmission losses	TWh	82.9	36.7	28.2	37.2
Average cost for wind+transmission	$/MWh	51.6	68.2	72.3	88.4

Table I. Assumptions and results for the siting model scenarios.

SCENARIO RESULTS – Figure 1 shows how the different scenarios distributed wind power production over the continent. The 'NoTrans' scenario without transmission costs shows where the best wind sites are in the data set. In the other end of the spectrum 'Spatial' shows how the model sited wind power, when it was forced towards more distributed siting.

Figure 2 shows wind power production duration curves for the 'Base' and the 'Spatial' scenarios. For comparison, a duration curve for a regional wind power production is also shown – in this case that of New England created with the same methodology.

Figures 3 and 4 combine hourly load time series with hourly wind power production time series to show how the net load (load less wind) duration curve is changed under different circumstances.

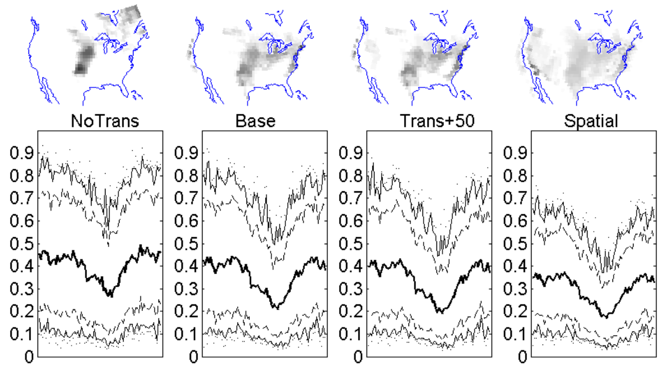

Fig 1. Different scenarios for wind power siting (maps of wind capacities). Variability is shown in the figures. The dots present the maximum and minimum found in the set, the thin solid lines are 0.5% and 99.5% quartiles, dashed lines are 5% and 95% quartiles, and the thick solid line is the mean. X-axis runs from the beginning of the year to the end. 'NoTrans' has no transmission cost and no land use restrictions, 'Base' is the base scenario, 'Trans+50' has 50% higher transmission cost, and 'Spatial' has restricted transmission across the mountains and less sites per grid square.

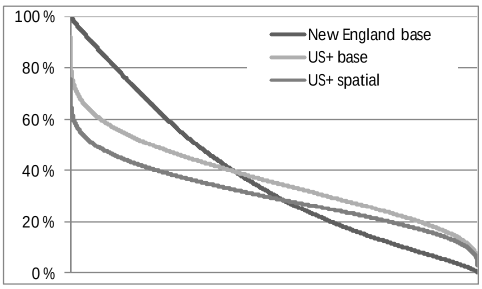

Fig. 2. Wind power production duration curves (six-hourly data from 1980-2001) for different scenarios.

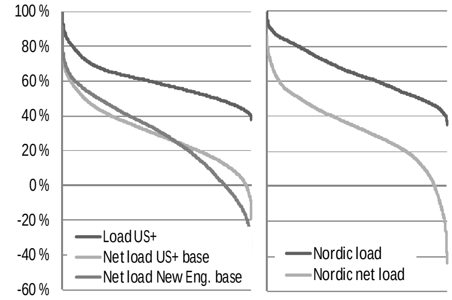

Fig. 3 & 4. Duration curves for load and residual load. Left figure is for US in 2000-2001 based on the article wind data. US load data is combined from hourly data from SPP, PJM, NE ISO, CAISO (Sep. 2000 - Dec. 2001), and ERCOT (2000 only). Right figure is for Nordic countries without Iceland in 2001 with both data based on real measurements.

CONCLUSIONS – The duration curves in the results section show that the difference in variability between continental and regional wind resource is significant, but large portion of variability will still remain in the continental power grid.

The results of a wind power siting model point out that there is likely to be a good reason to try to build super grids. The reduced cost of power from better wind resources seems to be a good enough reason at its own and the smoothing effect only makes it better. However, one rather large caveat is that the data does not properly include complex terrain wind sites and therefore many sites that have a good wind resource are missed. While these sites do not present nearly as large resource as the flat plains do, they may still be large in comparison with the consumption of electricity in those regions.

The results show that there will always be some wind power production in continental scale. This production can sometimes be rather small, in the order of 5-10% of the installed capacity. However, the data does not include local wind phenomena, which can be uncorrelated with larger weather patterns and therefore this conclusion might prove to be wrong with better wind data.

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