WEPROG

Weather & wind Energy PROGnosis

Using Ensembles for Large-scale Forecasting of Wind Power in a European SuperGrid context

Corinna Möhrlen and Jess U. Jørgensen

DEWEK 2010
Session 10/P4

Including physical Uncertainty from Ensembles

A Large Scale Wind Integration Study Using an artificial SuperGrid in the Western and Central part of Europe

Questions to be answered:

- How does the frequency distribution of the generation look ?
- How well does wind power fit the large scale demand ?
- Which countries fit best together in a SuperGrid?
- What happens with respect to day-ahead predictability ?
- What happens with respect to reserve requirements ?
- How do we use fully loaded interconnectors for balancing ?
- Will a SuperGrid only be feasible with Offshore Wind ?

Some Pros & Cons of a SuperGrid

- A larger market has some benefits, e.g. more competiton
- Forecast errors and hence reserve requirements reduce
- Less fossil fuel plant will be required

- More coherent prices in a large area for consumers and generators

- Need of additional interconnectors and grid infrastructure
- Need of a Super-TSO, existing TSOs may have to give up some tasks
- A large grid is more complex to model

Simulation of SuperGrid: Model Approach & Assumptions

Model Setup

Capacity is accumulated in MSEPS model grid points

- 13 countries
- approximately 1400 grid points from 2260 registered wind farms and ca. 26000 wind turbines in Denmark and Germany
- power curves generated from public data in Germany, Denmark and Ireland

A consistent handling of all wind power is required:

- Use the same model estimate for verification in all countries (no measurements, will create slightly worse result for countries where measurements are available)
- Use 00UTC and 06UTC forecasts for day-ahead horizon

Model Assumptions

- transmission capacity limits are ignore in this study
- existing shares/pools of wind power by different parties are ignored
- Capacity distribution from July 2010 kept constant over entire simulation period 2008/07-2010/07

Assumptions for Practical Integration of Approach:

- Centralized balancing of Wind Power in pools shared in slices
- Fixed percentages of total generation given to each forecast provider
- A meta forecast is made based on all forecasters reports to the central unit

Selection Criteria of Countries in the SuperGrid

Driving forces in the weather should be similar (lows from Atlantic or north pole)

Correlation with other country's generation (best range 0.40-0.95)

Correlation > 0.4 good for cross country balancing (<0.4 good for sale)

Low competition on reserve (need of new means for balancing)

Uniform distribution of capacity (especially extending to country borders)

Future interconnection plans (ambitious plans considered good)

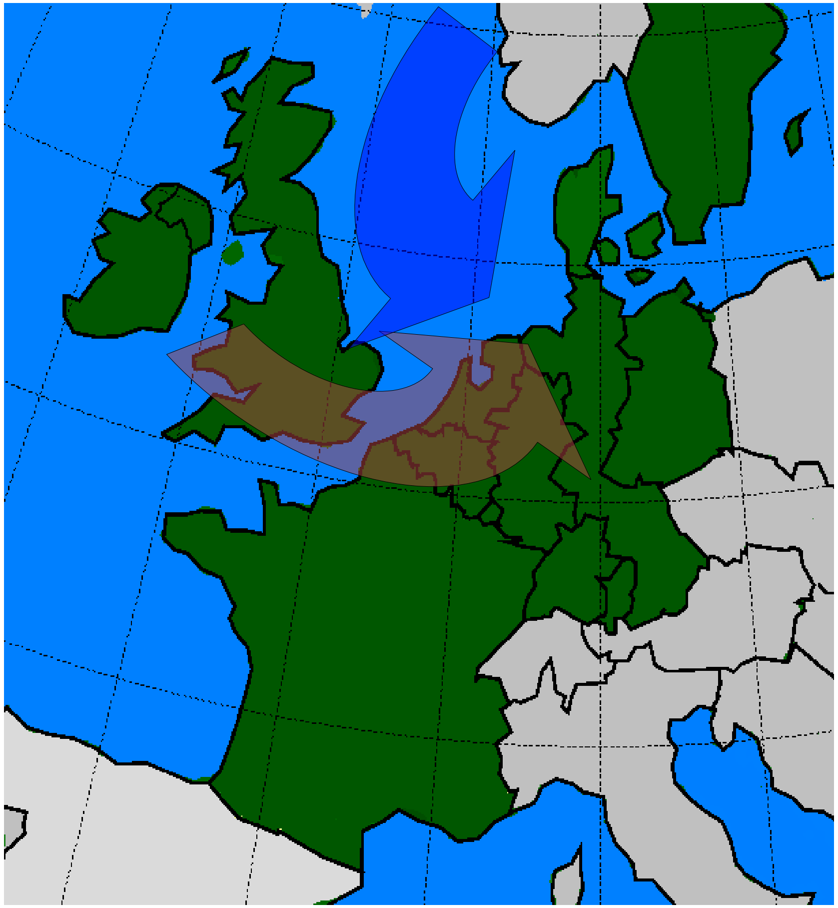
Wind generation potential (a high potential is likely to be developed)

Offshore Wind generation plans (offshore power and grid expansion)

Current level of publication (required for verification of the approach)

Selection: 8 countries = BE, DE ,DK, FR,IE, NL, SE, UK = 44C

Country Selection



The **selected countries** are marked as green area, and:

- mostly **experience the same kind of weather** and have many common borders and the potential for more interconnections.

- **offshore expansion** in North Sea and Baltic Sea **will further connect the countries** to each other.

- Southern France and the north of Sweden are somewhat detached, but still included.

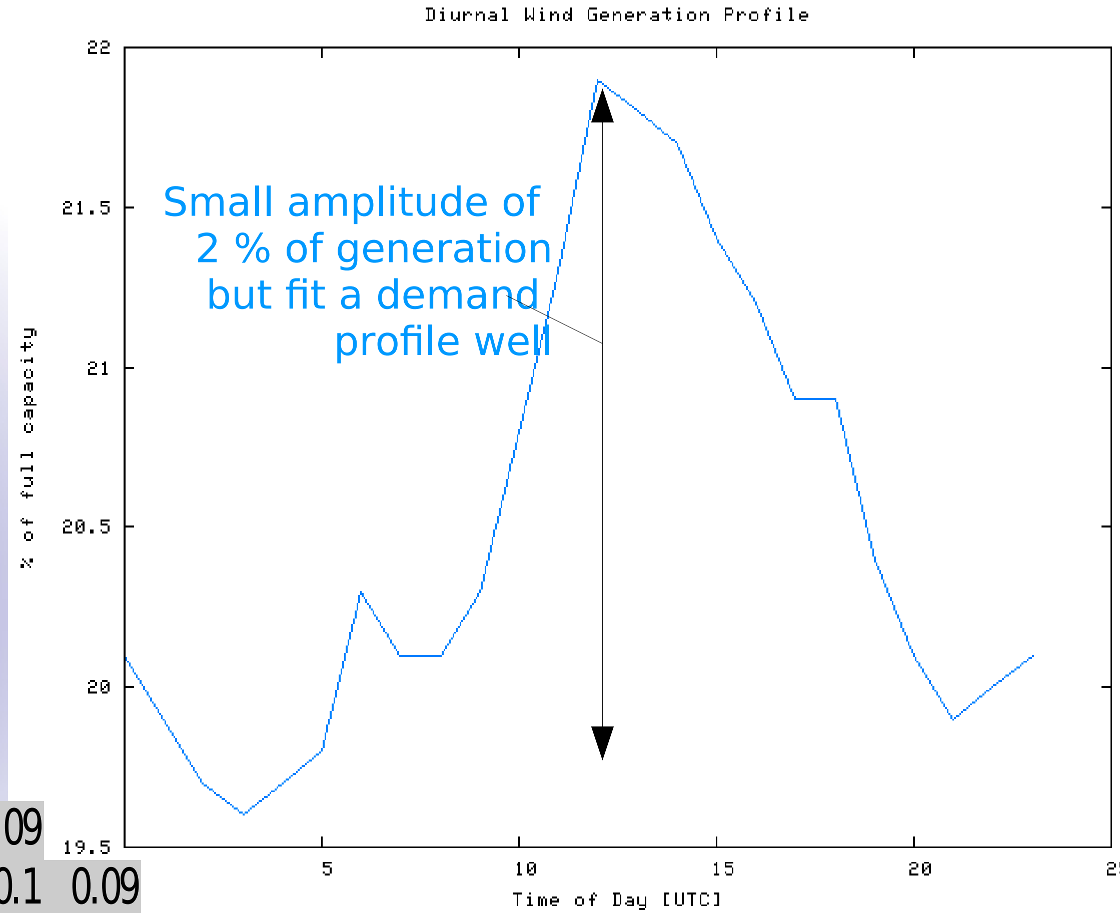
- Spain and France have very little capacity near the common boarder
- Italy has nearly all capacity far south
- The capacity in Norway and Finland is far north
- Austrian generation is concentrated near Hungary

==> Little possibility to exchange imbalance for these countries

WEPROG – Weather & wind Energy PROGnoses

Correlation of Generation & Diurnal Generation Profile

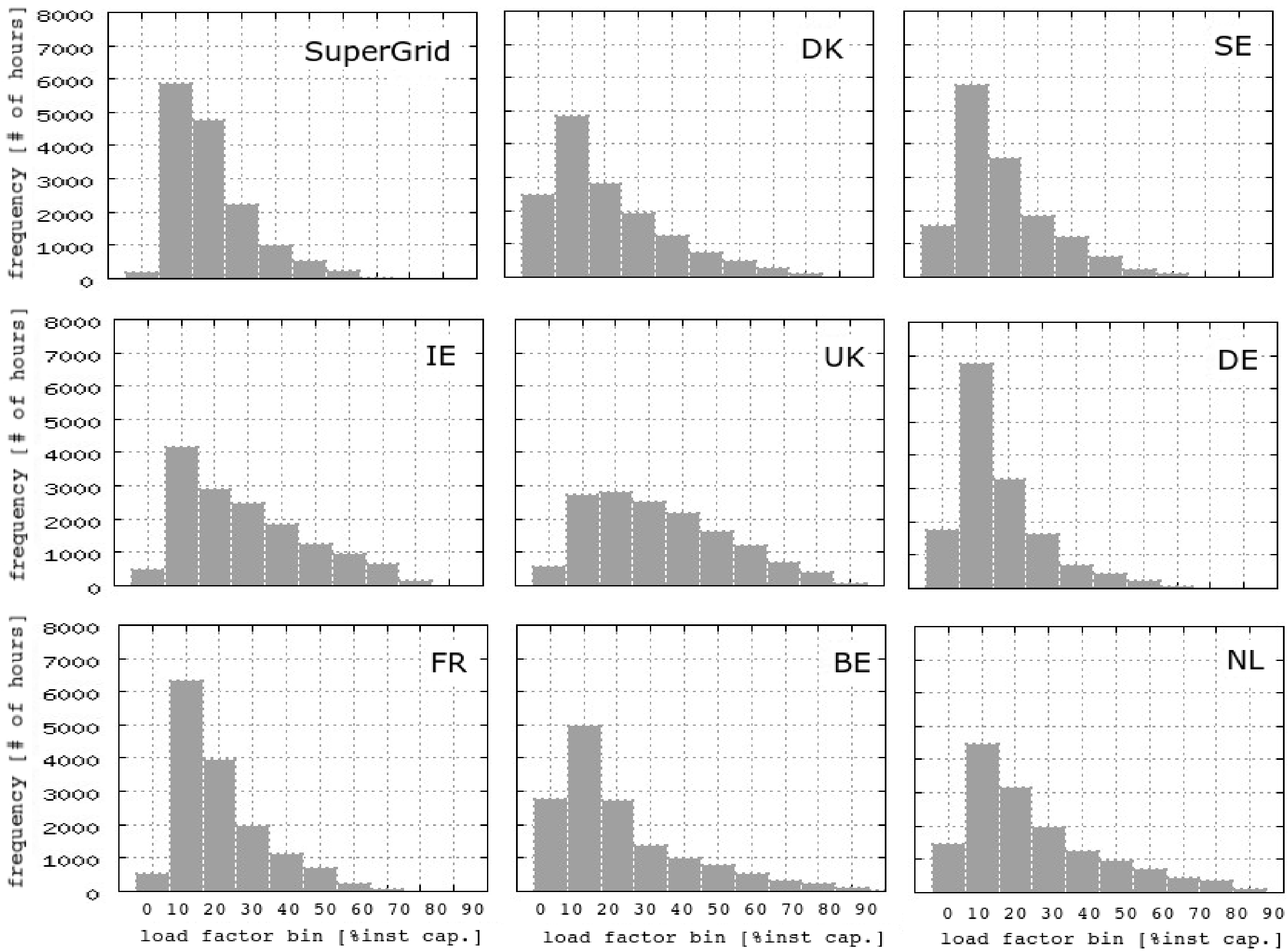
	All 13	SG	ie	de	dk	at	be	es	fi	fr	it	nl	no	se
SG	0.94													
ie	0.29	0.32												
de	0.88	0.95	0.17											
dk	0.67	0.74	0.21	0.68										
at	0.23	0.14	0	0.2	0.03									
be	0.72	0.77	0.28	0.63	0.34	0.04								
es	0.45	0.13	0.04	0.1	0.06	0.19	0.09							
fi	0.21	0.19	0.09	0.14	0.21	0.02	0.1	0.09						
fr	0.61	0.58	0.2	0.45	0.16	0.1	0.82	0.24	0.12					
it	0.24	0.02	-0.06	0.01	-0.07	0.39	0.05	0.39	0.04	0.21				
nl	0.79	0.86	0.29	0.74	0.51	0.03	0.86	0.06	0.13	0.6	0.01			
no	0.22	0.17	0.15	0.09	0.2	0.04	0.08	0.13	0.46	0.14	0.12	0.11		
se	0.51	0.52	0.17	0.45	0.68	0.06	0.25	0.12	0.56	0.17	0.02	0.34	0.47	
uk	0.66	0.72	0.42	0.49	0.53	-0.04	0.59	0.08	0.14	0.4	-0.03	0.74	0.17	0.34



Gray rows hardly help the green rows on balancing winc

Frequency distribution of the Generation

WEPROG – Weather & wind Energy PROGnoses



Very few hours with more than 50% concurrent generation and few hours with no generation

Evaluation of the Simulation

Simulation period

- July 2008 – June 2010

Target parameters

- Day ahead Error (traditional single forecast)
- Day ahead Uncertainty (EPS_{max} - EPS_{min})
- Forecast of day-ahead Error

Aggregation

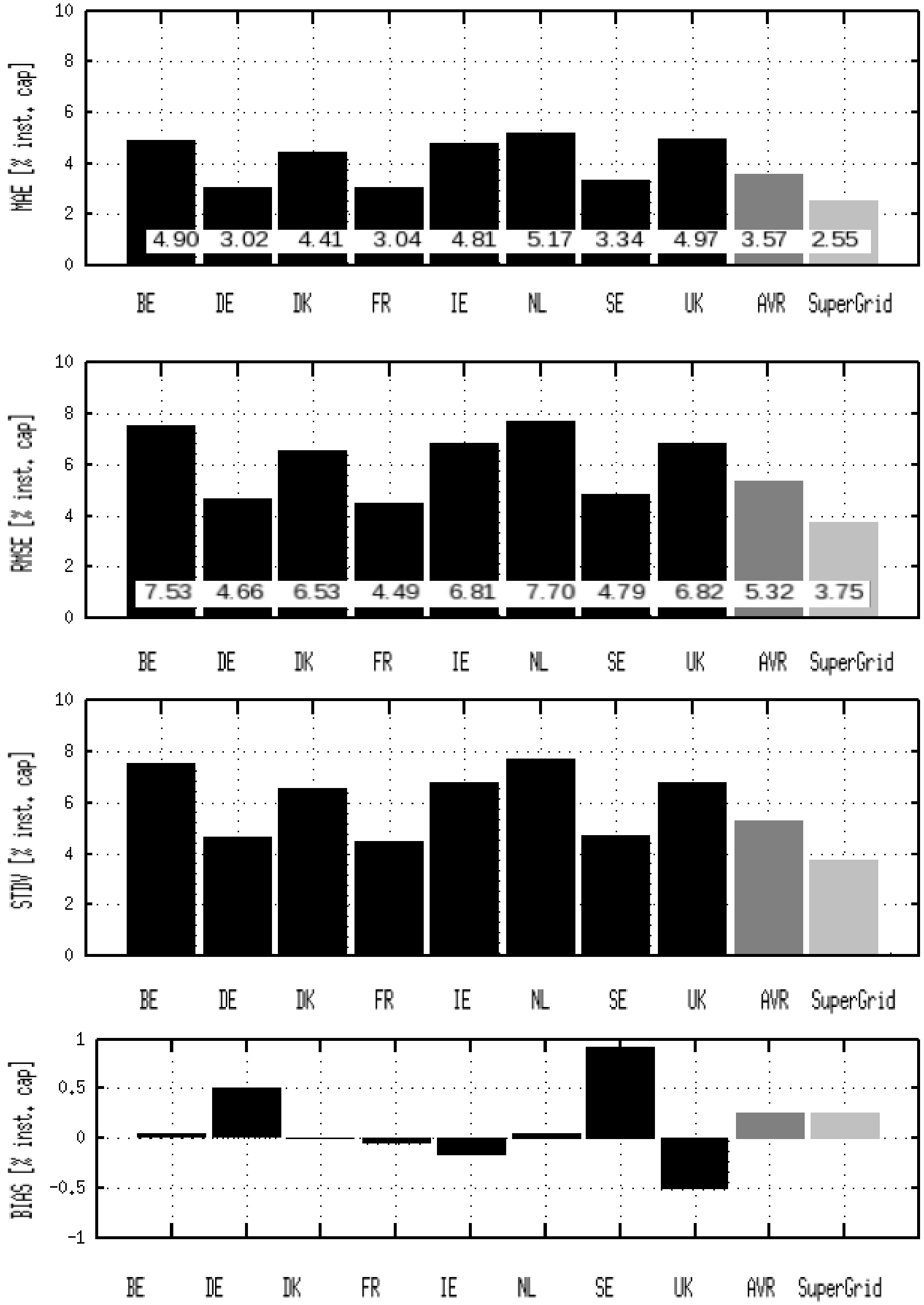
- Each Country
- Countries scaled up with capacity
- Entire SuperGrid

Day ahead Forecast Error Statistics - 00UTC forecasts -

no	Country	BIAS	MAE	RMSE	STDV	Capacity [MW]	RMSE [MW]	Gain [MW]
1	IE	-0.16	4.81	6.81	6.81	1412	96	43
2	DE	0.50	3.02	4.66	4.64	25500	1188	232
3	DK	0.00	4.41	6.53	6.53	3200	209	89
4	BE	0.04	4.90	7.53	7.53	642	48	24
5	FR	-0.05	3.04	4.49	4.49	4709	211	35
6	NL	0.05	5.17	7.70	7.70	2775	214	110
7	SE	0.92	3.34	4.79	4.71	1537	74	16
8	UK	-0.51	4.97	6.82	6.80	5089	347	156
9	AVR	0.25	3.57	5.32	5.31	44864	2388	705
10	SG	0.25	2.55	3.75	3.75	44864	1682	0
ratio	SG/SGsum	1.0	0.7	0.7	0.7			
saving		0.5	28.6	29.5	29.3			

Statistical values are in [% of installed capacity] unless otherwise marked

Day ahead Forecast Error - 00UTC



- SuperGrid generates ~**30% lower erro**r by aggregation over SuperGrid area
- Large countries with dispersed generation => low error
- Small countries => often higher error
- NL is located in the middle and benefit most

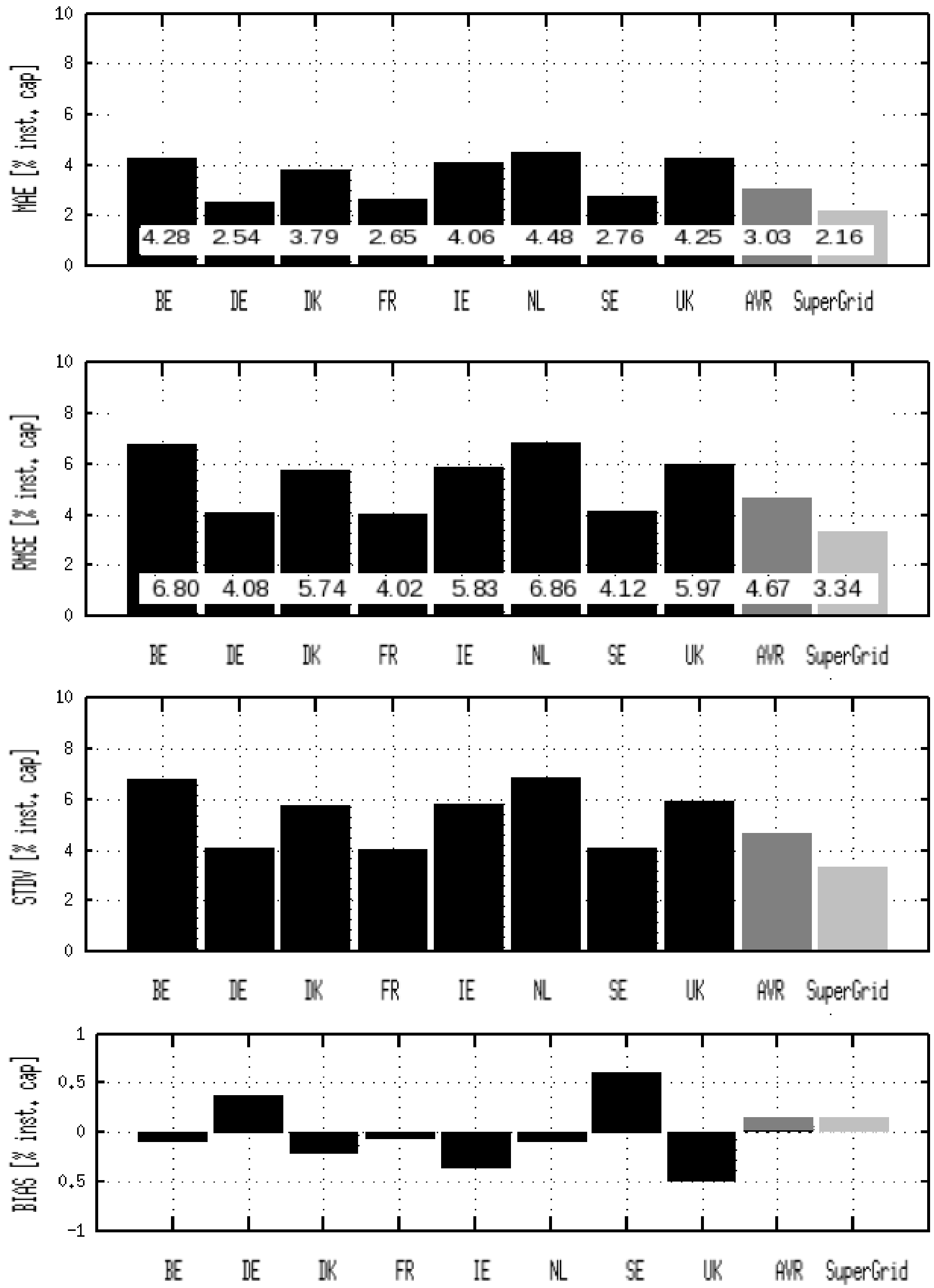
Day ahead Forecast Error Statistics - 06UTC forecasts -

no	Country	BIAS	MAE	RMSE	STDV	Capacity [MW]	RMSE [MW]	Gain [MW]
1	IE	-0.36	4.06	5.83	5.82	1412	82	35
2	DE	0.37	2.54	4.08	4.06	25500	1040	189
3	DK	-0.21	3.79	5.74	5.74	3200	184	77
4	BE	-0.09	4.28	6.80	6.8	642	44	22
5	FR	-0.06	2.65	4.02	4.02	4709	189	32
6	NL	-0.09	4.48	6.86	6.86	2775	190	98
7	SE	0.61	2.76	4.12	4.07	1537	63	12
8	UK	-0.49	4.25	5.97	5.95	5089	304	134
9	AVR	0.14	3.03	4.67	4.66	44864	2097	598
10	SuperGrid	0.14	2.16	3.34	3.34	44864	1498	0
ratio	-	-	0.71	0.71	0.72			
saving	-	-	28.8	28.5	28.3			

Note: forecasts still available before gate closure

WEPROG – Weather & wind Energy PROGnoses

Day ahead Forecast Error - 06UTC



06UTC shows the **same pattern as 00UTC** but with **much lower error** (RMSE):
- 1% lower error in average
- 0.5% lower error on SuperGrid

Real measurements from each area would confirm the result (tested in DE, DK, IE).

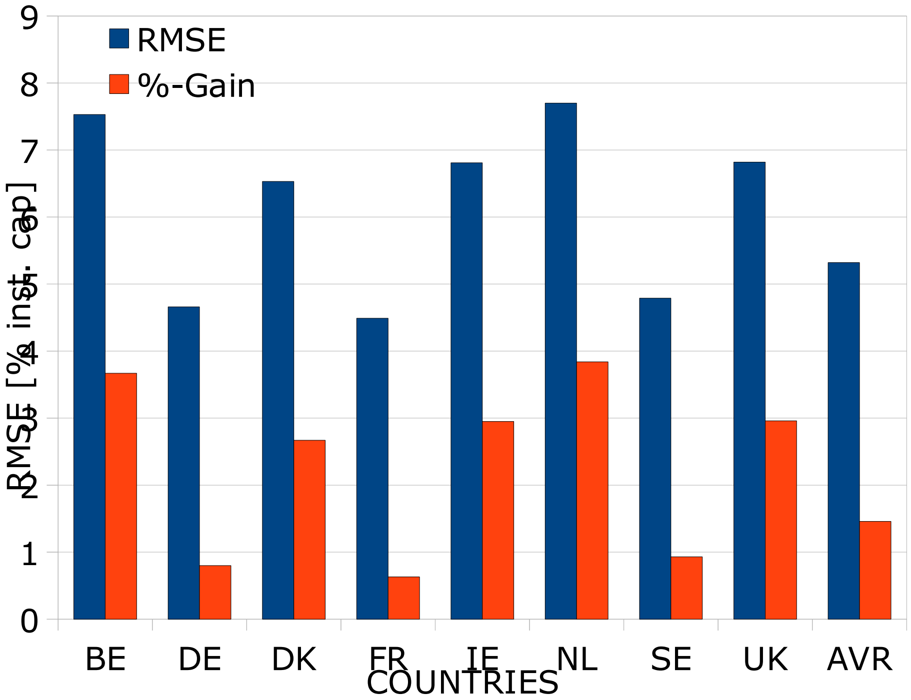
The result will most likely continue to scale with more detailed forecasting.

A **permanent error reduction of 600-700MW is a considerable cost reduction.**

Forecasts still available before gate closure

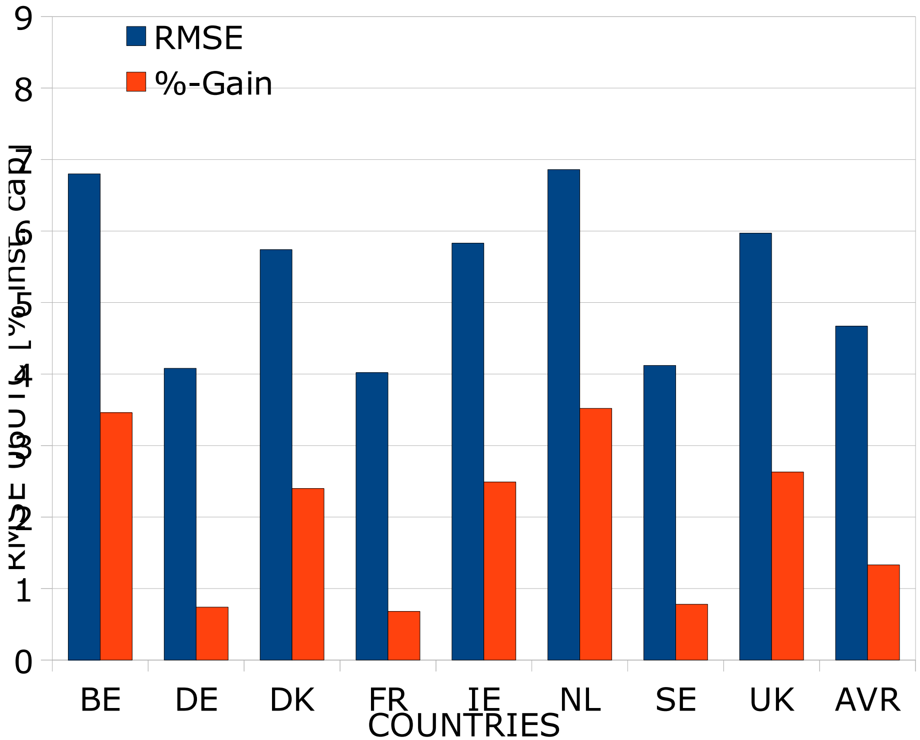
Day ahead Forecast Error & Gain from the SuperGrid RMSE [% inst. cap]

00 UTC



SuperGrid RMSE 00 UTC: 3.75%

06 UTC



SuperGrid RMSE 06 UTC: 3.34%

Note: forecasts available before gate closure

A fundamental problem to consider:
each Inter-Connector provides only 1-way Regulation

The forecasting process must consider 3 cases to maintain the possibility to exchange imbalances on the SuperGrid:

A) Full import (use lower percentiles or minimum of wind power forecast)

B) Import and Export (use RMSE optimized forecast or P50)

C) Full export (use upper percentiles or maximum of wind power forecast)

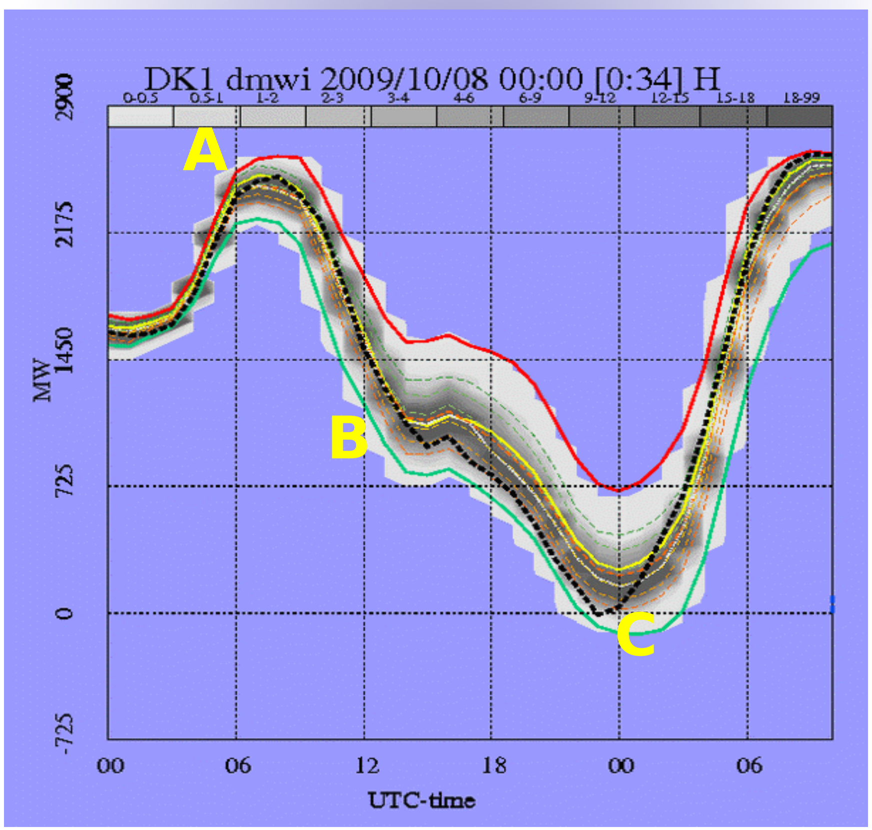
Forecast Step 1: Determine prices and flow direction with P50 forecast

Forecast Step 2: Select percentile from flow (cannot change flow direction)

Provides the highest level of grid security, because reserve is kept at a maximum level, but there may be an N-1 interconnector issue to consider in case C .

Competition factors within each Price Zone Confirm the use of Percentiles in Forecasting

Wind	Competition	Demand-wind	Preferred error	Wind Forecast choice
Low (A)	Low	High	-	Minimum or P10
Medium (B)	Medium	Medium	unknown	RMSE optimised
High (C)	High	Low	+	Maximum or P90



Case A: It is difficult to buy more power in the market, because all cheap generation is in use. The demand peak is short, so the most flexible and cheap Generation is already active

Case C: The challenge is to is to get rid of the power in the market, while many scheduled generators are eager to start especially because this wind peak is short lasting

How can the SuperGrid balancing be Implemented ?

It is expected that all wind farms sign in, because balancing of single wind farms and **small pools will not be competitive**.

A **central Market Operator** is required (MO) with decision right on all interconnectors and the obligation to get as much wind power sold as is technically feasible (with successive auctions if required)

Each country will be **payed by MO** based on what MO recover on the market. Each country pay wind farm owners according to the country's own specific incentive scheme and recover any loss locally. There is **no need to harmonize** the national scheme also not for recovery of balancing costs.

MO **handles forecasts transparent to the market with publication** every 6 hours in a easy to use format showing "Demand-intermittent generation" graphically and as percentiles

MO uses a **large number of providers, where each has to forecast for entire SuperGrid.** Only MO knows the weight of each forecast provider.

Conclusions

- **A 30% reduction of forecast errors** can be expected from the selected central SuperGrid of IE, UK, NL, BE, FR, DE, DK and SE => **more to be gained by the including a North Sea Offshore Grid**

- Correlation of generation suggests **three European clusters** (North, Central, South). France and Sweden divided into two parts and connected respectively to the south and north.

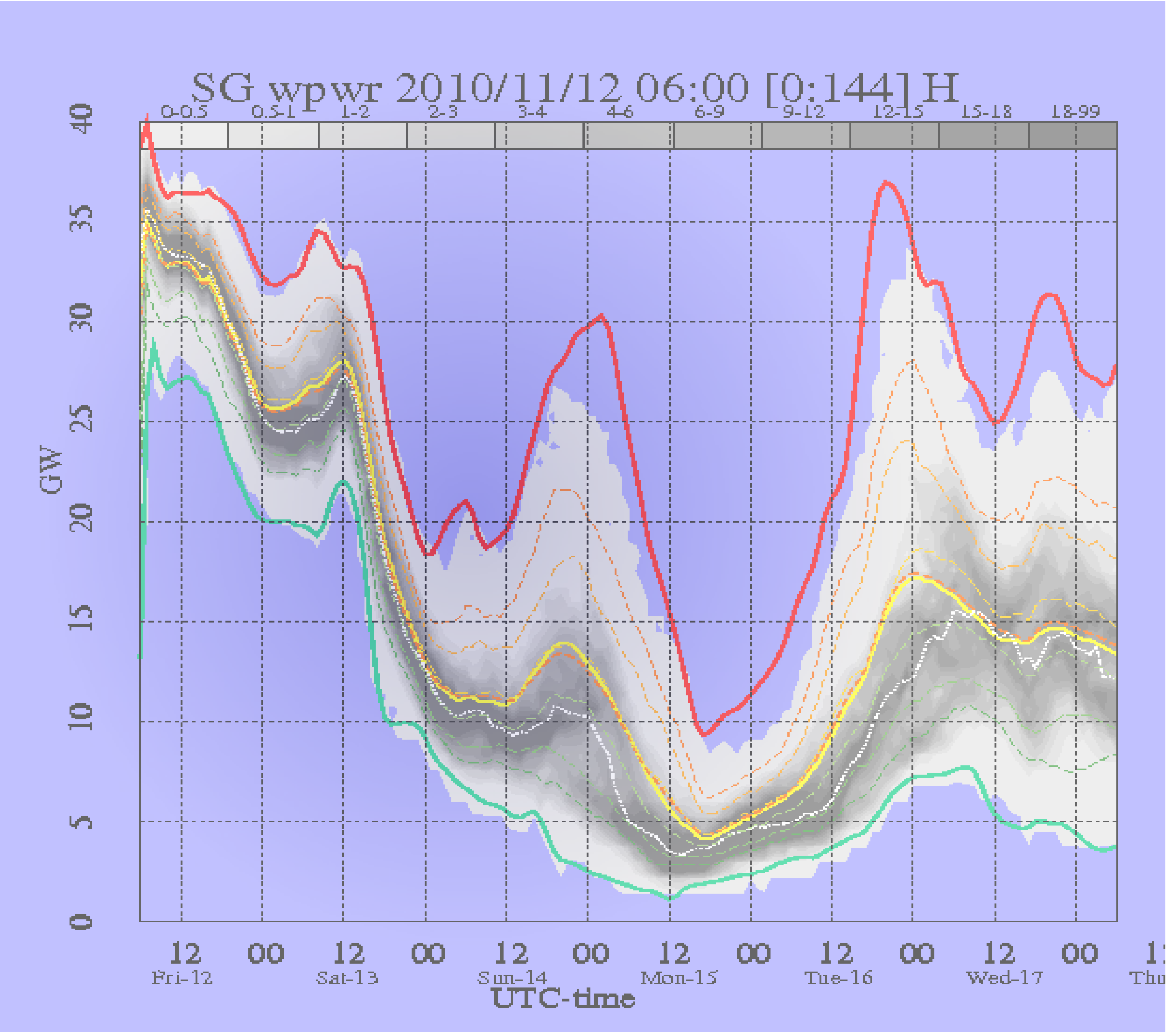
- Use of percentiles in forecasting of wind power ensures that **inter-connectors can be considered permanently available** for exchange of imbalances

- All considerations with respect to competition on the market and grid security factors **suggest the same systematic use of percentiles** in forecasting

- The maximum generation **exceeds only very seldom 60%** of the rated capacity and even more seldom, if all Europe is included

WEPROG – Weather & wind Energy PROGnoses

Thank you for your attention !



Corinna Möhrlen
com@weprog.com

Contact:
WEPROG ApS Denmark
Drejervænget 8
5610 Assens
Tel. +45 46922907

WEPROG GmbH Germany
71155 Altdorf/Böblingen
Tel. +49 (0)7031 414280

Email: info@weprog.com
Web: www.weprog.com

Acknowledgments
This Work was partially funded by the German project „RAVE -Gird integration of Offshore Wind parks“ (BMU ID:0325002) and the danish FORSKEL project DEWEPS (Project ID FORSKEL 2009-2-10260).