Transmission Grids Stressed by German Wind in 2019

Swedish colleagues recently noticed that day-ahead prices in Sweden were negative for the first time ever on 10 February 2020. The lowest price in Sweden was -0.20 €/MWh. This is not alarming, but the possibility disturbed the Swedish colleagues.

Day-ahead prices in EUR/MWh													
10-02-2020	SYS	SE1	SE2	SE3	SE4	FI	DK1	DK2	Oslo	Kr.sand	DE-LU	FR	NL
00 - 01	2,92	-0,09	-0,09	-0,09	-0,09	-0,09	-2,58	-2,58	10,83	10,83	-4,97	11,95	11,32
01 - 02	2,01	-0,2	-0,2	-0,2	-0,2	-0,2	-2,68	-2,68	10,08	10,08	-15,89	9,94	9,75
02 - 03	1,63	-0,1	-0,1	-0,1	-0,1	-0,1	-2,66	-2,66	9,76	9,76	-15,11	8,63	9,11
03 - 04	1,83	-0,07	-0,07	-0,07	-0,07	-0,07	-2,66	-2,66	9,79	9,79	-16,16	2,77	2,79
04 - 05	3,28	0,06	0,06	0,06	0,06	0,06	-0,75	-0,75	9,96	9,96	-14,93	2,58	2,6
05 - 06	7,81	4,11	4,11	4,11	4,11	4,11	0,01	0,01	10,51	10,51	-2	9,25	9,32
06 - 07	10,94	8,98	8,98	8,98	8,98	14,05	0,41	8,98	12,03	12,03	0,41	14,52	15,33
07 - 08	13,06	13,1	13,1	13,1	13,1	13,15	14,11	13,1	13,1	13,1	14,11	24,74	31,65

Table 1 - Spot prices for the first 8 hours of 10-02-2020 for selected price zones (Source: Nordpool).

It is more interesting that the spot prices for the same hour was -2.68 €/MWh in Denmark and -15.89 €/MWh in Germany. Strong winds cause overflow of electricity in Europe. In a European map of day-ahead prices, the expected overflow seems to create a sink in Germany. Even the Nordpool system price (SYS in table 1) yields, while the two southern price zones in Norway, Oslo and Kristiansand, are less influenced. Dutch and French prices are gradually decreasing during the first five hours.

Was the situation problematic?

A perfect market with a free flow of goods across borders will have the same spot prices everywhere. Different prices indicate obstacles at the borders between price zones.

Based on hourly day-ahead prices and actual flows across borders, this note tries to create an impression of the bottlenecks at the German borders in 2019.

An approximate method

We must distinguish between day-ahead planning and physical operation. Unexpected changes make regulating arrangements necessary in order to adjust the scheduled exchanges. Therefore, there is a discrepancy between day-ahead prices and recorded physical exchanges. However, only these two time series are available for the time being.

The identification of physical bottlenecks would require prices from the regulating power markets and physical exchanges. Bottleneck incomes are usually (at least in Denmark) based on day-ahead prices and scheduled exchanges.

Therefore, the quantifications of bottleneck hours in 2019 and bottleneck fees in this note must be regarded as approximations.

For each hour, a border is considered a bottleneck, if the day-ahead price difference at a border exceeds a certain threshold. The threshold is arbitrarily set to 1.00 €/MWh in this note. The bottleneck fee at each border per hour is calculated as difference in day-ahead price multiplied by the physical exchange (no threshold). Previous Danish results have shown a fair accuracy of the estimated bottleneck fees.

The spot prices have been downloaded from the ENTSO-E Transparency Platform. The currency is €/MWh for all countries except Poland. The Polish prices have been converted from Zloty/MWh for most of the year. The conversion factor was 4.25 Zloty/€. Therefore, particular reservations must be made for the results at the border between Germany and Poland.

Spot prices suggest reasonable function of the international markets

			Source: ENTSO-E	
Spot prices				
2019	Average	Max	Min	St.dev.
	€/MWh	€/MWh	€/MWh	€/MWh
AT	40,08	121,46	-59,78	13,06
CZ	40,20	109,30	-48,14	13,51
DK1	38,50	109,45	-48,29	13,16
DK2	39,84	109,45	-48,29	12,66
FR	39,53	121,46	-20,54	13,95
DE	37,68	121,46	-90,01	15,51
NL	41,22	121,46	-9,02	11,25
PL	49,94	115,32	1,18	17,68
SE4	39,81	109,45	0,47	11,28
CH	40,94	108,11	-39,45	12,32
LU	37,68	121,46	-90,01	15,51

Table 2 – Germany and 10 neighbours

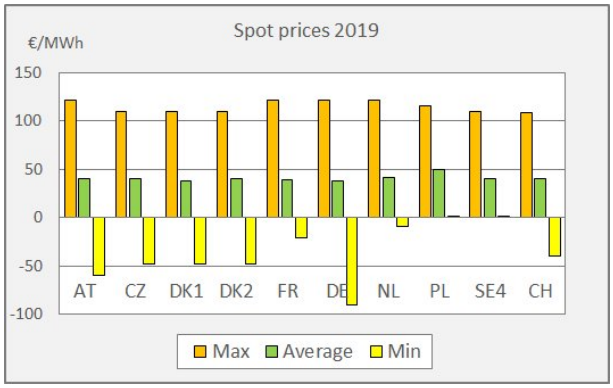

Fig. 1 - Moderate differences in average spot prices

Except for Poland, the average spot prices in table 2 are kept within a narrow range from 37.68 €/MWh in Germany and 41.22 €/MWh in the Netherlands. The Polish average is 49.94 €/MWh. The narrow range indicates a reasonable efficiency of the international electricity markets.

Luxembourg and Germany make one price zone and have therefore identical results.

As a major exporter based on fluctuating power production, Germany has the lowest average price and the largest price variation (fig. 1).

The standard deviation is another quantification of the price volatility (table 2). The moderate differences show the mutual interdependences in the markets.

Exchanges 2019

Borders					
2019	Import	Export	Net imp.	Max imp.	Max exp.
	GWh	GWh	GWh	MWh/h	MWh/h
AT-DE	494	11084	-10590	1860	3666
CZ-DE	1652	5599	-3947	2365	2860
DK1-DE	1681	4080	-2399	1454	1792
DK2-DE	1292	2343	-1051	585	600
FR-DE	14827	1718	13110	5223	3000
LU-DE	0	4033	-4033	0	790
NL-DE	2946	9135	-6189	4423	5074
PL-DE	6	10070	-10064	508	2026
SE4-DE	1306	565	741	611	596
CH-DE	3611	13012	-9401	3894	5909
Total	27817	61638	-33822		

Table 3 - Germany's net export was 33.8 TWh in 2019

Most borders have exchanges in both directions (table 3). The 10 borders create many combinations of operating conditions.

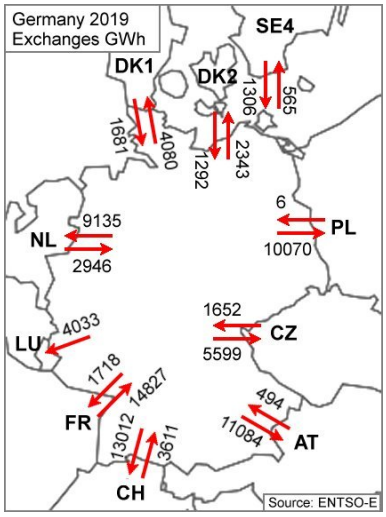

Fig. 2 - Transit through PL and CZ

In spite of the many combinations, fig. 2 reflects an overriding flow pattern.

Germany sends large amounts of electricity to Poland and to the Czech Republic to an eastern corridor towards Italy together with transit via Austria and Switzerland. Poland and the Czech Republic have installed phase shifters in order to reduce the flow through the corridor because they do not want to provide transmission facilities for transport of German electricity overflow to Italy.

Bottlenecks 2019 and cost of security measures

Congested 2019		of which import	export	Estimated revenue	
	hours	hours	hours	Mill. €	€/MWh
AT-DE	2459	220	2239	51	4,40
CZ-DE	6418	1804	4614	34	4,63
DK1-DE	2561	1008	1553	20	3,48
DK2-DE	3488	1008	2480	16	4,41
FR-DE	4226	2820	1406	54	3,28
LU-DE	0	0	0	0	0,00
NL-DE	3177	605	2572	60	4,97
PL-DE	8388	32	8356	135	13,41
SE4-DE	5634	2557	3077	12	6,58
CH-DE	6733	2082	4651	131	7,85
Tolerance:	1,00	€/MWh			

Table 4 - Congestion occurs in both directions for most borders. Average congestion income between 3.48 €/MWh and 7.87 €/MWh for all transferred energy (Poland not included)

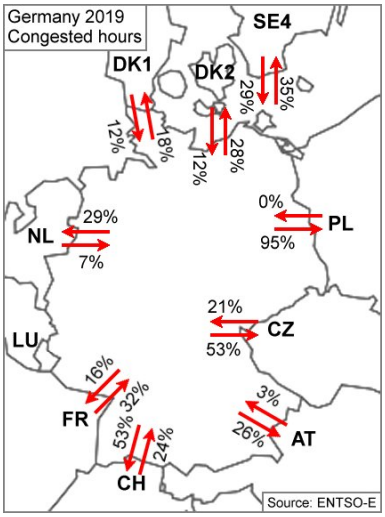

Fig. 3 - CH-DE congested 77% of the year

8760 hours in 2019 have been analysed. If the spot price difference at a border exceeds the tolerance (1.00 €/MWh), the hour is counted as congested (table 4).

The import from France to Germany was 14.8 TWh in 2019. It is not surprising that this large import has caused congestion in 2820 hours or 32% of the year. The largest recorded import in one hour from France was 5223 MWh. The import figures from all other countries were less significant.

The largest export border in 2019 was the border to Switzerland with 13.0 TWh causing 4651 congested hours (53% of the year). The largest recorded export in one hour to Switzerland was 5909 MWh. Other borders with more than 10 TWh exported are Poland and Austria. The export to the Czech Republic was only 5.6 TWh, but the border was congested 53% of the year.

Due to the large number of combinations, these figures cannot tell if the bottlenecks at the borders form a real problem, but looking at the cost of security measures may help us (fig. 4). Complete data for 2019 are not yet available, but in 2018 the measures included 21 TWh at an average cost of 68 €/MWh.

The question is if new transmission lines and new power-to-X facilities will be ready in time for pre-

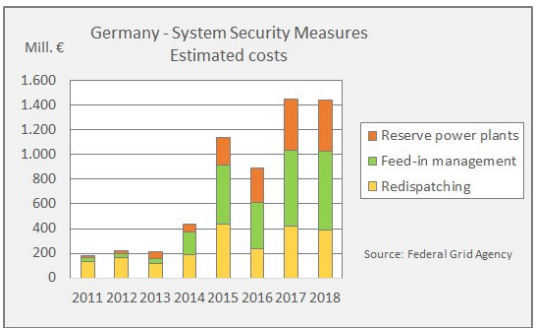

Fig. 4 – The average cost of German security measures in 2018 was 68 €/MWh

venting the cost of security measures and the curtailments of renewable energy sources from running wild. I shall follow up with new results when sufficient new data are available.

The congestion fees

The "Estimated revenue" in table 4 is also called the congestion fee or the bottleneck fee[1]. It is an income for the owner of the border crossing transmission line. The fee is the price difference multiplied by the transmitted energy. It arises as a surplus because the buyers on the expensive side of the border pay more than the sellers on the cheap side get.

According to previous Danish results, the congestion fees indicate a priority of the borders after their need for capacity. Table 4 suggests reinforcements at the border to Switzerland. The result at the border to Poland is ignored due to the doubt about the Polish spot prices, and because Poland does not want the increased transit.

Exchanges against price signals

Many different statistics can be made from the spot price and exchange time series. If the direction of a cross-border flow is against the incentives given by the price signals for that hour, the market couplings may have some deficiencies.

The border between Germany and the Czech Republic seems to have most problematic hours, but also the border to France, Poland and Switzerland show high values (table 5). The question is if the apparent transit from France via Germany to Switzerland could be prevented by a different grid structure at the French borders to Switzerland and Italy.

Due to the lack of data for the regulating power markets, the results in table 5 are only indications. Further analyses are necessary to show if and where the problems are real.

	Flow against	of which	
2019	price signals	import	export
	hours	hours	hours
AT-DE	57	24	33
CZ-DE	1985	672	1313
DK1-DE	133	0	133
DK2-DE	132	59	73
FR-DE	1196	1195	1
LU-DE	0	0	0
NL-DE	450	125	325
PL-DE	1138	11	1127
SE4-DE	241	47	194
CH-DE	1165	401	764
	Tolerance:	1,00	€/MWh

Table 5 - Hours with possible market problems

Perspectives

Last year, I made a map of European electricity flows in 2018 (fig. 5). When I have collected sufficient exchange data, I shall make a similar map for 2019. The exchange data can also be used for congestion analyses for other countries than Germany.

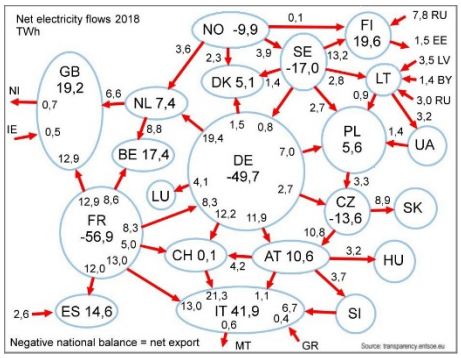

Fig. 5 - European net electricity flows in 2018

[1] Read more here: http://pfbach.dk/firma_pfb/pfb_lucrative_bottlenecks_2015_03_29.pdf