A comparison of wind integration experiences in some high penetration areas

IEA-Annex 25 Integration of large amounts of wind power

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Vattenfall, Råcksta

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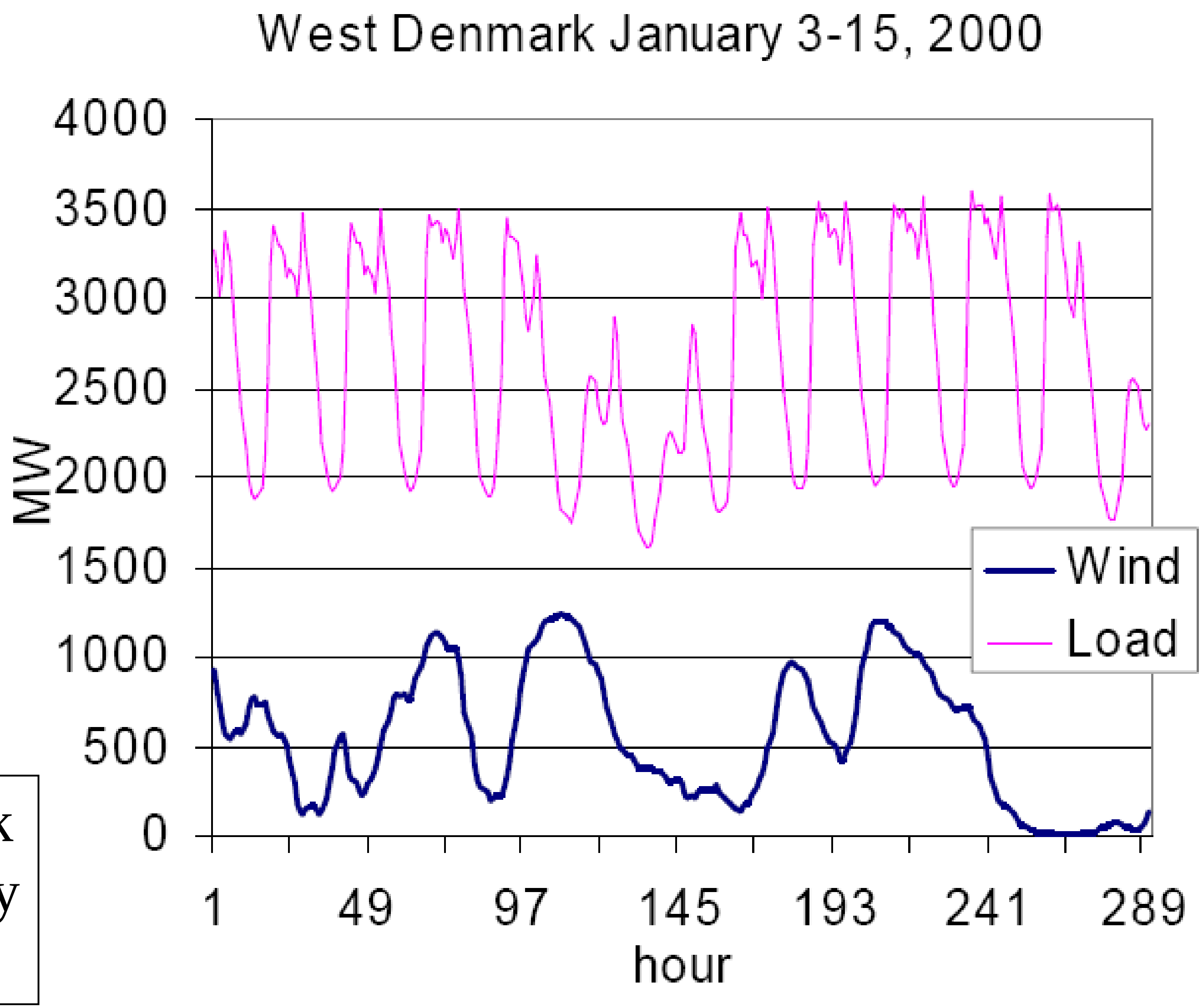
Medium penetration of wind power



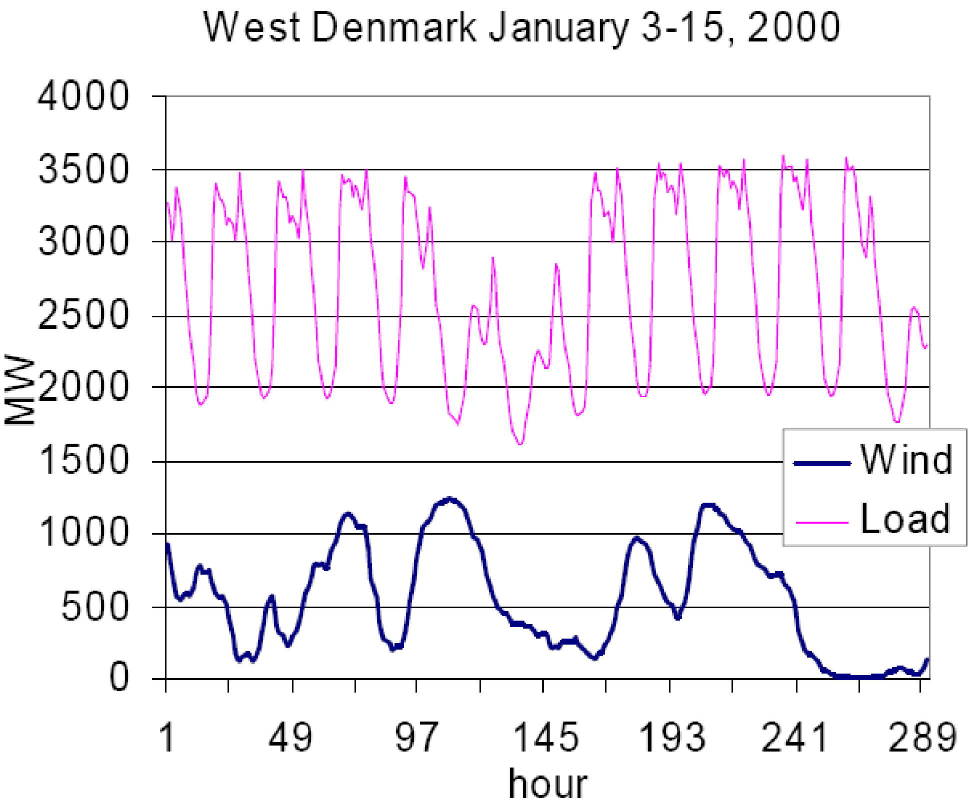
Total consumption and wind power production (20%) for illustration of wind power integration in an isolated power system.

West Denmark export capacity 2830 MW

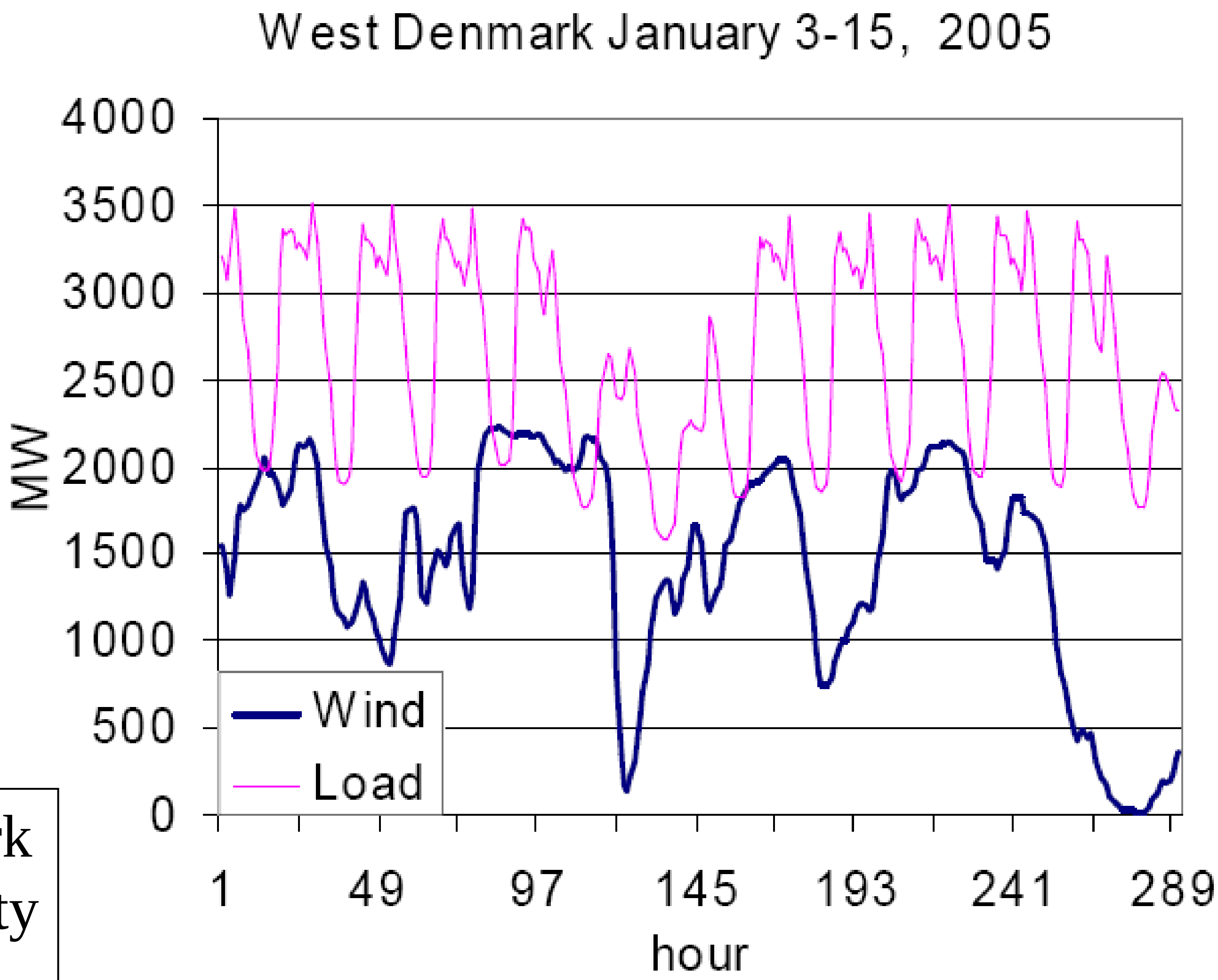
Medium penetration of wind power

Integration challenges:

a. Enough power plants at low wind
b. Enough power plants with fast control at high wind
c. System must survive dimensioning fault
d. There must be enough reserves to cover uncertain load + production
e. Handling of internal grid problems



High wind power penetration



Total consumption and wind power production (55%) for illustration of wind power integration in an isolated power system. The illustrative day of January 8 is here included

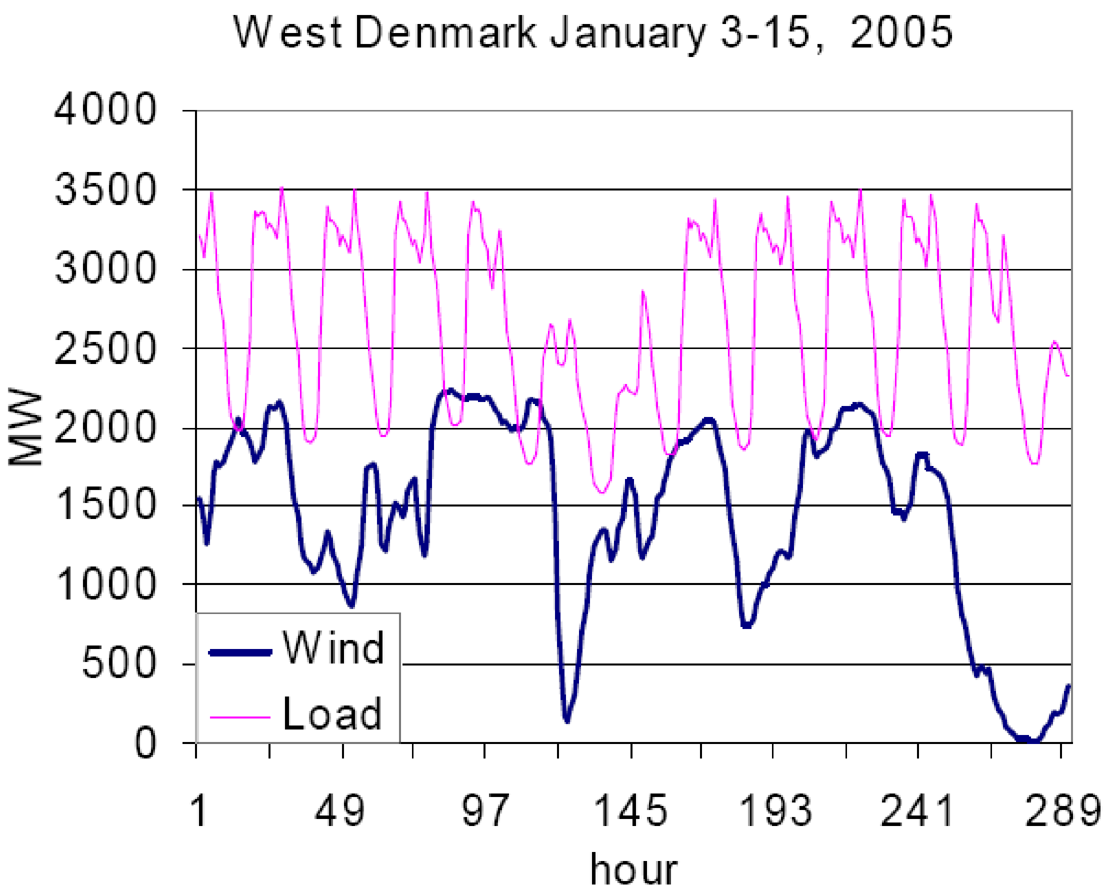
West Denmark export capacity 2830 MW

High wind power penetration

Additional integration challenges:

f. Possibility to regulate down available wind power during low consumption

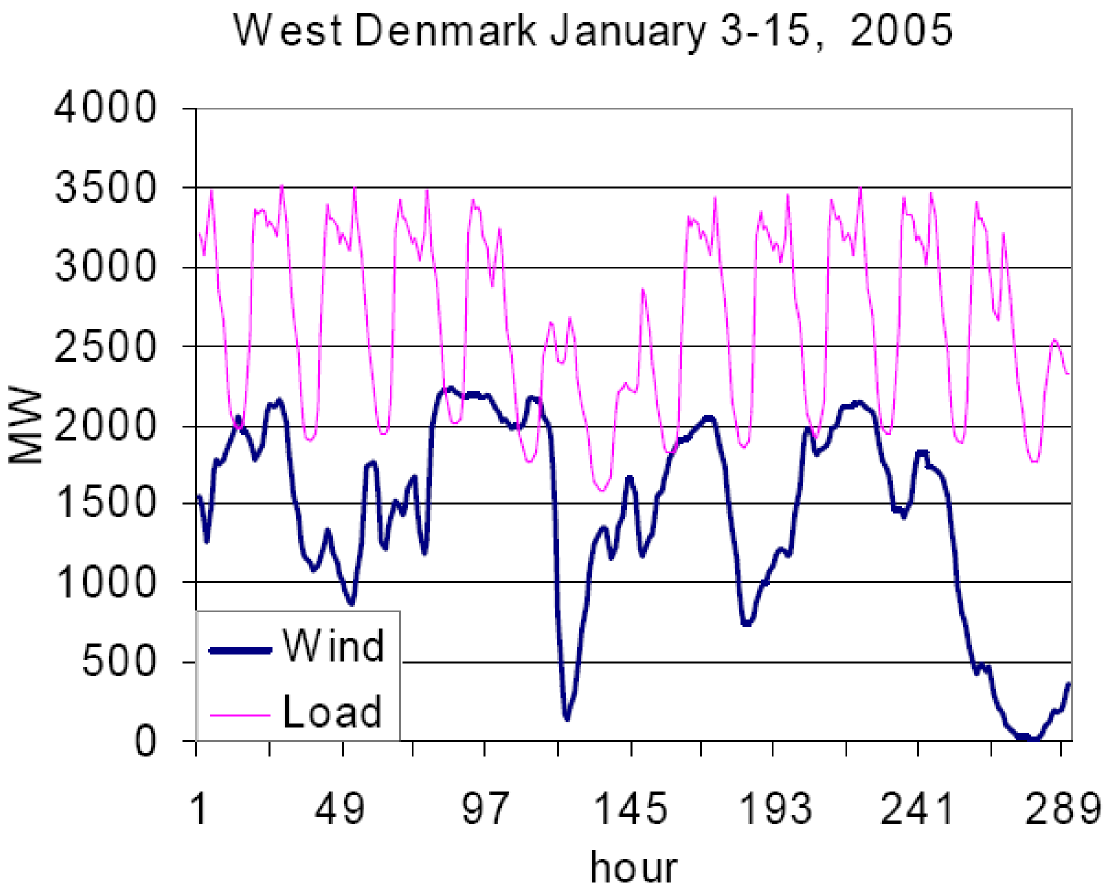
g. Possibility of continous control of wind power



High wind power penetration interaction with neighboring areas

Additional considerations:

- Balance continous load+production changes internally and/or externally
- Keep reserves internally and/or externally
- Consider internal and external dimensioning faults



Definition of "penetration level"

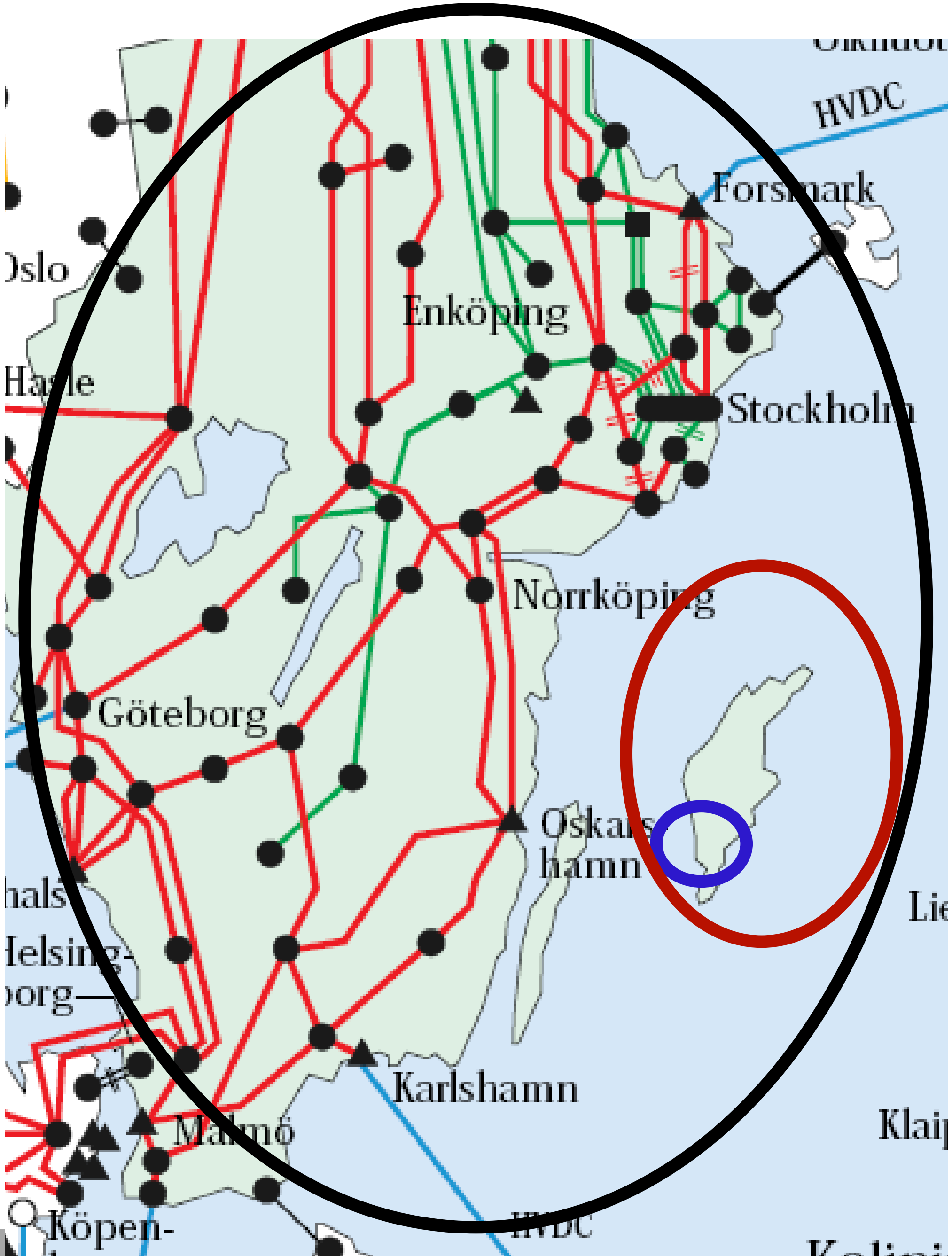
$$Maximal\ \ share\ of\ wind\ \ power = \frac{Maximal\ \ wind\ \ power}{Lowest\ \ consumption + possible\ \ exchange}$$

Region	Wind power	Share of local load energy	Maximal share of wind power
Näsudden (on Gotland)	50 MW	169 %	48%
Gotland	90 MW	19 %	40 %
West Denmark	2380 MW	21 %	58 %
Schleswig-Holstein	2275 MW	33 %	44 %

Problem		Gotland	Solution region?
a	Enough power plants at low wind	Import capacity from mainland enough. Local gas turbines for emergency situations.	Solved mainly outside region.
b	Enough power plants with fast control during high wind	The HVDC to mainland is easy to control, also around 0 MW (control enhanced to enable this), and from mainland side point of view wind power on Gotland is comparatively small	Solved outside region.
c	The system must survive a dimensioning fault.	Wind power would be part of dimensioning problem in cases of transmission faults. The HVDC link and mainland production can act as reserve.	Solved outside region.
d	Enough reserves at large decrease of total wind power	The HVDC to mainland is easy to control, and all balancing is therefore performed on the mainland. From mainland point of view, wind power production on Gotland is comparatively small.	Solved outside region
e	Handling of problem in internal grid	Reactive power support from synchronous compensator and a local HVDC-VSC (Voltage Source Converter). Not a limiting factor, except for c.	Voltage problem only within each region because of HVDC.
f	Possibility to down regulate wind power	Used frequently up to 2003 when the possibility to controllability around 0 MW on the HVDC was installed.	Currently only at rare grid problems.
g	Possibility of continuous control of wind power	Not implemented, since there are local gas turbines and a 35 MW diesel plant that are started at an outage of the HVDC link	Only of interest at isolated operation (very rare).

Problem		Denmark West	Solution region?
a	Enough power plants at low wind	Power production capacity enough	Solved inside region
b	Enough power plants with fast control during high wind	Regulating power (10 minutes) is traded at the Nordic TSO`s regulating power market (NOIS) and can be supplied from all Nordpool members, within the limit of the DC connections to Sweden and Norway. From the importer's point of view wind power in West Denmark is comparatively small	Solved in the Nordpool region (inside and outside region)
c	The system must survive a dimensioning fault.	Dimensioning fault is large conventional power plant or transmission line.	Solved inside and outside region
d	Enough reserves at large decrease of total wind power	Regulating power (10 minutes) is traded at the Nordic TSO`s regulation power market (NOIS) and can be supplied from all Nordpool members. The HVDC to Sweden and Norway is easy to control, and from the Nordic Power System`s point of view the necessary positive regulation power for West Danish wind power is comparatively small, but its availability is varying.	Solved inside and outside region
e	Handling of problem in internal grid	Reactive power support from synchronous compensator. Not a limiting factor, except for c.	Voltage problem is solved locally.
f	Possibility to down regulate wind power	Has been used, but very seldom	Currently only at rare grid problems.
g	Possibility of continuous control of wind power	Regulation capacities used as needed for one large wind farm. It's also possible to cut off wind farms. Of interest only at isolated operation	Only at large offshore wind farm.

Problem		Schleswig-Holstein	Solution region?
a	Enough power plants at low wind	In principle enough power plants are available in that region.	Solved inside region
b	Enough power plants with fast control during high wind	In principle enough power plants are available in that region (Since TSOs are not dealing with unit commitment as far as no congestion limits are exceeded and since the region is part of the interconnected power system of the UCTE power plants will be operated according to availability and costs.).	Solved inside and outside region
c	The system must survive a dimensioning fault.	Faults in the extra-high voltage grid can result in a sudden failing of a huge number of wind power plants in the affected region: up to 3,000 MW can fail, thereby putting the grid stability at risk [10]. In general outages of more than 3,000 MW are defined as endangered in the UCTE synchronously interconnected system. For further expansion of wind power, grid connection regulations are continuously improved by E.ON Netz to take care of grid stability and supply reliability.	Has to be solved inside region in future (grid codes with Fault-Ride-Through to avoid wind power becoming dimensioning fault)
d	Enough reserves at large decrease of total wind power	E.ON Netz has to tender and purchase adequate control power as well on basis of the day-ahead wind power prognosis.	Solved inside and outside region
e	Handling of problem in internal grid	Voltage regulation has to solved locally, as long as there are enough power plants online this is not a limiting factor (see answer to problem b). New wind farms have to contribute to the reactive power supply and voltage regulation. Depending on their size new wind farms have to keep either a certain power factor or have to feed in a certain amount of reactive power, which is given by the control centre, or have to participate in voltage regulation.	Voltage problem is solved locally. New wind farms are contributing.
f	Possibility to down regulate wind power	In mid 2003, E.ON Netz implemented generation management in ten regions of Schleswig-Holstein	Has been used since 2003
g	Possibility of continuous control of wind power	A continuous control of wind power is not possible due to the feed-in law (Renewable Energy Sources Act, 21.7.2004)	



Possibilities of external balancing

An illustration

Region	Wind power	Share of local load energy	Maximal share of wind power
Näsudden	50 MW	169 %	48%
Gotland	90 MW	19 %	40 %
Sweden	339 MW	0.4 %	1.5 %

Conclusions and comments

- A method for how to study and compare ”wind power penetration levels” is presented
- The method is applied to 3 areas: Gotland, Western Denmark and Schleswig-Holstein
- The possibilities to ”external balancing” is discussed.

A Journal paper

Experience from wind integration in some high penetration areas

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