Bottlenecks in the Nordic Grids during the Storm "Urd"

In my note, "The Electricity Markets and the Storm Urd", from 30th December 2016, the map in fig. 1 caused some wonder. At least 2000 MW wind power was curtailed in Denmark. The export to Sweden was about 400 MW, although the technical interconnector capacity is about 2400 MW. Sweden could maintain positive spot prices, even when Germany and Denmark had negative spot prices. What prevented a much larger export to Sweden?

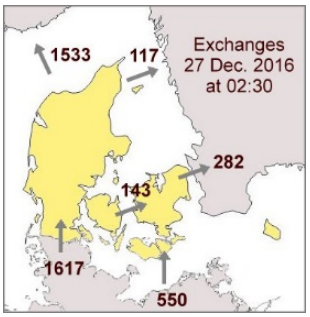

Fig. 1 - Danish exchange of power at the wind peak

This note is an attempt to identify bottlenecks in the Nordic grids during the period 22nd December to 31st December 2016.

The main source of data was Nord Pool Spot[1]. Other sources are Phelix Spot[2] and Energinet.dk.

Wind Power and Spot Prices

Strong winds in northern Europe in the Christmas days 2016 have characterized the power systems in several countries.

Energinet.dk publishes onshore wind speed on German one location, Malling in Jutland. The storm lasted just a few hours in the night between 26th and 27th December. Hourly average winds up to 20 m/s were recorded. The maximum 5 minutes average was 27 m/s.

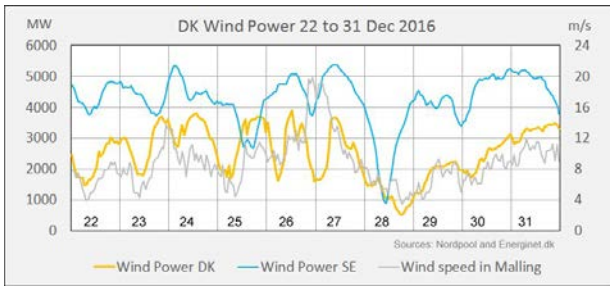

Fig. 2 - Wind power (DK & SE) and wind speed (DK)

The electricity markets have responded to the wind conditions. Germany and Denmark had negative spot prices during some of the nights. The spot prices were positive in Sweden and Finland for all hours, and Norway had a rather stable price about 25 €/MWh.

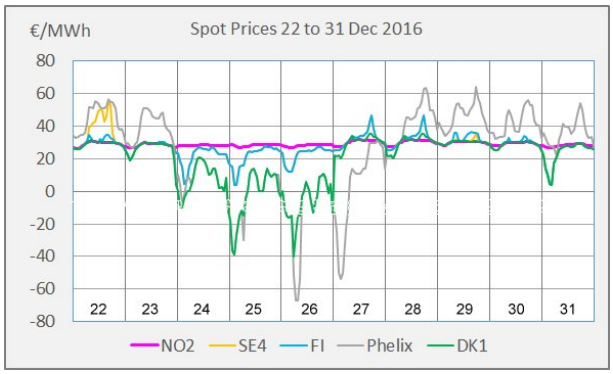

Fig. 3 - Spot prices from Norway, Sweden, Finland, Germany and Denmark. Phelix is the German spot price.

Danish wind power, particularly offshore, was curtailed during the nights from the 25th to the 27th December.

This is one of the reasons why the charts in fig. 2 and 3 cannot tell a story about the interrelation between wind and electricity markets. The electricity flows will help us understand the grid conditions. The import from Germany (fig. 1) and the low spot prices suggest a considerable surplus of power in Germany.

[1] http://www.nordpoolspot.com/
[2] https://www.eex.com/en/market-data/power/spot-market/auction#!/2017/01/08

Danish Export Options

Fig. 4 is an attempt to illustrate the power flows between Denmark and its neighbouring Nordic countries.

The map shows some of the Nordic price zones. Fig. 4 supports the following conclusions:

- DK1-NO2. Main transfer direction towards Norway. Fully loaded most of the time. Still a bottleneck in spite of the recent reinforcement.
- DK1-SE3. Main transfer direction towards Sweden. Fully loaded most of the time up to the changing capacity limits. A bottleneck most of the time.
- DK2-SE4. Changing capacity limits towards Sweden. A bottle neck about half the time.
- DK1-DK2. Main transfer direction towards DK2. A bottleneck most of the time.

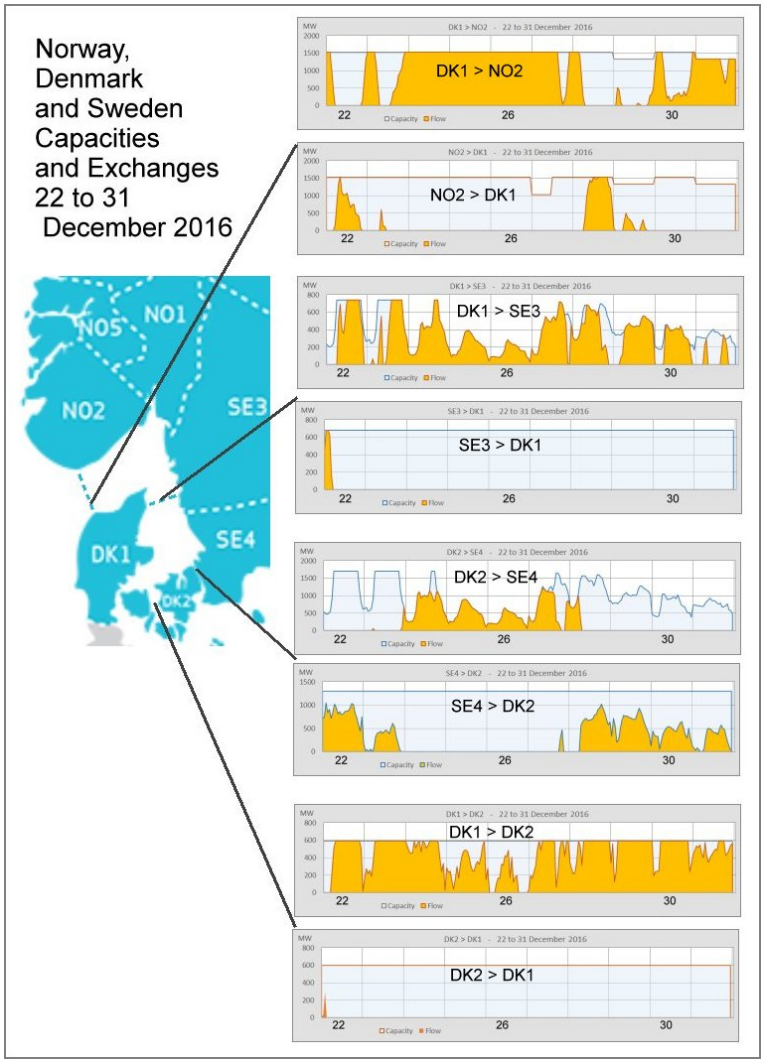

Fig. 4 - Danish exchanges 22 to 31 December 2016

Denmark had no additional export options during the hours with negative prices. The German export to Denmark put pressure on the spot prices and the Danish traders apparently preferred to curtail Danish wind power.

The Swedish curtailment of import capacity from Denmark was in the ten days up to 2352 MW and in average 1126 MW.

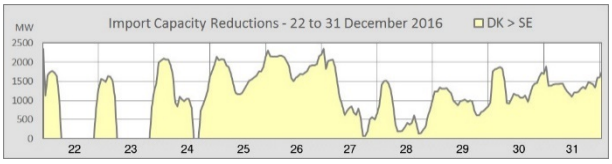

Fig. 5 - Swedish curtailment of import capacity from Denmark

We shall try to find the reasons for the Swedish grid operator, Svenska Kraftnät, to limit the import of electricity, in the first hand by examining the internal Swedish exchanges.

Internal Swedish Bottlenecks?

The Swedish electricity wholesale market has four price zones. Nordpool publishes hourly capacities and exchanges for all price zones.

Sweden has hydro power located in SE1 and SE2 and nuclear power in SE3. The main direction of power flows is from SE2 to SE4.

The nominal southbound capacities are:

- SE1 > SE2: 3300 MW
- SE2 > SE3: 7300 MW
- SE3 > SE4: 5300 MW

On the 28th SE2 > SE3 was 63 MW from full load, but there was no formal congestion.

SE3 > SE4 was congested on 22nd, 28th and 29th December. There was no northbound transfer in the ten days. The electricity production in SE4 is quite small, among other things due to the closure of the Barsebäck nuclear power station.

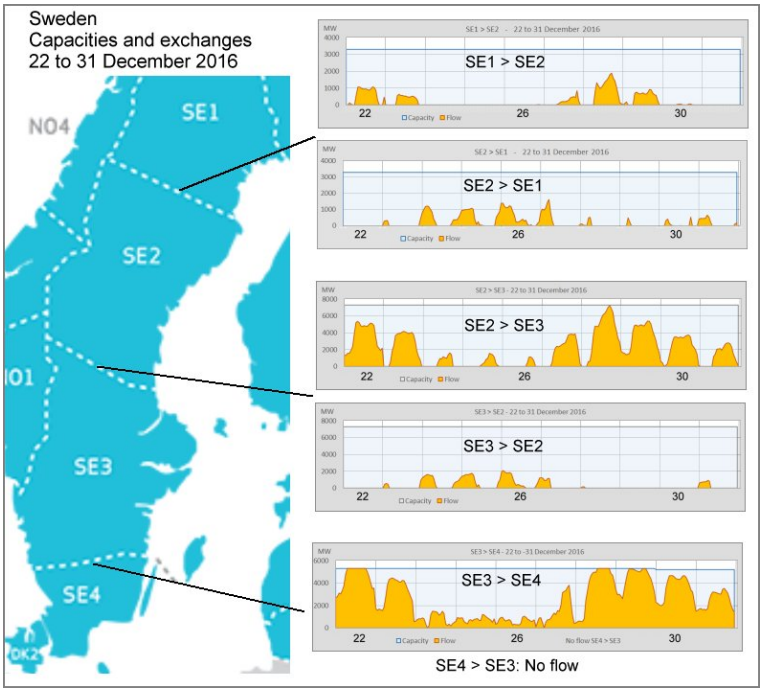

Fig. 6 - Internal Swedish capacities and exchanges

Apparently, internal bottlenecks did not prevent transit from Denmark to Norway.

Limits to Swedish Export to Norway and Finland?

The nominal transfer capacities from Sweden to Finland are:

- SE1 > FI: 1500 MW
- SE3 > FI: 1200 MW

The capacities were practically constant during the ten days. No export from Finland to Sweden was recorded.

The nominal transfer capacities from Sweden to Norway are:

- SE3 > NO1: 2095 MW
- SE2 > NO3: 1000 MW
- SE2 > NO4: 300 MW
- SE1 > NO4: 600 MW

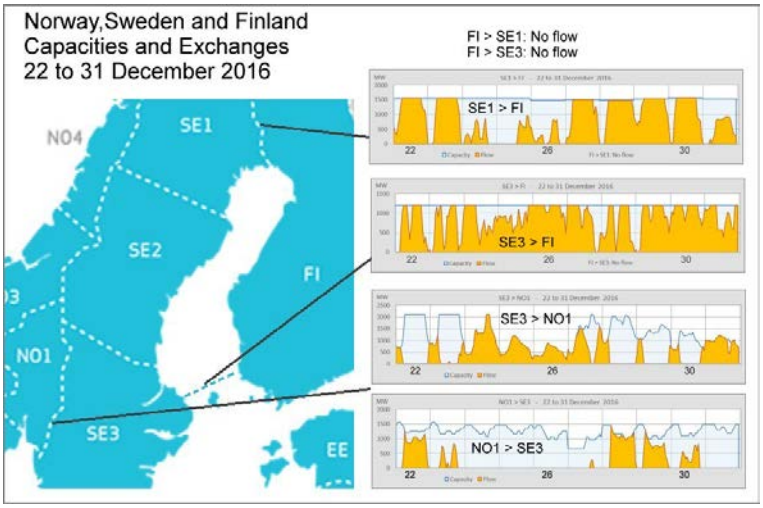

Fig. 7 - Capacity limitations between Sweden and Norway in both directions most of the time

The Swedish curtailment of export capacity to Norway was in the ten days up to 2479 MW and in average 1345 MW.

The question remains: Why did Svenska Kraftnät limit the transit from Denmark to Norway?

Reasons for Temporary Limitations

Grid operators must report the reasons for temporary limitations to Nordpool, hour by hour. A four digits code has been developed for the purpose[3]. The first two digits indicate the reason and the last two digits indicate the area or the location.

In the cases mentioned in this note, the Swedish limitations all have the code 1624, where 16 means "Stability" and 24 means "The West coast corridor in Sweden (SE3)".

Export limitations from Norway to Sweden have the codes 1545 ("Network failure" and "Norway South East (NO1)" or 1914 ("Unavailable system protection" and "The Hasle cut (NO1-SE3)").

The West Coast Corridor in Sweden

An excellent report (in Swedish) by the Swedish Energy Market Inspectorate[4] explains the background.

In 2006, the Danish Energy Association made a complaint about the congestion management in the Swedish grid. The argument was that limitations of international exchanges were used for solving internal Swedish congestion problems.

After negotiations with EU's GD Competition, Svenska Kraftnät introduced in 2011 a division of Sweden into four price zones. However, GD Competition accepted an exception regarding "the west coast corridor". Internal Swedish resources cannot remedy congestions in the corridor. Reduction of international exchanges would temporarily be allowed. In return, Svenska Kraftnät promised to build a 400 kV line Lindome-Stenkullen.

The line was ready for operation in June 2012, but the congestion problems remained, and curtailment of international exchanges seems still to be the routine.

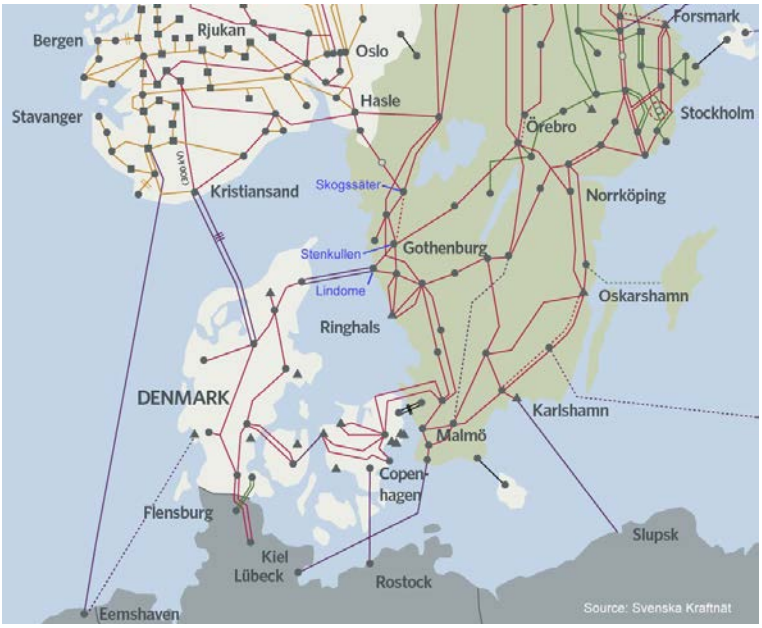

Fig. 8 - Reinforcements of the west coast corridor: Lindome-Stenkullen-Skogssäter

A new 400 kV line Stenkullen-Skogssäter is expected to increase the transfer capability in the west coast corridor significantly, by this line will not be commissioned until 2021[5].

A transit from Denmark will not be equally distributed along the borders between the price zones. The transit will mainly flow through the west coast corridor. Therefore, it is possible

[3] Nordpool: Reason codes and area/ location codes
[4] Energimarknadsinspektionen: Överföringsbegränsningar mellan Norden och Tyskland, Ei R2015:11
[5] Svenska Kraftnät – Network Development Plan 2016 – 2025

to overload the corridor without violating the nominal transfer capability between the price zones.

It is understandable that the report from the Swedish Energy Market Inspectorate calls attention to the corresponding problems in Germany. Sweden must accept criticism for its behaviour although the Swedish wholesale electricity market has been redesigned in order to ease the problems. It seems to be a firm attitude in Germany to defend a market model with only one price zone and to use reductions of international exchanges as essential measures for easing internal German congestion problems. This is a technical barrier to trade.

Years ago, the operational conditions in the Swedish grid were rather stable. The hydrological conditions controlled the main flows, and they changed only slowly. The power flows now depend on fluctuating wind energy, not only in Sweden, but also in the neighbouring countries, and particularly in Germany. This has added new challenges to the grid control in Sweden.

Conclusions

It is striking that positive spot prices can be maintained in Sweden, while the German and Danish prices are negative. On the other hand, we cannot exclude that the Swedish grid is being operated with reasonable and necessary security margins.

There is no doubt that the congestions cause considerable losses to the societies concerned. The idea of an electricity market with price zones is to serve supply and demand of electricity with optimal utilization of available transmission facilities.

The grid owners in Germany and Sweden state that new power lines will ease the problems. However, new wind and solar power plants are being built faster than the power lines. Therefore, a situation with sufficient transmission capacity seems all too distant, and the best measure in the short term seems to be a regular monitoring of grid performance and a follow-up with suitable adjustments of market designs.