TSOs finally recognize challenges from solar and wind

Urgent need for new backup and transmission facilities in Northern Europe

The necessary balance between electricity consumption and production is ensured by controllable production. Work has been going on for at least 25 years to let flexible consumption take over part of this task, but so far with very modest results.

Therefore, it is simple logic that the growing share of fluctuating production of solar and wind power together with the decommissioning of controllable production must sooner or later lead to a shortage of balancing resources.

The first sign of problems: fluctuating market prices

The electricity markets react to the shortages with price spikes and increased volatility. This should encourage new investment in controllable power plants, but climate policy has so far been more important to European decision-makers, so they seem to have ignored the significance of the price signals.

When operating reserves are depleted due to lack of capacity, the system operator must intervene to prevent major power system failures. Initially, customers are encouraged to support, either by saving electricity or by additional generation. If it does not work, controlled interruptions of supply (brownouts) may become necessary.

It has not yet come that far in Northern Europe, but we have been very close a few times in the last year.

Two critical grid incidents in Denmark in 2023

Energinet[1] published on 6 June 2023 information about two critical incidents in April and May 2023. The trouble indicators were extreme prices in the regulating power market, which is the system operator's last tool before direct interventions against producers or consumers.

The two cases are interesting because they represent two typical situations: an overflow and a shortage of power. They demonstrate the magnitude and nature of the new balancing problems.

April 10, 2023, was Easter Monday, i.e. a day with fairly low consumption. There were negative spot prices in Germany and Western Denmark. It was a clear sign that too much production had been planned the day before. The traders could restore their balances in the intraday market, but this did not happen to the desired extent. In Denmark, the system operator, Energinet, utilized all available reserves for downregulation, and the price in the regulating power market was for two hours at approx. €2,200 per MWh. A significant downregulation occurred for offshore wind turbines, while solar cells and onshore wind did not react to any significant extent.

DateUTC	HourUTC	DateDK	HourDK	SYSTEM	DK1	DK2	DE
				€/MWh	€/MWh	€/MWh	€/MWh
10-04-2023	12	10-04-2023	14	2,34	-7,84	9,99	-8,82
10-04-2023	13	10-04-2023	15	0,77	-7,33	1,76	-7,77
10-04-2023	14	10-04-2023	16	1,42	-3,10	2,21	-4,07
10-04-2023	15	10-04-2023	17	2,80	-0,07	2,30	-0,07
10-04-2023	16	10-04-2023	18	25,60	19,49	25,54	19,49

Table 1 - Moderate negative spot prices for DE and DK1

Germany had to get rid of approx. 20 GW (Fig. 1). This resulted in a heavy transit through Denmark towards Norway and Sweden, whereby the Danish networks were pushed to the limit. We do not know to what extent there were operating reserves left to cope with sudden failures.

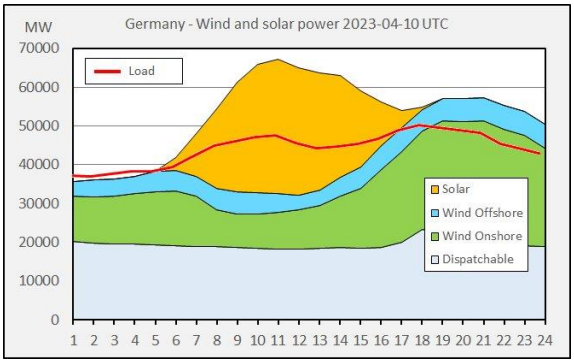

Fig. 1 - Germany exported up to 20 GW

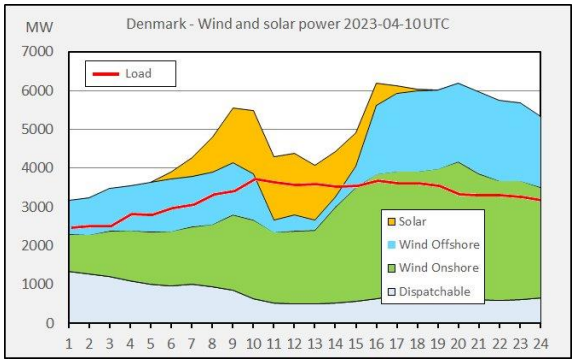

Fig. 2 - Clear downregulation of Danish offshore wind

On **May 10, 2023**, the production of onshore wind in the evening decreased faster than expected.

About 16:00 on Wednesday afternoon it was realized that the wind forecast was wrong (fig. 3). The forecasts are updated 5 hours ahead, 1 hour ahead and "current". The one-hour forecast changed from 17:00 and the 5 hours forecast from 21:00.

Energinet had 81 bids for upwards regulation and activated them all and paid € 4,699.75 per MWh. The next move would have been load-shedding.

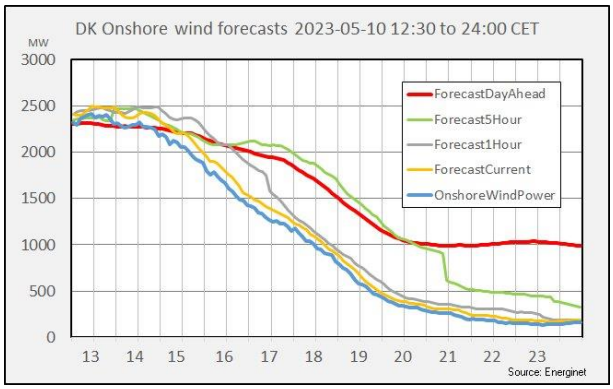

Fig. 3 - The gap between the day-ahead forecast and the onshore wind output was nearly 1000 MW at the end of the day.

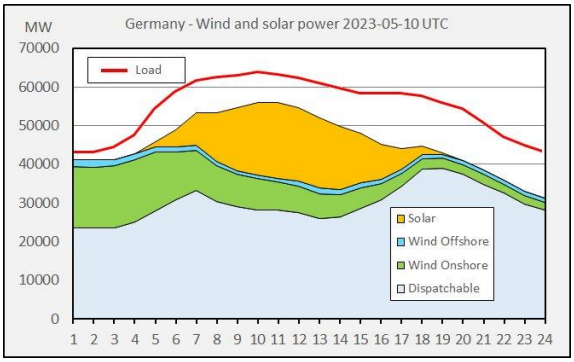

Fig. 4 - Germany imports up to 14.4 GW

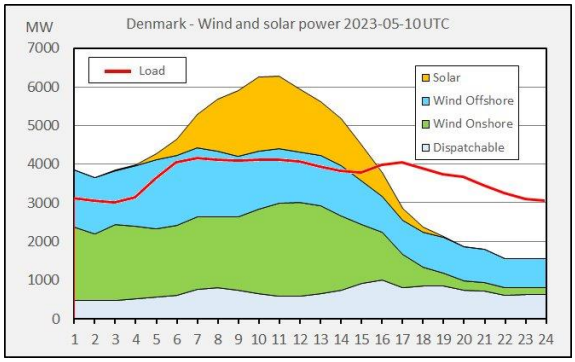

Fig. 5 - Denmark had supply problems in the evening

The graphs show the two days' power balances for both Germany and Denmark. The markets and grids tie the European countries closely together and Germany influences, by virtue of its size and central location, electricity systems in a large part of Europe.

The development of the German power system in the coming years will have an impact on the power systems in the rest of Europe.

Electricity shortage in Finland during a cold week in January 2024

In 2023, Finland had the most volatile spot market for electricity in Europe. This is reported by the Swedish media second-opinion.se[1] on 12 February 2024.

The spot price was negative for 467 hours in 2023 and the standard deviation of the spot price was €57 per MWh. Both numbers were European records. The year's highest and lowest prices touched European records for that year.

Thus, the market had given clear warnings that supply problems could arise in Finland.

In the first week of January 2024, large parts of Finland had temperatures of minus 30 degrees and below for several days in a row. This caused electricity consumption to grow. On 3 January it reached 15,000 MW, which was 700 MW higher than the forecast, made by the Finnish system operator, Fingrid.

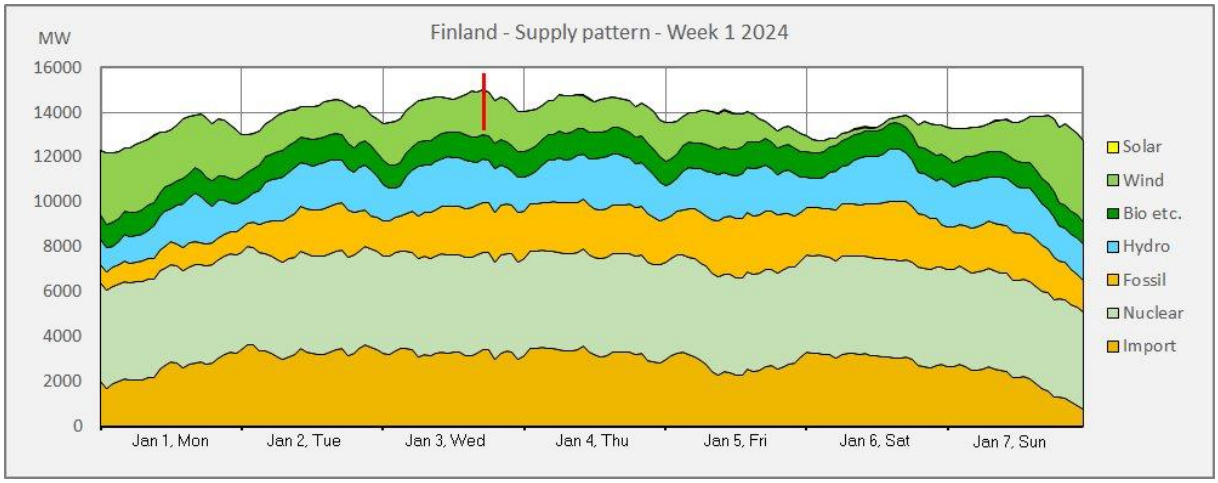

Fig. 6 - Finland barely managed with full imports, nuclear generation and a fair contribution of wind power.

At the critical time, Finland received over 3000 MW from Sweden, Estonia and Norway. Imports from Russia ceased in 2022. The nuclear power plants supplied 4364 MW and the Finnish wind power 1963 MW.

Fingrid declared enhanced alert and made several public appeals for limiting electricity consumption. Finland managed the supply without interruptions, but the margins were small and all contributions were essential to prevent interrupted supplies.

Fingrid and Svenska Kraftnät comment on the current problems

In the Finnish magazine Katternö No. 1 2024, the directors of the system operators in Finland and Sweden have acknowledged that the electricity supplies of the two countries are facing significant problems.

[1] https://second-opinion.se/finland-har-blivit-europas-extremland/

These statements are important signals to political decision-makers, not only in the two countries, but in the entire Nordic area. The hitherto one-sided focus on climate must be supplemented with other goals in order to create a sufficiently robust power system.

Asta Sihvonen-Punkka, CEO of Fingrid: **Now flexibility is the big question**

Asta Sihvonen-Punkka emphasizes the unstable spot market:


Asta Sihvonen-Punkka

> *The scarcity of electricity supply was naturally reflected in **the electricity price**. On Friday, February 5, the electricity price was at a record high: the average daily price on the electricity exchange was 890 euros/MWh (without VAT), during the most expensive hour 1,896 euros/MWh.*
>
> *The extreme situations we have now seen - on November 24 last year we had a negative electricity price of 500 euros/MWh, as a result of an incorrect tender on the electricity exchange - bring the issue of demand flexibility to the fore. Electricity use during the hours of this negative electricity price increased by an estimated 1,000 MW, and decreased by about the same amount when we had the record high electricity.*

A significant growth in electricity consumption will increase the problems:

> *In 2030, **electricity production** is expected to be close to 140 terawatt-hours (TWh) on an annual basis - to compare with 80 TWh last year (2023) - of which approximately half will be wind power electricity. Electricity use is forecast to increase sharply as industry and heat production become electrified. Fingrid estimates that electricity uses in Finland in 2030 will be roughly 130 TWh.*
> *Since such a significant part of electricity production is weather dependent, the ability to be flexible will be central during the periods when there is no wind. Flexibility can be found on the electricity user side, the electricity producer side or with batteries. The cold in January clearly showed the challenges. It only worked up to a certain limit to reduce electricity consumption, to move it within the day or to store the energy for a short time.*

The consequences can be serious:

> *If it is not possible to balance the use of electricity to a sufficient extent and at the same time we experience long-term disruptions in major power plants or if the supply of electricity from abroad is significantly reduced, we in Finland may experience a power shortage.*

New flexible resources must be able to last days or weeks:

> ***Fingrid's assessment is** that in the future Finland needs access to extensive flexibility, which covers the need for several days or even weeks. This resource can be provided through flexible electricity use, flexible weather-independent electricity production and energy storage.*
>
> *We need flexibility resources for both short-term and long-term needs. If these resources cannot be obtained on market terms, they need to be obtained in other ways. The solutions that come into question should be technology-neutral and cost-effective, because in the end it is the electricity users who pay*

Fingrid clearly recognizes a strongly growing need for operational flexibility, while the possible solutions are not specified.

Lotta Medelius-Bredhe, CEO of Svenska Kraftnät: **An unprecedented challenge**

In Sweden, electricity consumption is also expected to increase:


Lotta Medelius-Bredhe

> ***In general terms**, we estimate that electricity consumption has doubled in Sweden already in less than a generation. We have enough to do here, as we have applications for increased capacity withdrawal from the main grid which is in line with that development.*
> *To cope with this, a lot more electricity grids and electricity production need to be built. But more flexibility in the use of electricity is also needed.*

The construction time for new transmission lines is a serious obstacle:

> *However, **grid expansion** takes a long time and the industry's needs are now. It is therefore crucial that we can shorten today's lead times, where the permit process is a large part.*
> *For a few years now, we have been actively working to halve the lead times from today's fourteen to seven years, counted from when a network investigation begins until the line can be put into operation.*
> *We work to increase our own efficiency as well as with other actors who have an important role in the development of the electricity infrastructure - this includes the Swedish Armed Forces, the Energy Market Inspection, which gives us concessions, and the county administrations.*

Sweden needs fossil-free electricity and competitive electricity prices:

> *Now and in the future, access to fossil-free electricity will also be central to international competitiveness. Here, Sweden has a very good starting position as our country is almost one hundred percent fossil-free in electricity production.*
> *Unlike many other countries, we therefore do not need to change, but "only" develop capacity in networks and electricity production. That in itself is no small task.*

The need for flexibility is not given particular importance in Denmark

The Danish system operator, Energinet, publishes an annual report on electricity supply security[2]. The 2023 edition is a very realistic assessment, in which a growing risk of supply interruptions is predicted for the coming years. However, the report does not make it clear enough that new balancing resources should be given higher priority

The background is probably that it has become a Danish habit to buy balancing services abroad, and it has gone quite well so far.

As a result, the issue does not play any particular role in the political debate in Denmark, where the climate goals alone set the agenda. The planned hydrogen plants will be insufficient and will arrive far too late.

[2] Redegørelse for elforsyningssikkerhed 2023 (not yet available in English)

Germany to build 10 GW of gas-fired power plants

We did not notice much debate about flexibility in Germany either, but on February 5, 2024, the German Federal Ministry for Economic Affairs and Climate Action issued a press release[3] that begins as follows:

> *In order to decarbonise and ensure the security of our electricity supply, we need not only a consistent expansion of renewable energy and the grids but also modern and highly flexible climate-friendly power stations. In order to achieve this goal, Federal Chancellor Olaf Scholz, Economic Affairs Minister Robert Habeck and Minister of Finance Christian Lindner have agreed on the central elements of a Power Station Strategy and taken decisions on additional projects.*

The planned facilities are presented as follows:

> *Specifically, the Federal Chancellor, the Federal Minister for Economic Affairs and Climate Action and the Federal Minister of Finance agreed to invite tenders for new hydrogen-ready gas-fired power station capacity of up to 4 times 2.5 GW under the Power Station Strategy in the short term. These gas-fired power stations are to be fully converted to hydrogen between 2035 and 2040, with the specific conversion date to be set in 2032, and are to be set up in locations where they are useful to the system. The funding will be provided by the Climate and Transformation Fund.*

Obstacles will be cleared:

> *In addition, it was agreed that obstacles standing in the way of the establishment and operation of electrolysers will be fully removed and all options to accelerate the expansion of electrolysers, particularly those useful to the system, explored. Furthermore, it is to be ensured that there will be no double-charging of levies and fees on the electricity used for storage and electrolysis, thus providing incentives for the production of hydrogen that are both market-based and useful to the system. All existing regulatory obstacles will be removed to allow for the unrestricted use of surplus electricity.*

This is good news considering how dependent we all are on whether things go well or badly in Germany.

California model for public information on operating reserves

The Californian system operator, CaISO, has since 1998 developed the interaction with electricity consumers on handling situations with a shortage of electricity. This is done by classifying abnormal operating conditions from "Flex alert" to the serious "Energy Emergency Alert 3 (EEA3)" and "Transmission Emergency" (see appendix 1, valid from 2022).

The system has proven its worth in the past years. See the overview 1998-2021 on Appendix 2. The first serious test was the crisis in 2000 and 2001, which ended with the collapse of the electricity market due to an inappropriate market design. The last EEA3 is from 2022 (overview 2022 and 2023 on Appendix 3)..

[3] https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2024/02/20240205-agreement-on-power-station-strategy.html

Appendix 1

Grid Emergencies History Report

California ISO

Reference for Events that Occurred After May 2022:

Flex Alerts are a call to consumers to voluntarily conserve energy when demand for power could outstrip supply. This generally occurs during heatwaves when electrical demand is high. The ISO can declare a Flex Alert whenever there is expected stress on the system. Visit http://www.flexalert.org for more information on Flex Alerts, how to conserve energy, and to sign up for notifications.

RMO (Restricted Maintenance Operations) requires generators and transmission operators to postpone any planned outages for routine equipment maintenance, ensuring all grid assets are available for use.

EEA Watch when the Day-Ahead analysis is forecasting that one or more hours may be energy deficient.

Energy Emergency Alert 1 (EEA1) when real-time analysis is forecasting that one or more hours may be energy deficient.

Energy Emergency Alert 2 (EEA2) when all resources are in use and emergency load management programs are needed.

Energy Emergency Alert 3 (EEA3) when it has taken all actions listed above and cannot meet expected energy and contingency reserve requirements. Notice issued to utilities of potential electricity interruptions through firm load shedding.

Transmission Emergency is declared by the ISO for any event threatening or limiting transmission grid capability, including line or transformer overloads or loss. A Transmission Emergency notice can be issued on a system-wide or regional basis.

California ISO

Summary of Restricted Maintenance Operations, Alert, Warning, Emergency, and Flex Alert Notices Issued from 1998 to April 2022

	Flex Alert	Restricted Maintenance Operations	Transmission Emergency	Alert	Warning	Stage 1 Emergency	Stage 2 Emergency	Stage 3 Emergency	1-Hour Probable Load Interruptions	Voluntary Load Reduction Program
1998	N/A	8	N/A	7	8	7	5	0	N/A	N/A
1999	N/A	12	N/A	2	6	4	1	0	N/A	N/A
2000	20	77	N/A	34	85	55	36	1	N/A	N/A
2001	26	168	N/A	180	181	70	65	38	N/A	N/A
2002	1	18	N/A	3	4	2	1	0	N/A	N/A
2003	0	10	N/A	0	0	1	0	0	N/A	N/A
2004	6	16	6	1	2	1	0	0	N/A	N/A
2005	7	13	5	0	2	1	2	0	N/A	N/A
2006	18	16	0	1	5	3	1	0	N/A	3
2007	6	18	4	1	3	1	0	0	N/A	N/A
2008	3	10	0	0	1	0	0	0	N/A	N/A
2009	0	6	6	0	2	0	0	0	N/A	N/A
2010	0	8	1	0	1	0	0	0	N/A	N/A
2011	2	17	2	0	1	0	0	0	N/A	N/A
2012	2	134	0	0	0	0	0	0	N/A	N/A
2013	3	11	0	0	0	0	0	0	N/A	N/A
2014	1	8	1	0	1	0	0	0	N/A	N/A
2015	2	10	0	1	2	0	0	0	N/A	N/A
2016	3	11	0	0	0	0	0	0	0	N/A
2017	4	18	9	0	0	1	0	0	0	N/A
2018	2	22	2	0	0	0	0	0	0	N/A
2019	1	2	3	0	1	0	0	0	0	N/A
2020	10	20	2	9	7	0	6	2	1	N/A
2021	8	24	0	0	4	0	1	0	0	N/A
2022	0	0	0	0	0	0	0	0	0	N/A
TOTALS	**125**	**657**	**41**	**239**	**316**	**146**	**118**	**41**	**1**	**3**

Appendix 3

Revision Date: 12/15/2023

California ISO

Summary of Restricted Maintenance Operations, Flex Alerts, Transmission and Energy Emergencies Issued from May 2022 to Present

	Flex Alert	Restricted Maintenance Operations	Transmission Emergency	EEA Watch	EEA1	EEA2	EEA3
2022	11	16	10	9	6	5	1
2023	0	6	2	2	1	0	0
TOTALS	**11**	**22**	**12**	**11**	**7**	**5**	**1**