PTDF Analysis
Insights from Detailed Grid Modeling

Aleksei Seleznev,
Director IT, Montel - SYSPOWER
23 Jan 2025

MONTEL

Who we are

Long Term Power Outlook

Nordic/Baltic and European power forecast for up to 40 years

Risk report

PPA analysis and area-specific report

SYSPOWER

Web tool – data, forecasts and analysis on power markets

Montel SYSPOWER -

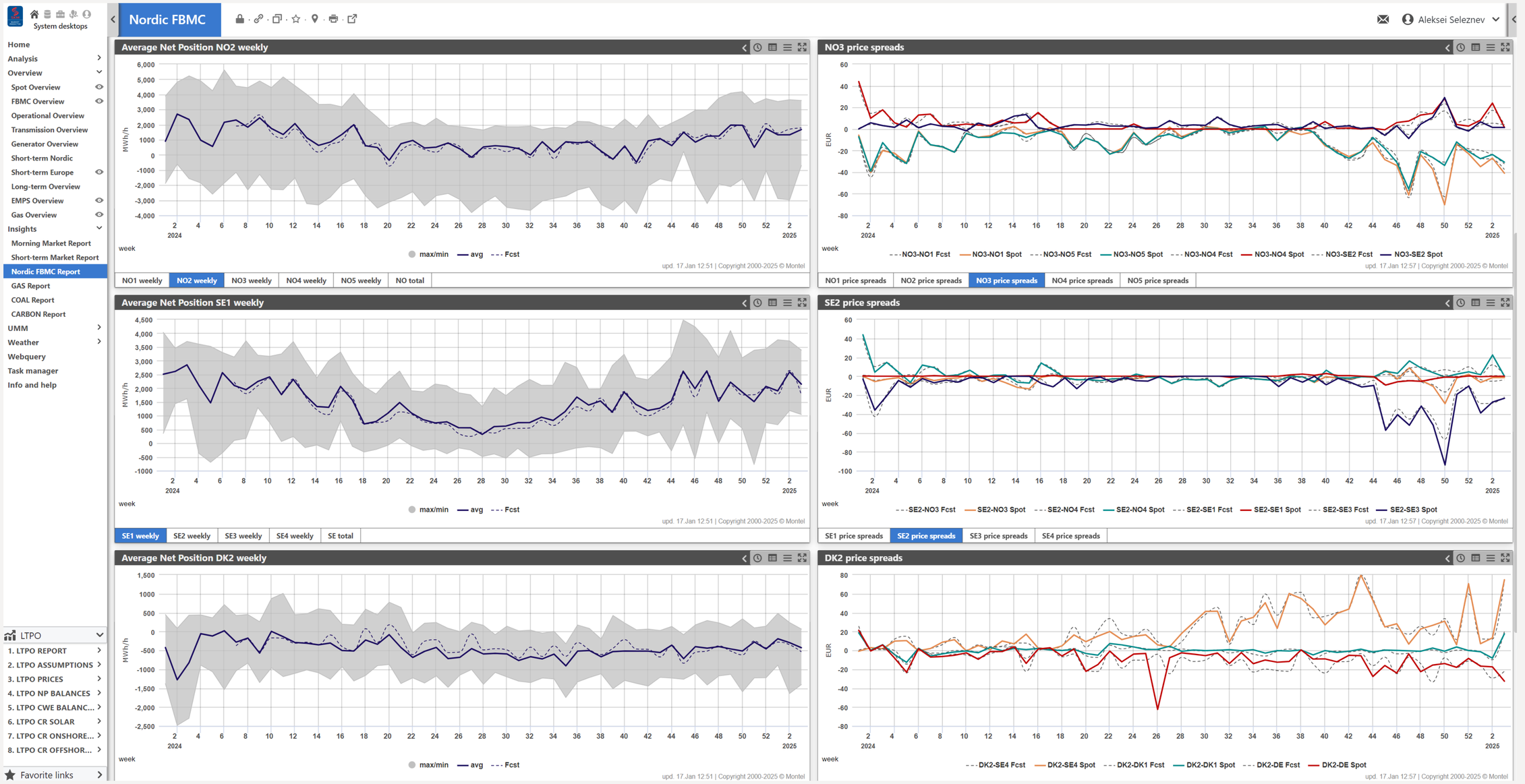
leading provider of analysis and advisory services for Nordic power and renewable markets

Profitability of RES production

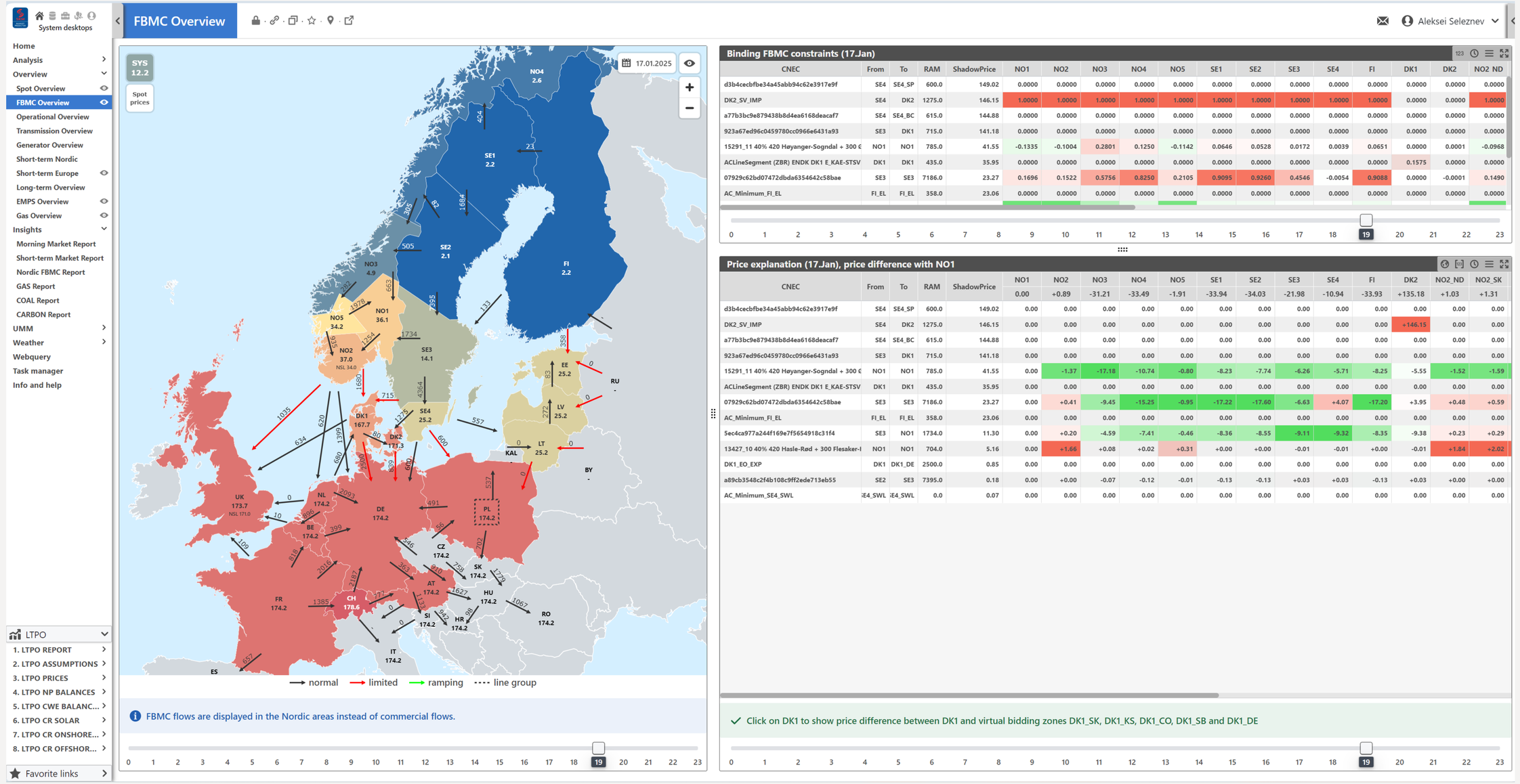
Standard and tailor-made calculations

Advisory

SYSPOWER Analytical Platform. Nordic FBMC Insights



SYSPOWER Analytical Platform. FBMC Overview



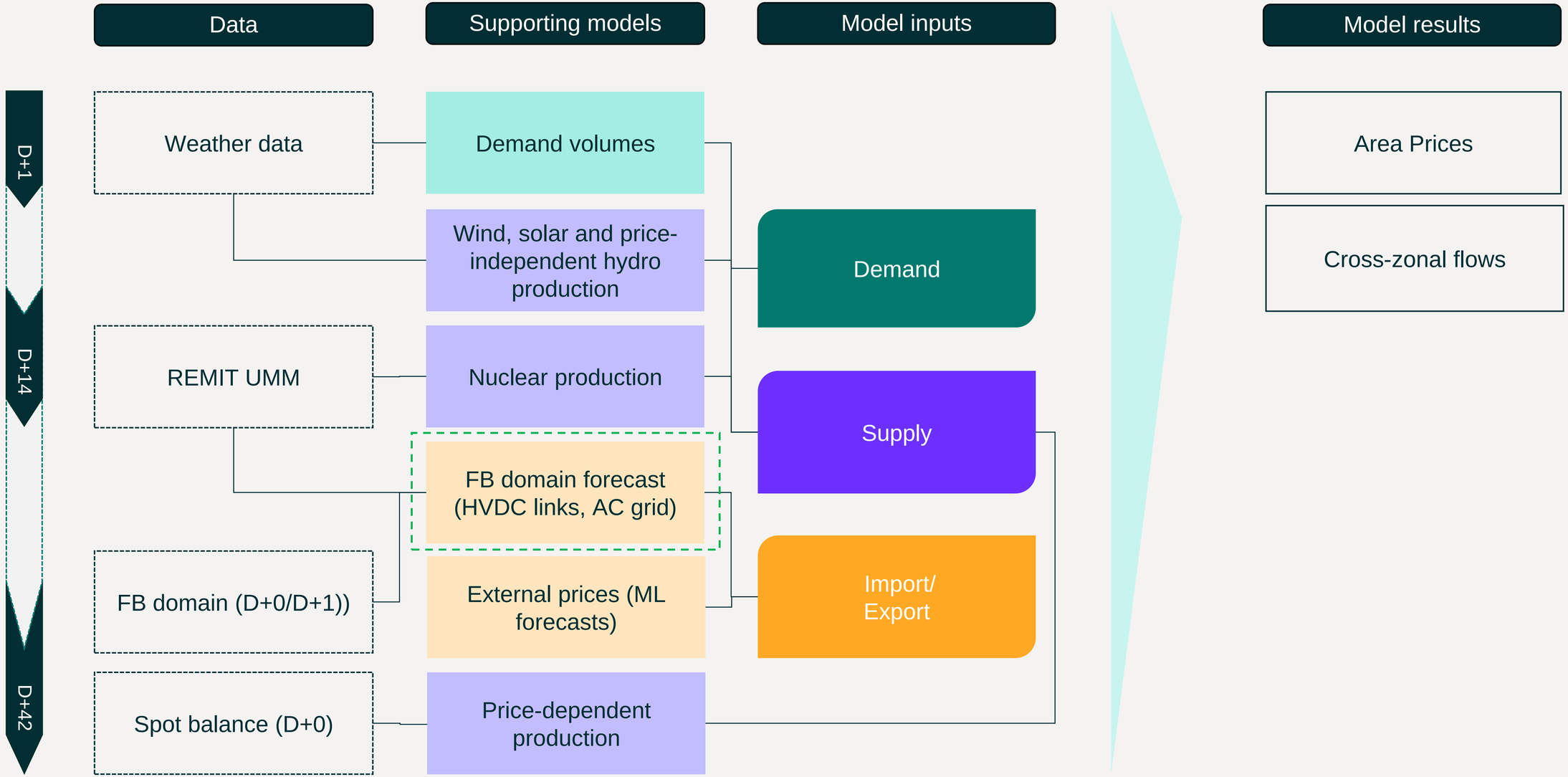
Binding FBMC constraints (17.Jan)

CNEC	From	To	RAM	ShadowPrice	NO1	NO2	NO3	NO4	NO5	SE1	SE2	SE3	SE4	FI	DK1	DK2	NO2_ND
d3b4cecbfbe34a45abb94c62e3917e9f	SE4	SE4_SP	600.0	149.02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DK2_SV_IMP	SE4	DK2	1275.0	146.15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000
a77b3bc9e879438b8d4ea6168deacaf7	SE4	SE4_BC	615.0	144.88	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
923a67ed96c0459780cc0966e6431a93	SE3	DK1	715.0	141.18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15291_11 40% 420 Høyanger-Sogndal + 300 €	NO1	NO1	785.0	41.55	-0.1335	-0.1004	0.2801	0.1250	-0.1142	0.0646	0.0528	0.0172	0.0039	0.0651	0.0000	0.0001	-0.0968
ACLineSegment (ZBR) ENDK DK1 E_KAE-STSV	DK1	DK1	435.0	35.95	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1575	0.0000	0.0000
07929c62bd07472dbda6354642c58bae	SE3	SE3	7186.0	23.27	0.1696	0.1522	0.5756	0.8250	0.2105	0.9095	0.9260	0.4546	-0.0054	0.9088	0.0000	-0.0001	0.1490
AC_Minimum_FI_EL	FI_EL	FI_EL	358.0	23.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Price explanation (17.Jan), price difference with NO1

CNEC	From	To	RAM	ShadowPrice	NO1	NO2	NO3	NO4	NO5	SE1	SE2	SE3	SE4	FI	DK2	NO2_ND	NO2_SK
					0.00	+0.89	-31.21	-33.49	-1.91	-33.94	-34.03	-21.98	-10.94	-33.93	+135.18	+1.03	+1.31
d3b4cecbfbe34a45abb94c62e3917e9f	SE4	SE4_SP	600.0	149.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DK2_SV_IMP	SE4	DK2	1275.0	146.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	+146.15	0.00	0.00
a77b3bc9e879438b8d4ea6168deacaf7	SE4	SE4_BC	615.0	144.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
923a67ed96c0459780cc0966e6431a93	SE3	DK1	715.0	141.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15291_11 40% 420 Høyanger-Sogndal + 300 €	NO1	NO1	785.0	41.55	0.00	-1.37	-17.18	-10.74	-0.80	-8.23	-7.74	-6.26	-5.71	-8.25	-5.55	-1.52	-1.59
ACLineSegment (ZBR) ENDK DK1 E_KAE-STSV	DK1	DK1	435.0	35.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07929c62bd07472dbda6354642c58bae	SE3	SE3	7186.0	23.27	0.00	+0.41	-9.45	-15.25	-0.95	-17.22	-17.60	-6.63	+4.07	-17.20	+3.95	+0.48	+0.59
AC_Minimum_FI_EL	FI_EL	FI_EL	358.0	23.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5ec4ca977a244f169e7f5654918c31f4	SE3	NO1	1734.0	11.30	0.00	+0.20	-4.59	-7.41	-0.46	-8.36	-8.55	-9.11	-9.32	-8.35	-9.38	+0.23	+0.29
13427_10 40% 420 Hasle-Rød + 300 Flesaker-I	NO1	NO1	704.0	5.16	0.00	+1.66	+0.08	+0.02	+0.31	+0.00	+0.00	-0.01	-0.01	+0.00	-0.01	+1.84	+2.02
DK1_EO_EXP	DK1	DK1_DE	2500.0	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
a89cb3548c2f4b108c9ff2ede713eb55	SE2	SE3	7395.0	0.18	0.00	+0.00	-0.07	-0.12	-0.01	-0.13	-0.13	+0.03	+0.03	-0.13	+0.03	+0.00	+0.00
AC_Minimum_SE4_SWL	E4_SWL	E4_SWL	0.0	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

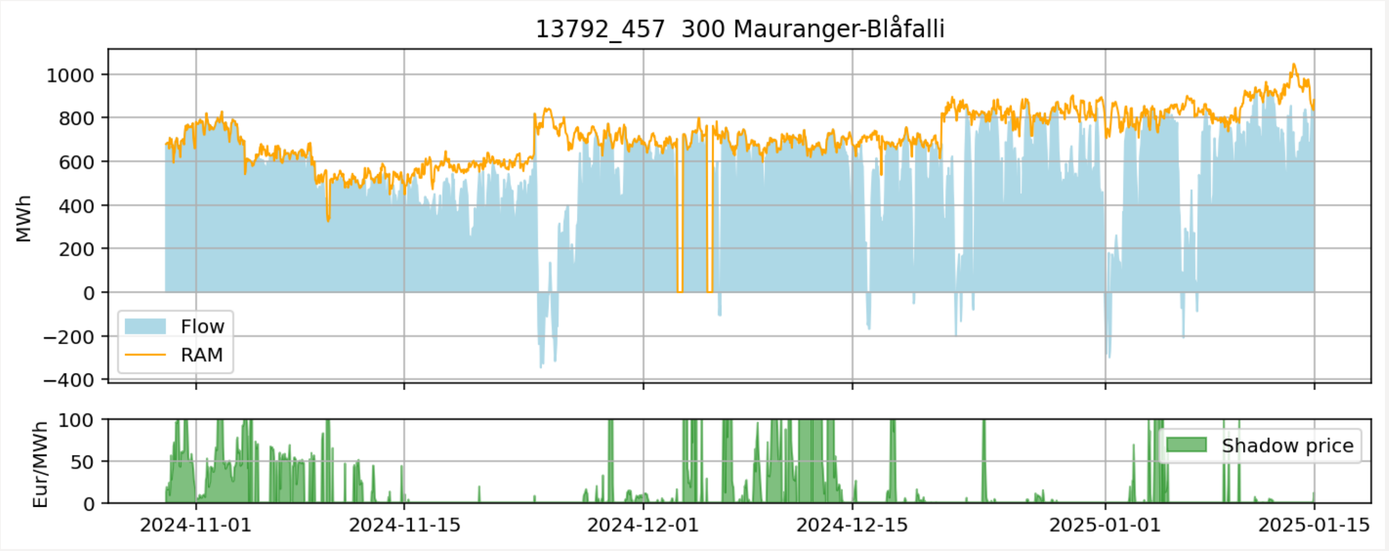
Short-term analysis process

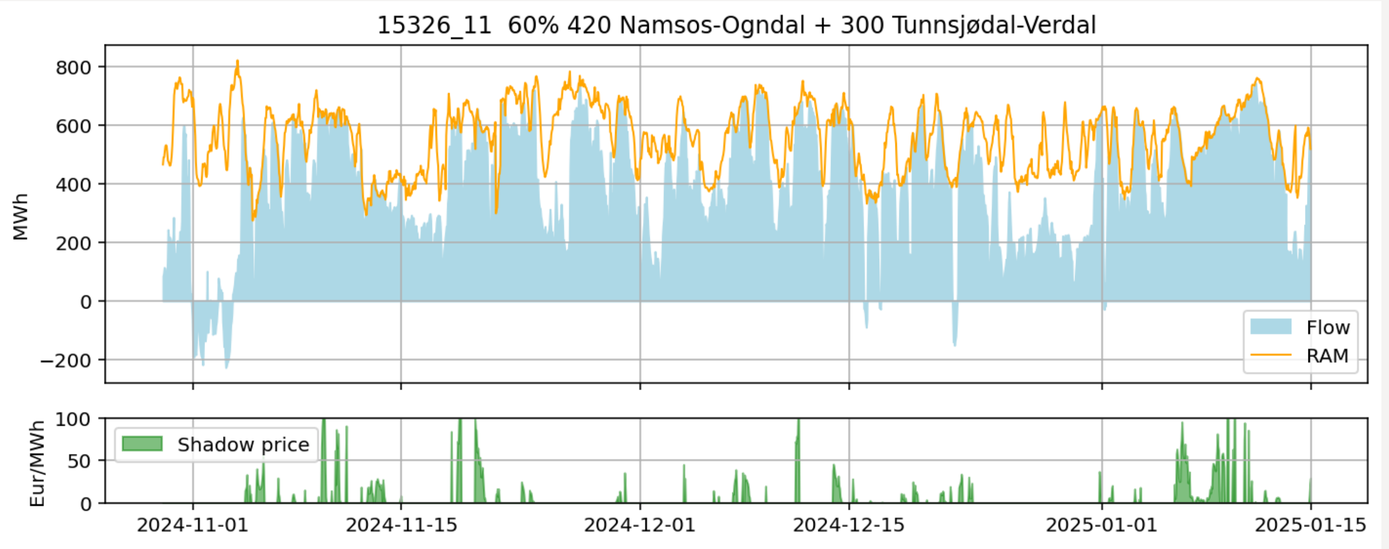


Binding constraints: 80 days of the Nordic FBMC - I

Non-encrypted active CNECs (excluding HVDCs, SE3-DK1, and SE1-FI)

Tso	ZoneFrom	ZoneTo	CnecName	ShadowPrice	Hours
STATNETT	NO5	NO5	13792_457 300 Mauranger-Blåfalli	94.65	609
STATNETT	NO1	NO1	15291_11 40% 420 Høyanger-Sogndal + 300 Øvre Vinstra-Fåberg	34.58	415
STATNETT	NO4	NO4	15326_11 60% 420 Namsos-Ogndal + 300 Tunnsjødal-Verdal	28.72	340
STATNETT	NO5	NO5	15288_11 80% 300 Refsdal-Modalen + Aurland1 T4 Transformator S	57.47	206
STATNETT	NO1	NO1	15291_11 40% 420 Moskog-Høyanger + 300 Øvre Vinstra-Fåberg	34.67	178
STATNETT	NO2	NO2	13792_458 65% 420 Rød-Grenland + 300 Rød-Porsgrunn	88.75	172
STATNETT	NO5	NO5	L1034_325.437 65% 420 Aurland 1-Usta + 65% 420 Aurland1-Sima + 300 Sogndal-Hove	189.48	103
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_KAE-LYK_3 1 N Terminal : N	389.25	90
STATNETT	NO2	NO2	L15827_10 20% 420 Rjukan-Kvilldal + 300 Husnes-Børtveit	81.72	78
STATNETT	NO3	NO3	13792_418 40% 300 Øvre Vinstra-Fåberg + 420 Moskog-Høyanger	23.92	77
ENERGINET	DK1	DK1	PowerTransformer ENDK DK1 TJE KT51 2 Terminal : S	46.96	74
ENERGINET	DK1	DK1	ACLineSegment (ZBR) ENDK DK1 E_KAE-STSV Z1 F Terminal : F	184.53	66
STATNETT	NO4	NO4	15326_11 65% 420 Tunnsjødal-Namsos + 300 Tunnsjødal-Verdal	41.03	49
FINGRID	FI	FI	FI_P1_VUOLIJOKI-ALAPITKA_PETAJAVESI-PYSAYSPERA	134.9	46
ENERGINET	DK1	DK1	PowerTransformer ENDK DK1 ASR KT51 1 Terminal : P	96.5	43
STATNETT	NO2	NO2	14311_182 97% Sauda T2 Transformator P + Sauda T3 Transformator P	55.73	40
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_AND-BDR 1 N Terminal : N	10.52	25
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_FOU-MOSV 1 F Terminal : F	45.48	24
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 C_KAS-REV_2 1 F Terminal : F	17.71	24
STATNETT	NO1	NO1	13427_11 40% 420 Hasle-Tegneby + Hasle T6 Transformator P	39.91	23
STATNETT	NO1	NO2	15320_10 420 Sylling-Rjukan + 420 Hasle-Rød + 300 Sylling-Flesaker + 300 Tegneby-Flesaker	13.24	18
STATNETT	NO3	NO3	13792_457 300 Vågåmo-Øvre Vinstra	43.7	12
STATNETT	NO1	NO1	13427_11 40% 420 Hasle-Tegneby + 300 Hasle-Tegneby	9.78	10
ENERGINET	DK1	DK1	PowerTransformer ENDK DK1 TRI KT51 1 Terminal : P	250.41	9
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_FGV-FVO 1 N Terminal : N	38.14	8
STATNETT	NO1	NO1	13427_10 30% 420 Hasle-Rød + 300 Sylling-Flesaker	15.32	8
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_ADL-ÅBØ 1 F Terminal : F	2.76	5
ENERGINET	DK1	DK1	PowerTransformer ENDK DK1 ASR KT51 2 Terminal : S	150.29	5
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_VHA-ÅBØ 1 N Terminal : N	37.94	5
ENERGINET	DK1	DK1	ACLineSegment (ZBR) ENDK DK1 E_STSV-VID Z1 F Terminal : F	316.69	5
ENERGINET	DK1	DK1	PowerTransformer ENDK DK1 TJE KT51 1 Terminal : P	17.29	5
STATNETT	NO1	NO1	L15827_10 50% 420 Hasle-Rød + 300 Sylling-Flesaker	13.98	4
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_AND-BDR 1 F Terminal : F	51.65	3
STATNETT	NO5	NO5	15291_11 70% 420 Ørskog-Viklandet + Aurland1 T4 Transformator S	30.56	3
STATNETT	NO1	NO1	L13576_11 30% 420 Tegneby-Hasle + 300 Flesaker-Hof	202.55	3
STATNETT	NO2	NO2	L77_11 20% 420 Rjukan-Kvilldal + 300 Husnes-Børtveit	32.17	3
STATNETT	NO3	NO3	15291_183 55% 420 Nea-Klæbu + 420 Namsos-Ogndal + 300 Tunnsjødal-Verdal	41.29	3
STATNETT	NO5	NO5	15291_11 70% 420 Ørskog-Viklandet + 70% 132 Kjelbotn-Bø Rauma + Aurland1 T4 Transformator S	20.01	3
STATNETT	NO2	NO2	L15834_183 100% 420 Samnanger-Sima + 300 Husnes-Børtveit	13.96	2
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_HASV-MAL 1 N Terminal : N	110.14	2
STATNETT	NO1	NO1	15291_11 40% 420 Viklandet-Ørskog + 40% 132 Bø-Kjelbotn + 300 Øvre Vinstra-Fåberg	61.79	2
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 C_ASR-TJE 1 F Terminal : F	16.02	2
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_FOU-MOSV 1 N Terminal : N	5.33	1
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_SHE-SØN 1 N Terminal : N	5.28	1
ENERGINET	DK1	DK1	ACLineSegment ENDK DK1 E_TAN-TJE 1 F Terminal : F	1.1	1
ENERGINET	DK1	DK1	PowerTransformer ENDK DK1 KIN KT51 2 Terminal : S	14.04	1
ENERGINET	DK2	DK2	PowerTransformer ENDK DK2 ISH T42 2 Terminal : S	19.88	1



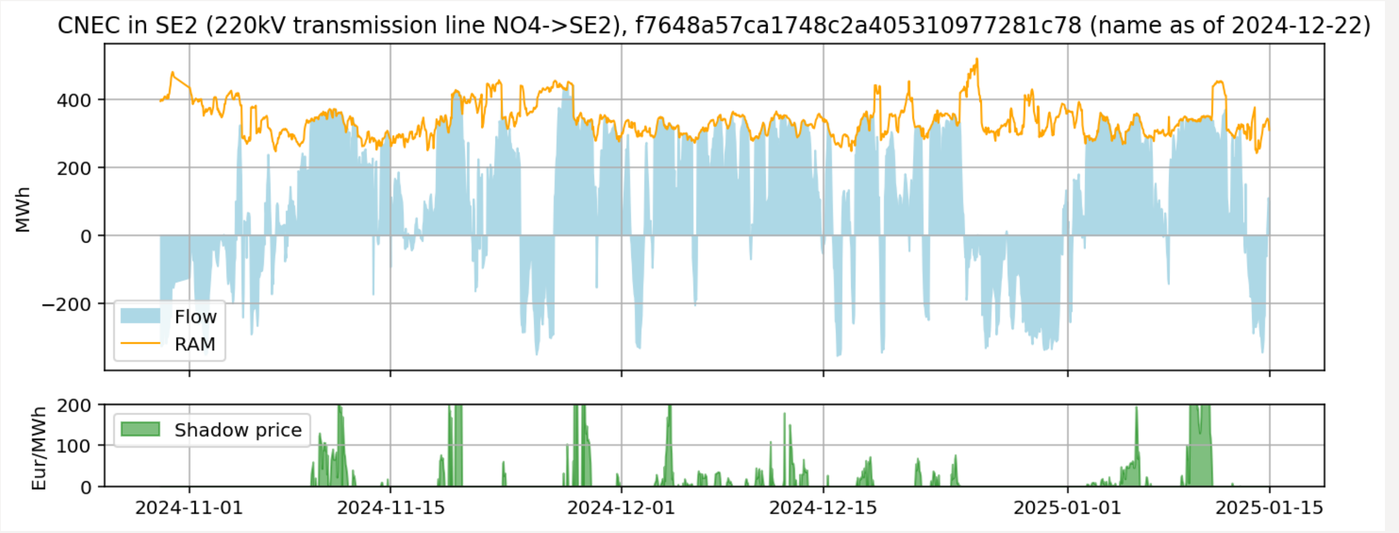


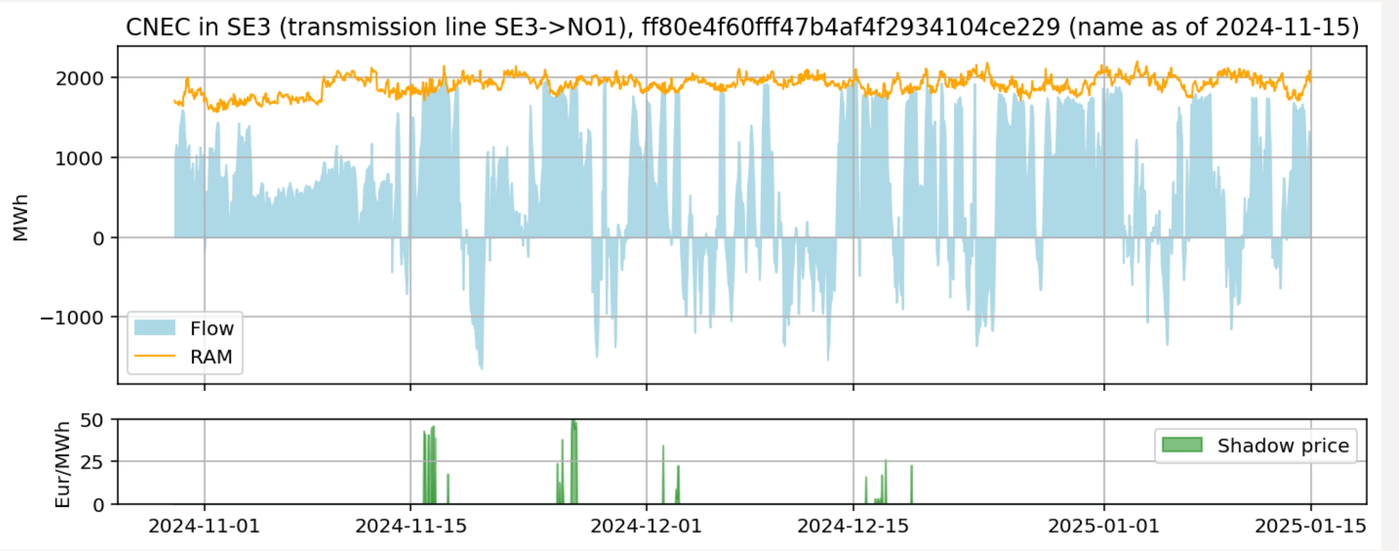
Binding constraints: 80 days of the Nordic FBMC - II

Encrypted active CNECs (excluding HVDCs, SE3-DK1, and SE1-FI)

id	Tso	ZoneFrom	ZoneTo	CnecName (names are not persistent between different dates!)	ShadowPrice	Hours
670	STATNETT	SE2	SE2	f7648a57ca1748c2a405310977281c78	76.70	409
753	SVK	SE2	SE2	ff6afda83a7d441192e9e562c53243f1	312.77	302
750	SVK	SE2	SE2	f218b848e19f4d6e8ff69853ebc7c529	113.92	284
799	SVK	SE3	SE3	ece2ac65b00e496ca11f8af3d2ea36ed	180.00	179
751	SVK	SE2	SE2	d44b6190b40a4b799b9d18a948b417e3	127.89	128
770	SVK	SE2	SE2	f2bfd4c5c4894e35a8ceb7cc3dae635e	185.83	91
646	STATNETT	NONE	NONE	fe177ce538d04d8d8aad6c52b055a323	24.94	90
659	STATNETT	SE1	SE1	f9e1968d2900455eb98b1c4ebfc6d21d	18.10	83
749	SVK	SE2	SE2	ab1998f0c03f4d6986622274aa797cc2	225.88	44
616	STATNETT	NO3	NO3	fbb01db4ba894c0f8bc23a02f0085cc1	30.89	41
827	SVK	SE3	SE3	ff80e4f60fff47b4af4f2934104ce229	28.52	41
673	STATNETT	SE2	SE2	f1f3e1ebcc984312ae54cf5890866803	247.61	38
729	SVK	SE1	SE1	c7f588157d8b424bbce27ff2fe4a716d	3.49	38
786	SVK	SE2	SE2	edb674fd23dd40729c949758d13dcfec	109.71	36
682	STATNETT	SE2	SE2	4043ad1a1c6f4b56a838112208991a6c	112.03	23
615	STATNETT	NO3	NO3	6a12bd80884f41868b95468142c0ac8c	15.71	19
814	SVK	SE3	SE3	cd60f5ab89cd4029a2f29e8506862fde	131.35	19
857	SVK	SE4	SE4	60220c9ba3804cdb8a82d0ecca47b92b	16.65	19
780	SVK	SE2	SE2	f2864bf32292456289948e8a1e9d667f	6.00	18
591	STATNETT	NO1	NO1	b538940b30144322a29cecb6fbe821e0	21.92	17
651	STATNETT	NONE	NONE	f9114f515a734ed59da03e1d32c55827	5.92	17
590	STATNETT	NO1	NO1	e63a91cc450d4ff6afc7ba722975d089	11.98	14
821	SVK	SE3	SE3	30bf19ea52724513a51b59899d028b71	493.00	14
811	SVK	SE3	SE3	e67d51c6615a4ddd9f5f070da1c472f2	58.06	13
800	SVK	SE3	SE3	9fabfc3ee8074014b88290a41ce26cd5	534.72	8
592	STATNETT	NO1	NO1	7e9f4fbbceaf46299f931b1e1f29c435	37.54	6
620	STATNETT	NO3	NO3	e9402366790349ba8066400cf0e3dbd8	42.86	6
623	STATNETT	NO3	NO3	5be9ef41e5734fde9483105f98b3f23e	1.68	6
815	SVK	SE3	SE3	f22a80c265394bb8b225ce37159e952f	41.19	5
832	SVK	SE3	SE3	390eaec5e04f4c15bee2d7578fe43cfb	8.20	5
589	STATNETT	NO1	NO1	f4ad3a136b444488a8144d63dcda6a5c	1.83	4
761	SVK	SE2	SE2	c31c155925524403b4e3b198defd2843	33.54	4
860	SVK	SE4	SE4	e42fcd49f5d44868aa1e00f8e522e64e	3.28	4
618	STATNETT	NO3	NO3	39520db1d3d94212af2ec904d3ecabcf	8.73	3
648	STATNETT	NONE	NONE	54ac53d52c524f4aaf6893acdca3499c	3.86	3
611	STATNETT	NO3	NO3	9c164046dd3643fb864584b59db41a02	11.11	2
625	STATNETT	NO3	NO3	f376da7bfdcc4f6d8a0d927d219d5abb	3.28	1
725	SVK	SE1	SE1	db36a99d29d64e22a0658f6546ba89b8	63.57	1
726	SVK	SE1	SE1	d1390d7730c44673a161c1c21e172d70	5.12	1
787	SVK	SE2	SE2	e92acc10271440bfae7bec9b03c9772e	97.72	1
788	SVK	SE2	SE2	d1f4ae07dc1b4d8881de4d43274bd345	161.62	1

- 12322 unique encrypted CNEC names over the period
- 260 unique encrypted CNEC names for active CNECs
- Only 41 different active CNECs



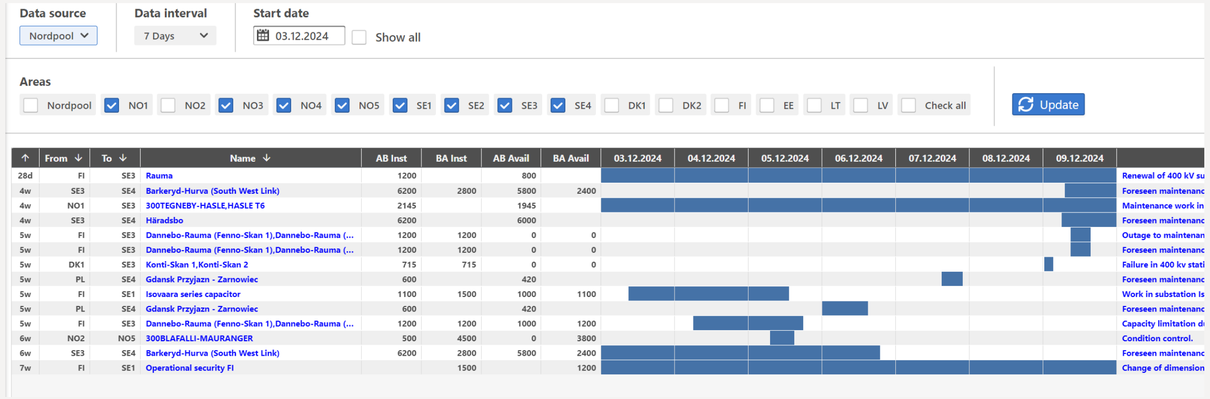


FB Domain Analysis Framework

- Transmission constraints, reference net positions and reference power flows are published daily by 10:30 on jao.eu for each CNEC:

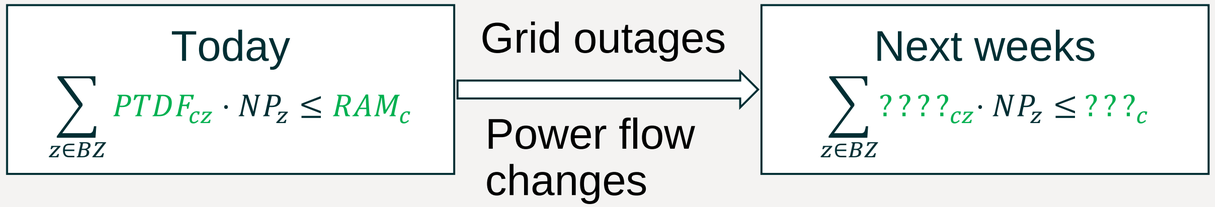
$$\sum_{z \in BZ} PTDF_{cz} \cdot NP_z \leq RAM_c, \forall c \in CNECs$$

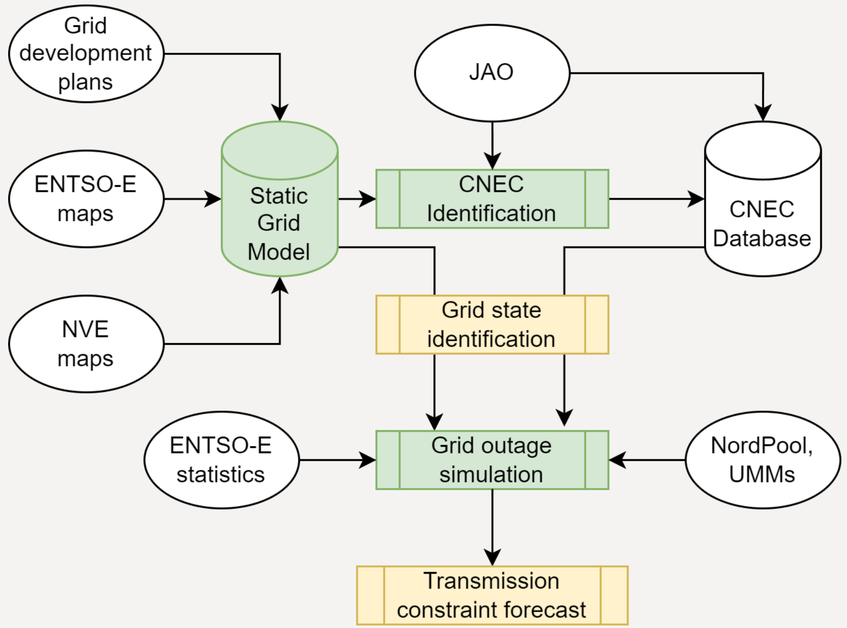
- Grid maintenance plans are available through the Urgent Market Messages (UMM) system:



- Detailed grid models are not available for Nordics
  - But public grid maps are available (ENTSO-E, NVE, etc)
- The names of Swedish CNECs are encrypted and cannot be used to determine the exact locations of these elements
  - But models can provide insights into their names and locations

CnecName	NO1	NO2	NO3	NO4	NO5	SE1	SE2	SE3	SE4	FI
13f1b741ccbf4a7480ab08d81b0b739c	0.0315	0.0280	0.1154	0.1333	0.0402	0.0048	-0.0121	-0.0039	-0.0010	0.0034
00b4f01b41bb477ebe9020fe454135aa	-0.0631	-0.0268	0.2846	0.1400	0.0067	0.0434	0.0183	0.0064	0.0016	0.0420
29f4582c8acf44dc8f0af65ec3e16c98	0.0215	0.0193	0.0789	0.0975	0.0271	-0.0182	-0.0092	-0.0038	-0.0009	-0.0182
2dc2ed54c1ec413e924dbfe9e215be39	0.0116	0.0103	0.0426	0.1327	0.0147	0.01	-0.004	-0.002	-4E-04	0.0087
6d56d1e6f9834c5e8f5b841374c1afe1	0.0315	0.028	0.1154	0.1333	0.0402	0.0048	-0.012	-0.004	-0.001	0.0034



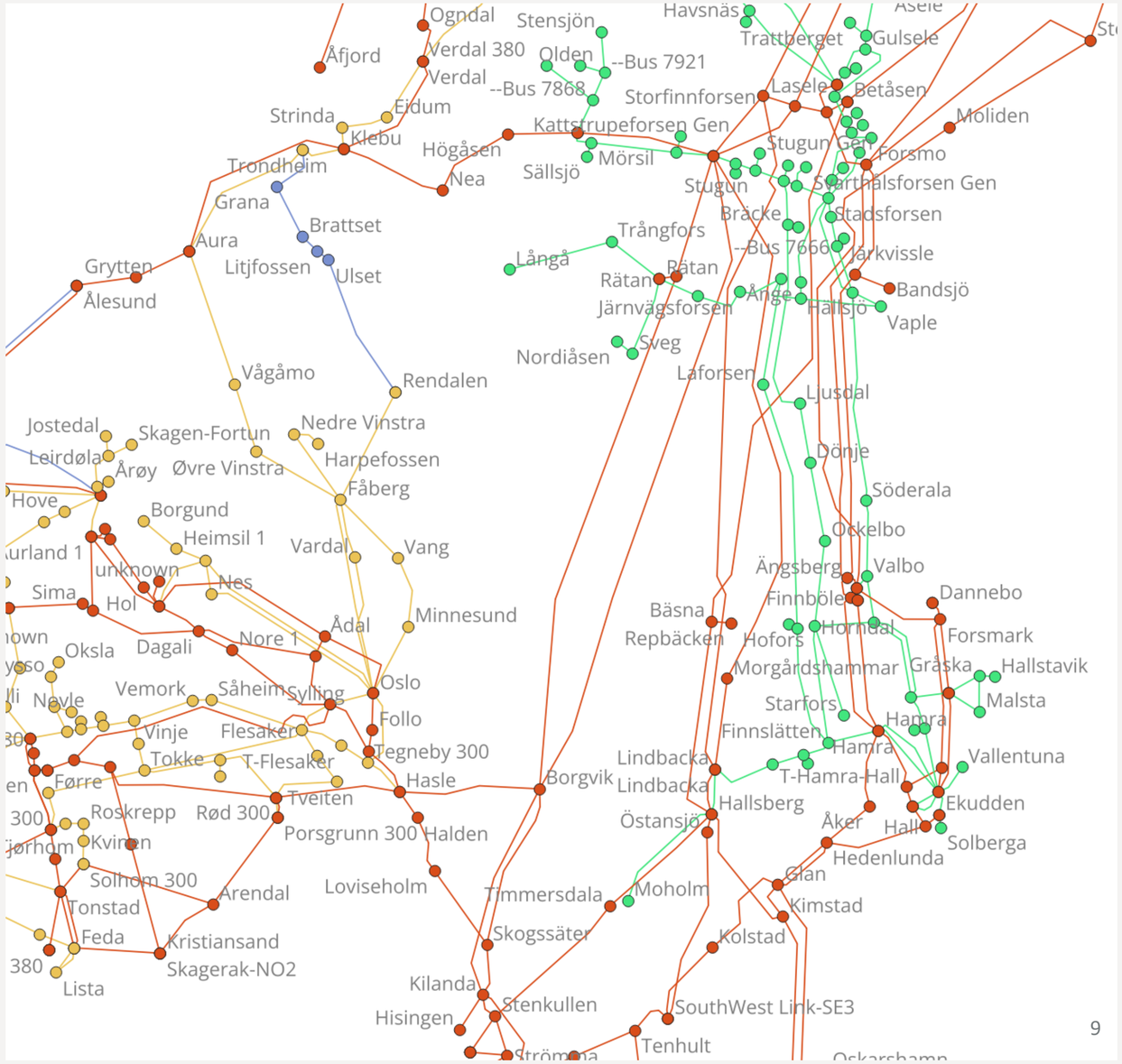


Nordic Grid Model

- Further development of PyPSA-Eur[1] and Nordic-490[2] models
- Based on ENTSO-E and NVE grid maps:
  - Coordinates for substations and generators
  - Voltage classes and geometries for overhead transmission lines
  - Coordinates for HVDC converters
- Transmission system 220+ kV, some important parts of 130 kV
- Model statistics:

Nodes	**520** (380kV – 202, 300kV – 101, 220kV – 140, 130kV - 77)
Lines	**617** (380kV – 263, 300kV – 114, 220kV – 145, 130kV - 95)
Transformers	**60**
Generators	**1075**

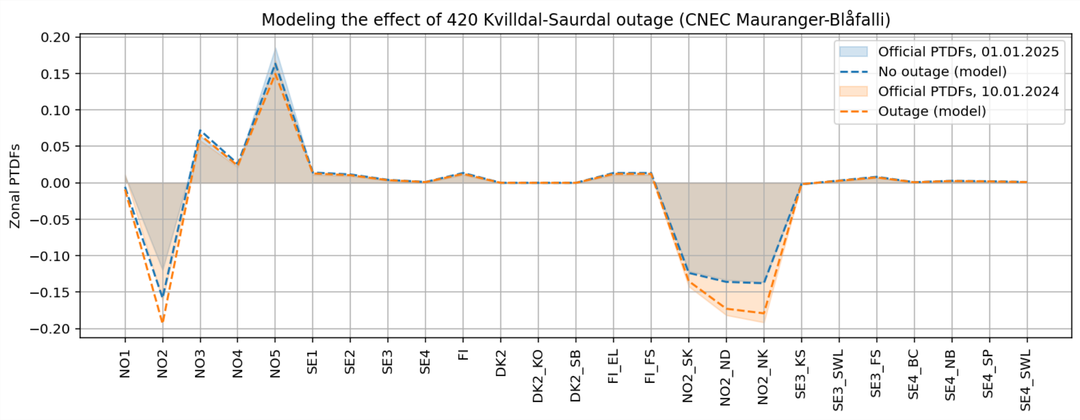
- Grid impedances estimated based on voltage class and line length
- Series capacitors fitted using an optimization-based model
- Topology developed in QGIS and exported to Python
- DC-OPF model is used to calculate nodal sensitivity factors (PTDFs)
- Static and dynamic GSK strategies are employed to transform nodal PTDFs into zonal PTDFs.



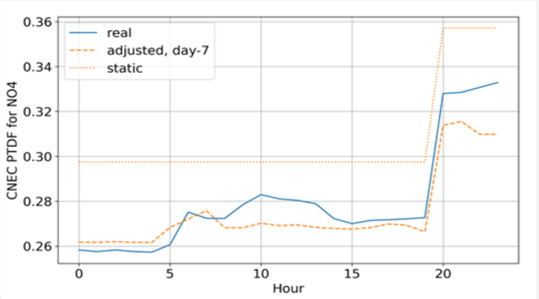
1. Hörsch, J., Hofmann, F., Schlachtberger, D. and Brown, T., 2018. PyPSA-Eur: An open optimisation model of the European transmission system. Energy strategy reviews, 22, pp.207-215.
2. Kumar, A.S., Kouveliotis-Lysikatos, I., Nycander, E., Olauson, J., Marin, M., Amelin, M. and Söder, L., 2021, June. Open nodal power flow model of the nordic power system. In 2021 IEEE Madrid PowerTech (pp. 1-6). IEEE.

Grid topology changes: analysis and modeling

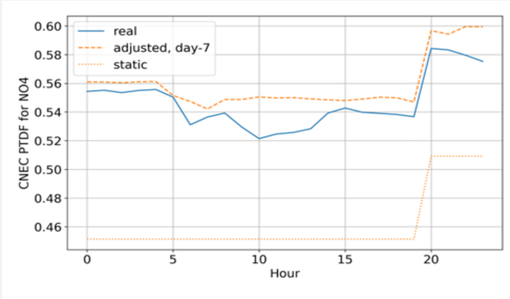
- Changes in grid topology can be observed in CNEC PTDFs
  - However, for some CNECs, significant volatility is introduced by GSKs
- Nodal PTDFs (HVDC hubs) demonstrate better stability as they are not affected by GSKs
- Observing multiple CNECs simultaneously helps identify grid topology state, even if changes are not reflected or are inaccurately reflected in UMMs



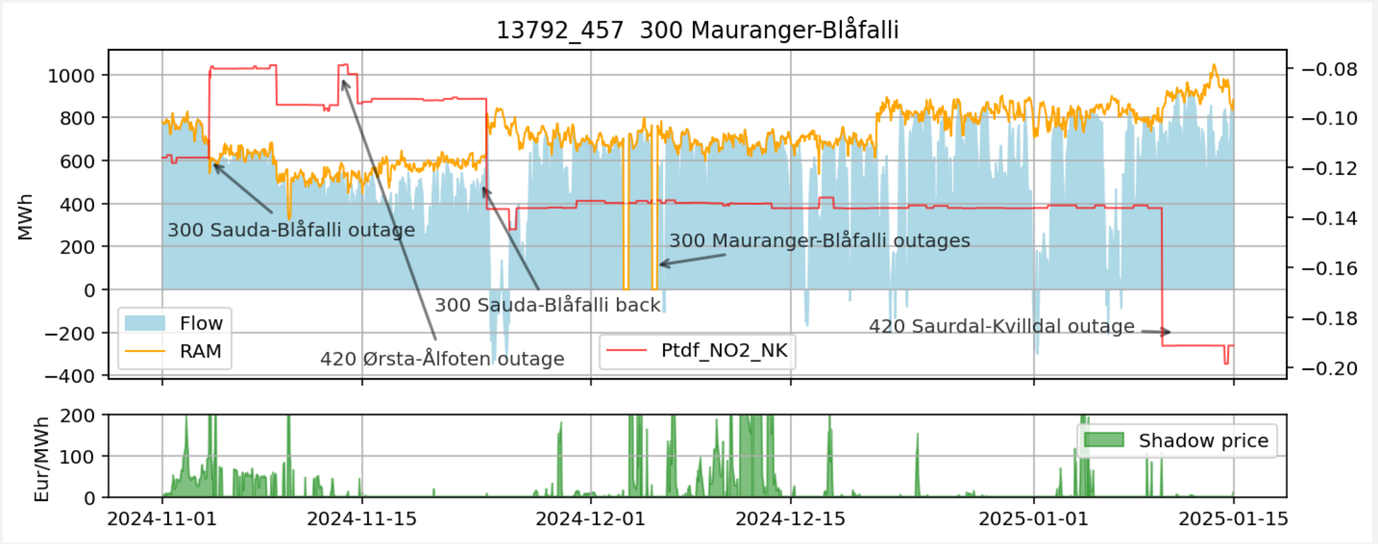
Model of transmission line outage started at 20:00 (220 Ajaure – Gardikfors). GSKs are important.

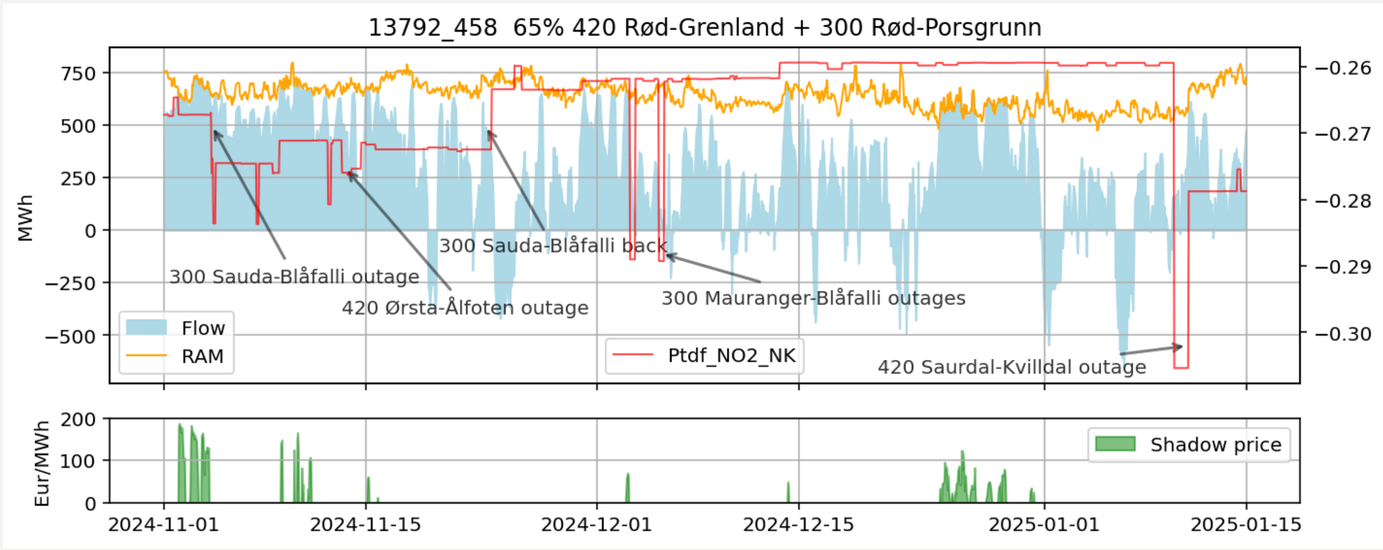


Changes in PTDF for 420 Tunnsjødal-Namsos+300 Tunnsjødal-Verdal



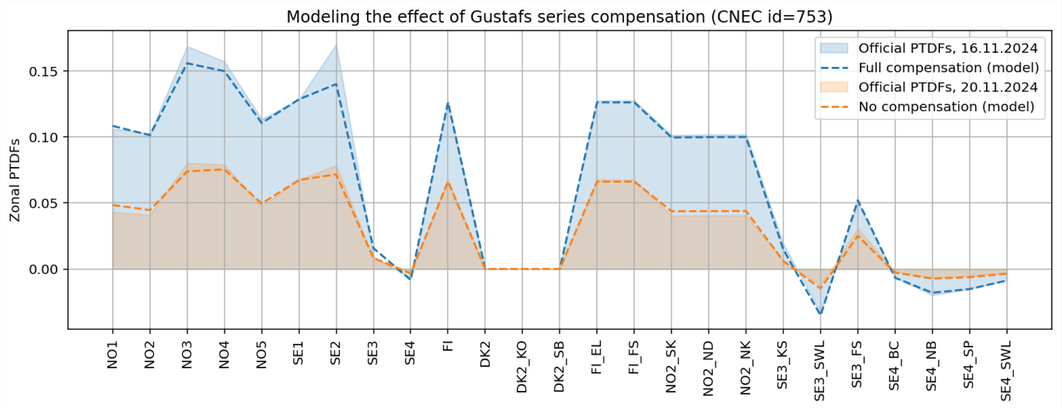
Changes in PTDF for Border_CNEC_NO4-SE1

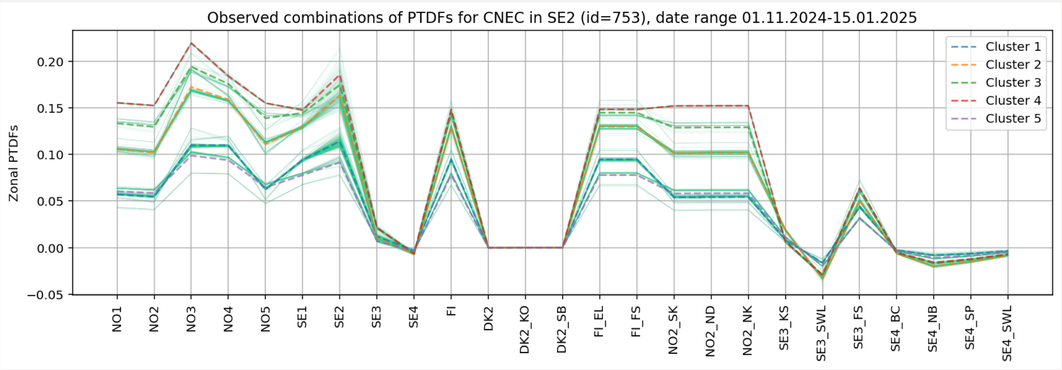


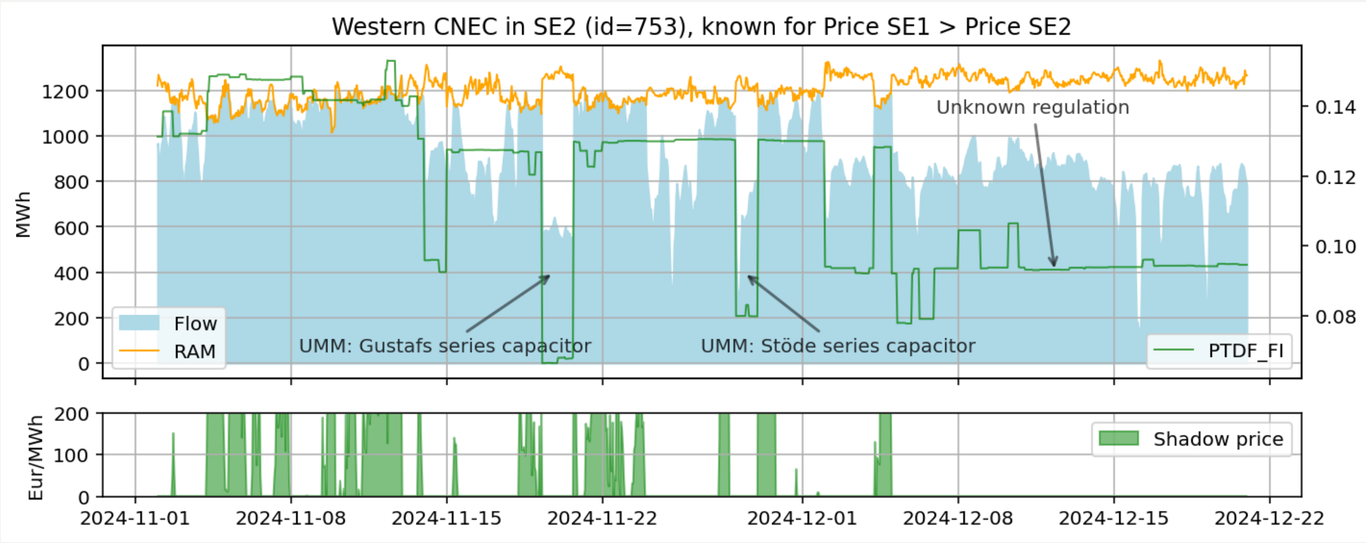


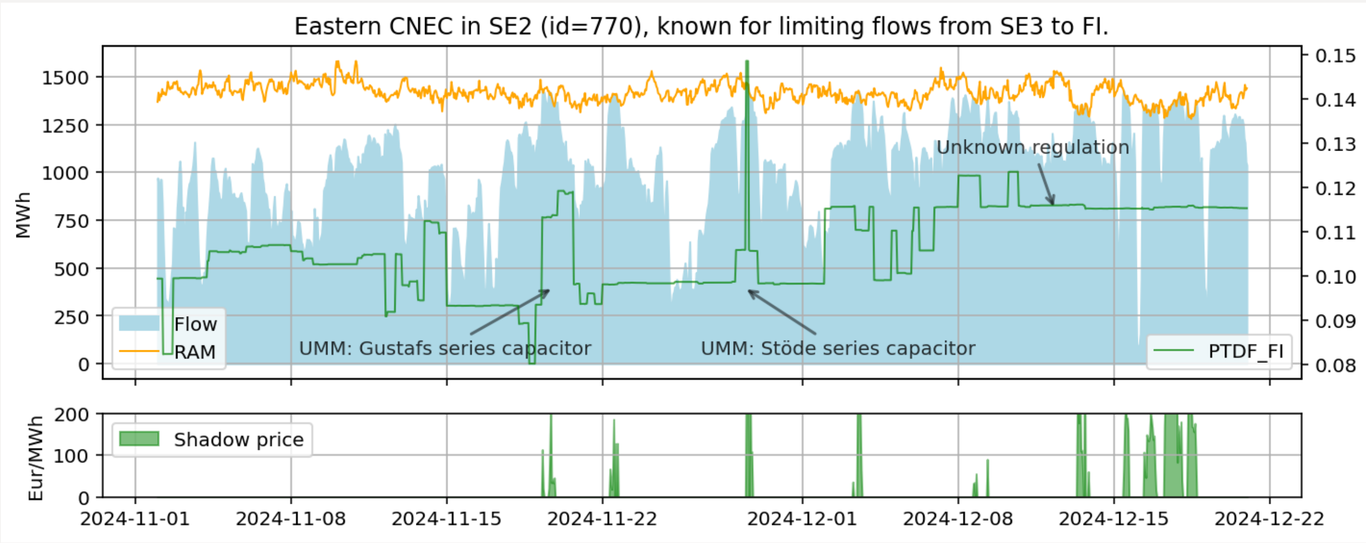
Series compensation: analysis and modeling

- Series compensation is applied on 400kV transmission lines SE2-SE3 and on Letsi – Petäjäskoski (SE1-FI)
- Exact compensation level is uncertain and power-flow specific
  - Models can be used to fit compensation levels to historical data, but accurately predicting future levels remains challenging.
- Insufficient number of CNEs in SE2 hinders identification
- Limited amount of information in UMMs
  - 05-06.12 significant changes were observed in CNECs in SE2. No UMMs!









Example: why price in SE1 is higher than in SE2

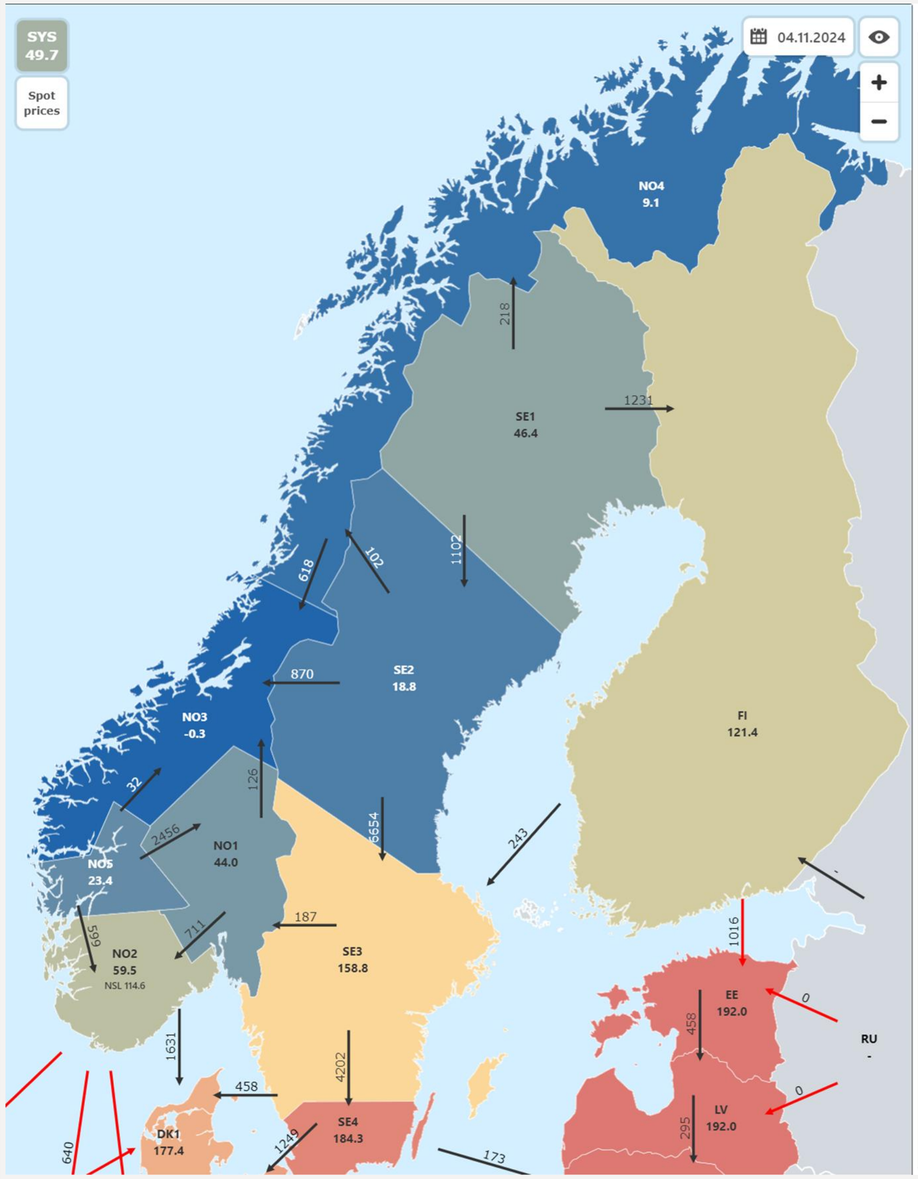
- Price spread SE1 > SE2 with flow SE1->SE2 was introduced with FBMC.
- The reason is in capacity limitations for transmission lines on SE2-SE3 interface.
  - When these constraints are active, the price in SE2 is usually lower than in SE1, even if the flow goes south.
  - This is due to Ptdf_SE2 > Ptdf_SE1 on these CNECs
- Grid in SE2 is not uniform, and different nodes have different sensitivity factors for these CNECs.
  - With help of detailed grid model, it can be visualized as “nodal prices”
- Considered date 04.11.2024 16:00 has several active CNECs. Most important for the calculations are:
  - 10a62bda216d4e9f88bd55cb77d0ec8b (SE2)
  - 13792_457 300 Mauranger-Blåfalli (NO5)
  - FI_PTC_RAC_SE1-FI (SE1-FI)
  - 15291_183 55% 420 Nea-Klæbu + 420 Namsos-Ogndal + 300 Tunnsjødal-Verdal (NO3)
- Nodal price :

$$\lambda_n = \lambda_{slack} - \sum_{c \in CNECs} PTDF_{cn} \cdot \lambda_c, \forall n \in N$$

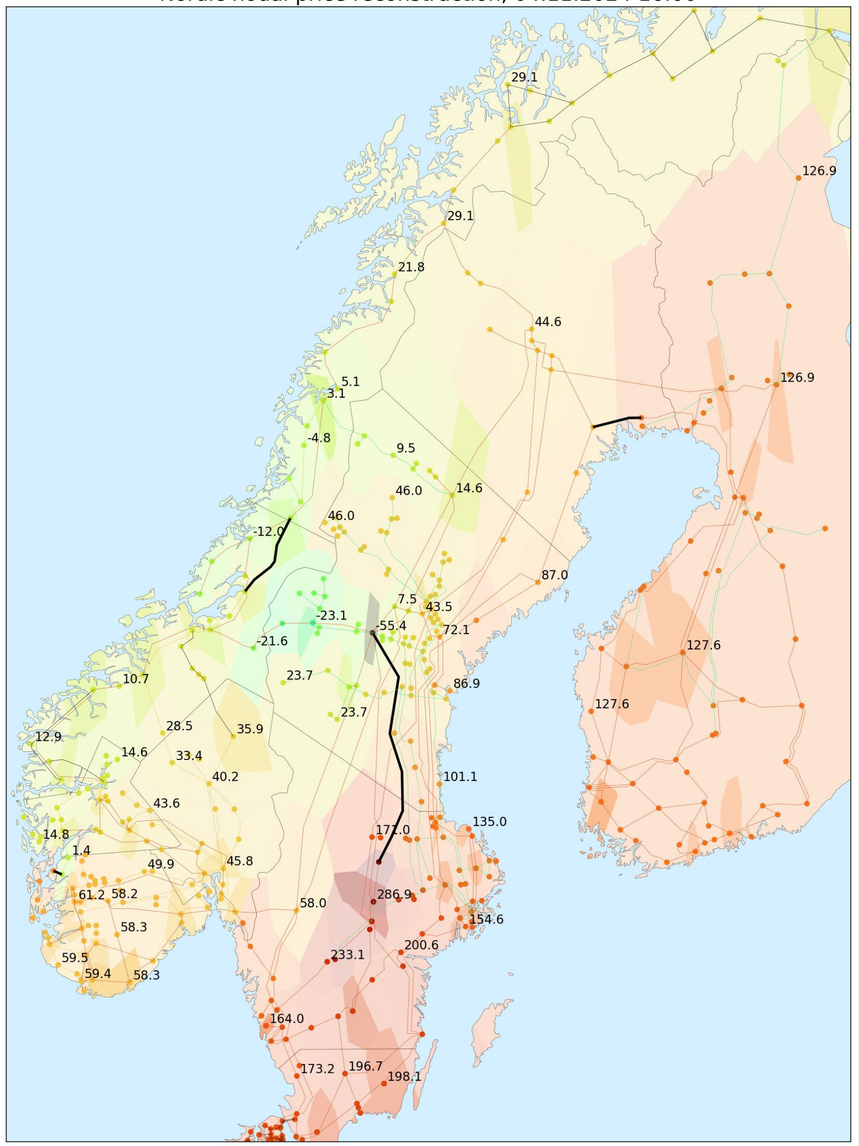
λ_{slack} - price in slack node (DK2), λ_c - shadow price of the CNEC and $PTDF_{cn}$ **- node-to-slack PTDF of the CNEC**. Zonal price is GSK-weighted average of zone’s nodal prices:

$$\lambda_z = \sum_{n \in N_z} \lambda_n \cdot GSK_{nz}, z \in BZ,$$

- NB! This is not a real nodal market simulation. All generators and loads in the zone contribute to the zonal net position according to their GSKs and cannot reoptimize these GSKs.



Nordic nodal price reconstruction, 04.11.2024 16:00



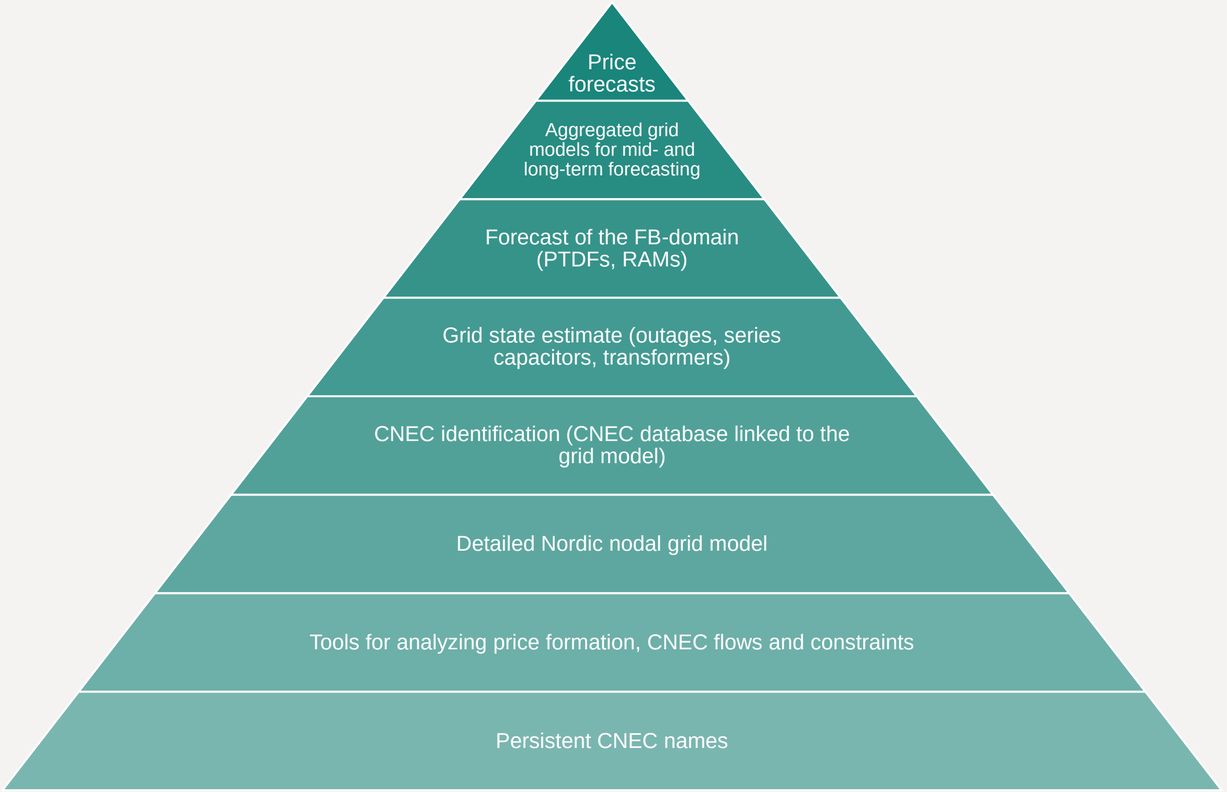
Summary

- Nordic FBMC has significantly increased the transparency of transmission grid constraint management:
  - FB domain provides a lot of useful information (CNECs with reference flows, PTDFs, RAMs), whereas previously we only had UMMs and d+1 SDAC NTCs.
- Detailed grid modeling is possible even without assistance from TSOs:
  - The grid model, based on geographical maps, shows reasonable results, accurately estimates PTDFs, and responds to changes in grid topology as expected.
  - The model can be verified and adjusted using the published FB domain, with unknown parameters estimated through optimization-based algorithms.
- Developing and maintaining such models is costly and time-consuming. Smaller participants may rely on services from Solution Providers:
  - Detailed grid model is used for de-anonymizing encrypted CNECs, providing support for analysis.
  - A high level of grid detail is required for short-term forecasting (up to 14 days).
  - Aggregated grid models can be used for medium- and long-term forecasting.

- TSOs can significantly contribute by:
  - Making static grid models publicly available (Statnett, SVK, Fingrid).
  - Stopping CNEC name randomization (SVK, #WeNeedCnecNames).
  - Providing more accurate data on grid parameter changes through UMMs and remedial actions.
  - Publishing mid-term forecasts of the FB domain

- Additional tools, beyond JAO's publication tool, should be developed by Solution Providers to assist participants with FBMC :
  - Price formation analytics.
  - Analytics and visualization of grid constraints for different time horizons.
  - Stable CNEC names (currently, SVK randomizes CNEC names daily, making analysis difficult).

Detailed grid modeling approach



Thank you!
Q&A

Aleksei Seleznev,
Montel – SYSPOWER

Feel free to reach out to me on LinkedIn if you have any questions.
https://www.linkedin.com/in/a-seleznev

MONTEL