Nordic Capacity Calculation Methodology Project (Nordic CCM)

# Operational learning points during the external parallel run of the Nordic flow-based methodology

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# Content

# Introduction

External parallel run (EPR) is conducted to ensure a proper implementation of the Nordic flow-based methodology (FB) and an adequate comparison to the current capacity calculation method (NTC). During the EPR, Nordic CCM has ensured and will ensure necessary improvements of our input data, modelling and processes in general. Hence, the EPR should be used as a learning-by-doing experience. This means that during the EPR, the comparison between NTC and FB has at times been affected by issues in either one of the approaches. This should not disqualify the NTC capacities or FB domains, or the market coupling results computed with them. Neither of the processes are able to capture perfectly all possible aspects at all times, and the varying levels of contribution (e.g., primary focus being on the operational issues instead of simulations), differences in process timings, or other mistakes may have affected the comparability of the NTC and FB results. It should be noted that also after go-live, the Nordic TSOs and Nordic RCC will continue to improve the flow-based process as and when needed.

This document aims to collect and explain the operational learning points that the TSOs have encountered during the EPR. The document covers both the KPI reporting period of the NRA report (12 December 2022-12 March 2023) but also new findings that have been encountered after publishing the 3-month NRA report. It should be noted that the SEW impacts of the operational learning points may be either positive or negative, when comparing FB to NTC, and depend on the specific case.

# Overview and affected time periods

This section lists the most important identified operational learning points during the last six months that are further clarified later in the document. Some items are still ongoing, which is indicated with an arrow at the right end of the time interval. Others only affected the results for a certain time period. Transparent lines indicate that the issue was present, but that it did not affect the results.

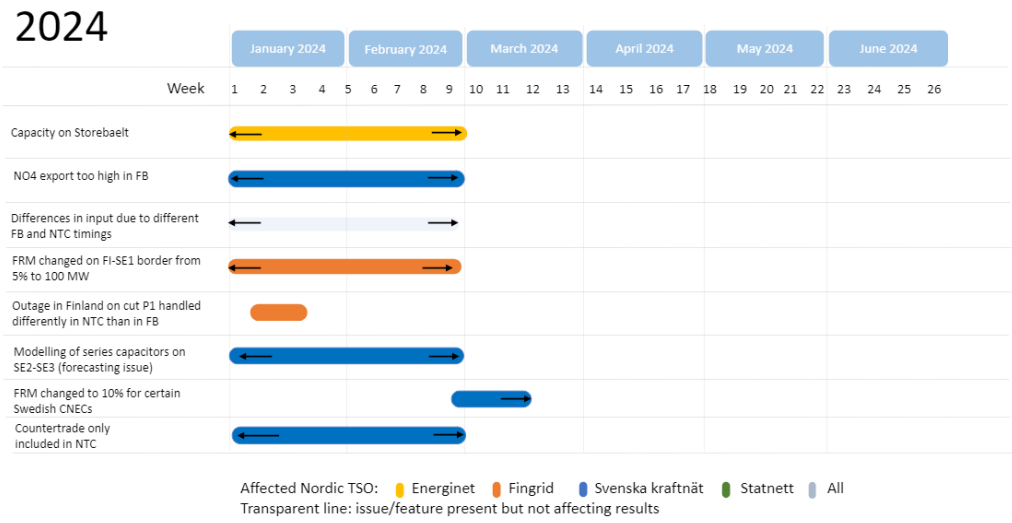


Figure 1. Timeline of the most significant operational learning points during 2024. A more detailed timeline for all items can be found in the Appendix.

# Identified operational learning points

## Countertrade only included in NTC

**Please note!** This text has been updated on February 27th, 2024. The relevant period has been updated and the previous version of the Operational learning points also stated that the inclusion of countertrade would be ready before Go-live.

Svenska kraftnät had procured production resources in the south of Sweden during the period December 2022 – September 2023 and from December 2023 and onward production resources have been procured again. These acquired resources, when activated, have bolstered capacity in the Net Transfer Capacity (NTC), enabling a more substantial flow between SE2 and SE3. The procured production resources are currently not included in the FB domain. Consequently, the 'missing' production

resources in FB contribute to a larger flow being allowed between SE2-SE3 in NTC than in FB. The procured production resources resulted frequently in an increased NTC-capacity on the border SE2->SE3 during the period December 2022 until mid-March 2023 and June 2023 until mid-September 2023. During the periods mid-March 2023 until the start of June 2023 and December 2023 until the publishing day of this document the NTC-capacity on the same border has only been increased for a few days.

It has not been possible to prioritize the inclusion of the countertrade in the FB domain and it is foreseen to be implemented when such implementation has reached a satisfactory level of development quality but is not expected to be ready before FB go-live. The border between SE2 and SE3 is the largest corridor in the Nordic CCR for transporting electricity from North to South. When the grid topology (see also the Section about Series compensator modelling) and countertrade modelling in FB does not match the one in NTC, this has an impact on the cross-border capacity and henceforth on the comparison of prices, congestion income, and welfare distribution between flow-based and NTC.

## Modelling of series capacitors on SE2-SE3

**Series capacitors in FB modelled with even distribution of flows**

Between 12 December 2022 and 28 February 2023, the series compensators on the SE2-SE3 border had different setups in FB and NTC. The practice in FB was to have an even distribution of expected flows on the capacitors. In NTC, the operational status is instead adjusted to the expected situation in operation. This resulted in the maximum permissible flow in NTC being higher than in FB, which led to some network elements situated on the SE2-SE3 border being the most constraining elements in the Nordic CCR. Since 1st of March 2023, the management of the series capacitors has been improved in FB to fit the expected operational status. This has resulted in a better alignment of the maximum allowed flow between NTC and FB. Note: For a few instances since March 1, 2023, the modelling of series capacitors has again not matched the setup in NTC. This occurred on 21 March, and 3-6 April 2023.

**Forecasting issues in FB compared to NTC**

After the management of the series capacitors in FB was improved in March 2023, there is a risk remaining that the forecast of the situation in operation differ from the real outcome. This means that recurrently, for some hours or days there can be differences in the series capacitor setup in FB compared to NTC which affect the flow on the SE2-SE3 border. The forecasting issue is expected to decrease after FB go live

as the timings of IGM creation and receival of the market outcome will be changed compared to the timings during EPR.

## Error in visualization of flow in NTC on SE3-SE4 border

Since the start of the EPR (December 2022), the flow in NTC on the SE3-SE4 border has been calculated incorrectly in the post-market scripts that are used to visualize the data and create the reports. This calculation flaw stems from an error in how the flow on the South West Link is represented on the border, resulting in a too large flow on the SE3-SE4 border for the NTC data. As this error comes from the visualization of data rather than the market optimization, it does not have an impact on the SEW figures. However, it affects the values of flow on the border for NTC in the Appendices of the weekly market reports. This error was rectified starting from week 20 publication.

## NO4 export is too high in FB

Part of the explanation of why the net position in NO4 is higher in FB than in NTC is more varying, and sometimes higher capacity between NO4-SE1 in FB than in NTC. The current GSK strategy is not optimal for some production units near the NO4-SE1 border. Svenska kraftnät is assessing how these can be revised and improved.

Earlier, there was too high export in NO4 in FB due to wind production in northern Norway that the capacities in FB did not consider. Estimation from RES has been added to the IGMs as of September, so this is no longer a significant issue.

## Capacity on Storebælt

For the entire EPR period the capacity on DK1->DK2 has in flow-based been set to 600 MW instead of the correct 590 MW that is the case in NTC. The issue stems from internal IT programs which complicate the process of setting the correct capacity.

## Fenno-Skan (FI-SE3) ramping

Ramping refers to active power flow change of HVDCs between one market time unit (MTU) to another. It has been observed that FB allocated flows on FI-SE3 have had a higher variation compared to NTC allocated flows. Occasionally, ramping has been higher than what is technically possible in the operation of Fenno-Skan. Similar outcome is not observed from the NTC results.

Potentially Fenno-Skan ramping restrictions could be applied in FB go-live. Ramping will be further studied with a 600 MW/h ramping limit. Currently HVDCs within a synchronous area do not have ramping according to Nordic System Operational Agreement (SOA).

## Number of polarity reversals

Polarity reversals on HVDCs have been observed to occur quite frequently in FB which is not consistent with the current usage of HVDC equipment in NTC. Further analysis is ongoing.

## IT issues affecting allocation constraint

In the process of creating the IGM for 3 April 2023, an allocation constraint on the DK1↔DK2 border was incorrectly submitted. When the error was discovered, it was too late to submit a new allocation constraint through an internal IT system that handles this, and manual editing was not possible. In total this limited the transfer capacity for eight MTUs for both FB and NTC.

## Incorrect IVAs for an out-of-service CNE

For five hours on 20 March 2023, a CNE which was supposed to be out-of-service due to maintenance was still part of the IGM and market coupling, although it should not have been. In order to avoid this CNE having an impact on the system operation, operators applied IVAs to set the RAM to zero. As the CNE had been part of the optimization it had a PTDF value ≠ 0, and with a RAM of zero the CNE limited the system very much since the NP could not be increased in certain places without violating the limits of this CNE.

Normally, CNEs on lines with maintenance are not part of the IGM, and cannot be constraining (get shadow prices, for example). Instead, the IVAs on the RAM should have been set to a very large number in order not to have this CNE constraining the system. Also, IVAs should have been applied on related CNECs that would have been affected if the CNE had not been part of the IGM.

## NO4 export too low in FB

In week 11, there was a software update of the tool creating Statnett's IGMs, to improve the RES modelling. However, there was a bug affecting the first weeks (end of week 11 to mid-week 13), by setting all the RES units to their maximum production

levels. This limited the net position in NO4 too much in this period, resulting in lower prices in FB than NTC.

## aFRR and/or mFRR capacities not included in FB domain

aFRR capacities were not included in the flow-based domain but were included in NTC due to data processing errors on the following days: 25-27 December 2022 and 14 January 2023. This resulted in slightly larger flow-based domains.

A similar issue occurred on 21 October 2023, when the FB domain does not include already allocated capacity for aFRR and mFRR, resulting in slightly larger flow-based domains.

## Differences in input due to different timings in FB and NTC

There are two different deadlines for providing NTC and flow-based capacities to the market, and this can result in different transmission capacities if e.g. an interconnector trips between those deadlines. Both capacities are correct, but the different timings led to different transmission capacities and results. An example of this was observed on 8 January 2023 on the LT-SE4 border.

Another example was observed on the 29th of October. From MTU 1 to MTU 18, the capacity provided on Nordbalt was different in FB and NTC. A scheduled outage on the HVDC link was terminated earlier than anticipated, which was not captured in FB due to different deadlines. The capacity was in FB set to 0 but was 700 MW in NTC for that period. This impacted the resulting FB prices for the period and the FB flows in the grid. Additionally, the AAF flows in NTC were also incorrect for that period due to this issue.

A third example was observed on the 24$^{th}$ & 25$^{th}$ of December 2023 on Kontiskan (DK1-SE3). On the 24$^{th}$ between 9-10, ENDK needs to disconnect KontiSkan2, which is right after the NRCC published the capacity to the NEMOs. ENDK adjusts the capacity to 345 MW and the NRCC published the reduced capacity at 09.50. The FB-domain was already cleared at 08.50, shortly before KS2 needed to be disconnected. Due to the short timeline, the focus was on updating the NTC-capacity. This resulted in higher flows on DK1-SE3 in the FB-domain than available in NTC.

## RM calculated differently in FB and NTC

In the current implementation of the flow-based approach, the default Reliability Margin (RM) is a fixed number (5% of Fmax) and not yet defined with statistical approach in accordance with approved CCM. In NTC, each TSO defines Transmission Reliability Margin (TRM) as a certain set value in MW for the relevant border. The RM in FB serves the same purpose as TRM in NTC, which is to account for uncertainties in the system.

## AC load flow not included in contingency scenarios

The AC load flow is not applied when assessing contingency scenarios, as it has been agreed to be implemented after the flow-based go-live. Instead, DC load flow is used in current implementation. This affects the RAM calculation accuracy as DC assumes voltages on grid nodes to be 1.0 p.u. when contingencies are calculated. In AC load flow the real grid node voltages are defined and applied in contingency calculation.

## Small discrepancies due to PTDF rounding

For the external parallel run, the NRCC has published and weekly updates an Excel file with the market simulation results. The file includes data from week 50 of 2022 and adds a new week each week when new simulation results are available. NRCC also weekly publishes a Grid Constraint Matrix. In theory, multiplying the PTDFs in the Excel sheet or the GC-matrix (or the values in JAO) with the net positions found in the Excel sheet should yield the values for already allocated capacity, given by F_AAC in the Excel sheet. However, the PTDF values used for calculating F_AAC have been rounded to three decimals, but the calculation of F_AAC have five decimals. Thus, there becomes a small difference between the two values. This might be the reason why there are sometimes small overloads in FB. This has been corrected as of week 34 but will not be recalculated for the previous weeks.

## Lower flows on NO5-NO2 in flow-based

**Please note!** This text has been updated. The previous version of the Operational learning points stated that the flows on NO1-NO2 flows were unrealistically high due to the high capacity on NO5-NO2.

After deeper analyses, Statnett has found that the flows indicated by the flow-based simulation results are realistic and does not create overloads in the situations analyzed. The domains from the flow-based simulations are outside the NTC

domains, which is why the solution seemed over-optimistic. The flow-based capacity on NO5-NO2 was reduced from week 34 2023 as an attempt to reduce the flow on NO1-NO2. As the NO1-NO2 flows are now deemed realistic, the capacity on NO5-NO2 has from week 43 2023 been increased back to its normal capacity.

## Lower flows on NO5-NO1 in flow-based

Statnett operates with temperature dependent thermal capacities. In NTC, these capacities are updated automatically based on measured temperatures or weather forecasts. For flow-based, these thermal capacities are set manually. During the later parts of summer 2023, the thermal capacities were set to 20°C for flow-based. However, during the fall when air temperature dropped, there was no change made to the thermal capacities for flow-based. This resulted in lower capacities and flows on all lines, but it is most noticeable on the lines between NO5 and NO1. Since week 43 2023, thermal capacities with a lower temperature have been added.

## Missing IVA on Fennoskan

Fennoskan capacity (FI-SE3) was reduced -1200MW by IVA on Saturday July 15th due to an outage in the Swedish grid. The IVA should have been applied also during Sunday 16th – Thursday 20th July (weeks 28-29) to set RAM=0 for the whole period of the outage but this was not done. However, this had no impact on the EPR market results because there was no market flow from FI to SE3.

## Wrong hours for outage on Baltic Cable

The RAM on Baltic Cable was incorrectly set to be zero for MTU 1-7 on the 6th of September and for MTU 17-23 on the 15th of September 2023. The RAM should have been 615 MW for these hours, which is the NTC capacity that was submitted to the market, meaning that the FB domain was smaller than it should have been for the hours mentioned above. The error stems from an error in an internal system at Svenska kraftnät.

## Incorrect FAAC NTC flows

The FAAC NTC flow (PTDF*NP_NTC) from the SE3-SE4 that travels on the South West Link is determined by a set of rules. These rules were incorrectly configured from the start of the EPR until week 31 2023 in the scripts that create the grid constraint matrix. In these scripts, the direction of the NTC flow on the South West Link was set in the opposite direction to what it should have been. This affected the

market report appendices and the market results file that were published at the time. The scripts were altered by the RCC to fix the error mentioned above during week 31. The fix did not completely solve the problem and another error occurred which most notably impacted the flow on the SE4-DK2 border. This error was fixed for the publication of week 36 2023. The appendices and GC-files for week 31-35 have been re-uploaded with the correct FAAC NTC flows. Please note that in the market results file the whole EPR data is recalculated each week, so during this time the issue affected also historical data. Both issues have been corrected as of week 36.

## IVA missing on DK1 borders

On October 2nd and 3rd 2023, the capacity from DK1 was reduced on multiple borders in NTC due to maintenance on an internal grid element. The related NUCS message can be found here. This type of maintenance cannot be handled in the current version of the capacity calculation. Consequently, for FB the full capacity was provided, whereas an IVA should have been applied. The allocated flow with FB was 215 MWh higher on Kontiskan and 490 MWh higher on Skagerrak than NTC. This exceeds the secure domain allowed and would have resulted in countertrading in production.

A similar issue occurred for DK1-NO2 and DK1-SE3 on October 23rd 2023, from 0:00 – October 25th 15:00. An IVA was missing, which caused at max. 167 MW higher flows in FB than NTC from NO2 to DK1, and at max. 75 MW higher flows in FB than NTC from SE3 to DK1.

## FRM changed on FI-SE1 border from 5% to 100 MW

The method of percentage based FRM (5% of Fmax), which has been used on all bidding zone borders in the Nordic flow-based EPR until November 2023 (cf. the item “RM calculated differently in FB and NTC”), has been assessed not to be sufficient for the FI-SE1 bidding zone border due to physical limitations. Currently in the NTC capacity calculation a fixed TRM (Transmission Reliability Margin) of 100 MW is used. The same value of 100 MW will be applied for FRM on the FI-SE1 bidding zone border. This fixed FRM is required due to the physical limitations and the inherent linear relationship between net position and border flow when the Finnish grid effectively has only one AC bidding zone border (FI-SE1). The physical limitations are based on frequency containment reserves, high variability of loads close to the FI-SE1 bidding zone border, and limitations of AC border lines. In effect, this change reduces the PTC (Power Transfer Corridor) capacity on FI-SE1 by 100 MW from Fmax instead of the 5% from 10 November 2023 (W45) onwards in the

EPR simulations. The impact of this change is that the maximum flows on SE1-FI border are expected to slightly reduce from what has been observed in the EPR so far, and thus, the maximum flow will be close to NTC maximum flow.

## Violation of Kontiskan constraints

A non-redundant Konti-Skan constraint has been mathematically neglected on several occasions by Euphemia due to the wrong input file from the NRCC to the NEMOs. The violations have occurred when IVAs were applied on this constraint by Svenska Kraftnät. Violations have occurred in the following weeks during 2023.

- Week 36: 9 instances of constraint violations. The constraint was at most exceeded by 715 MW
- Week 38: 12 instances of constraint violations. The constraint was at most exceeded by 245 MW
- Week 42: 17 instances of constraint violations. The constraint was at most exceeded by 350 MW

The violations have occurred when IVAs have been applied on this constraint by Svenska Kraftnät. The error causing the violations has been rectified in week 46 and no further violations are expected.

## Mismatch between the CNEC and PTC capacity for the SE1-FI border

The flow on the SE1-FI PTC (flow towards Finland) is limited to 1200 MW when the nuclear power plant Olkiluoto 3 in Finland is producing over 1300 MW. On 21.11.2023 the production forecast for Olkiluoto 3 was over 1300 MW but during the day the plant operator notified that they have to continue their outage that had started a few days before. This caused a mismatch within flow-based parameters between the Olkiluoto 3 production that is used in the IGM and the one used to determine SE1-FI capacity. Due to timing differences, power transfer corridor (PTC) capacities were given as if Olkiluoto 3 was not producing over 1300 MW (which indeed was the case and corresponds to NTC) but in IGM the production was over 1300 MW (based on the outdated forecast) which affects CNECs. The limit imposed by the CNEC near the SE1-FI border was ~1300 MW, so above what should have been allowed in the situation the IGM described (Olkiluoto production over 1300 MW). This could have been solved by a more recent production forecast and possibly a new IGM, or with an IVA which was not used.

## Increased price in NO5 due to overloads on transformers in NO2

At the end of December and the beginning of January, there were many hours where transformers (Sauda) in a substation in NO2 were fully loaded in FB and had a high shadow price. In NTC, the flows were much higher, providing a higher SEW than in FB. However, the operators had to use countertrading and grid splitting in the operational hour to avoid overloads, as the flows from the market result are too high. The issue occurs when there is high import from the continent to the Nordics, and there is a deficit in parts of NO5 and NO2. In FB, production is increased in NO5 to avoid flow from NO2 to NO5, thus relieving the transformers. The prices in NO5 increase but provides a more secure operational domain without the need for countertrade or grid splitting. The situation and the FB solution is still being analysed, but the operators are more convinced with the FB solution rather than how they handle these situations in NTC.

## North Sea Link prognosis causes limitations on NO1→SE3

In FB, a prognosis for North Sea Link (NSL – HVDC line between NO2 and UK) is included in the IGM, and when the flow is high, the RAM on some CNECs is limited. An example of this is 4 and 5 December, where the capacity on NO1→SE3 was limited in FB. In NTC, the prognosis on NSL is not a standard part of the capacity calculation. Thus, the FB capacity calculation is theoretically better, but may be too limiting or not limiting enough if the prognosis is wrong. However, this is still a better way of handling the NO1→SE3 capacity than how it is done in NTC, even if in some cases the SEW is lower in FB than in NTC.

## Outage in Finland on cut P1 handled differently in NTC than in FB

On week 2 (8-9th January) and week 3 (17-18th January) a CNEC located on cut P1, mid-Finland, is constraining the market results, leading to high shadow prices on the P1 CNEC towards south. This situation is related to an outage that was handled differently in FB than it was in NTC, leading to negative SEW impacts compared to NTC. In FB, the outage causes a limitation on the concerning CNEC, which also affects cross-border flows from SE1 to FI. In NTC, the limitation is not visible to the markets in the transmission capacity that is given to SE1-FI border. This is due to a

change in switching that can change the topology of the grid, enabling higher flows on cut P1 and on the SE1-FI border. The correct way to handle this would have been to give the PTC limits on P1 assuming the switching change (topology change) can be used in real time. Fingrid is looking into how to handle such situation in the future to avoid unnecessary market limitations in the FB setup.

## FRM changed to 10% for certain Swedish CNECs

Svenska kraftnät has identified the FRM (Flow Reliabiliy Margin) of 5% on all Swedish CNECs not to be a sufficient marginal to manage all market outcomes. In order to ensure operational security, Svenska kraftnät increases the FRM on 13 certain CNECs to 10%, starting from the 26th of February 2024. The increased FRM means an increased marginal to cover for uncertainties, and the increase of the FRM means that the RAM of the CNEC is reduced proportionally to the size of the FRM. The change gives a better opportunity to validate the market outcome and reduces the risk of overloads. The Nordic CCM explains that the reliability marginal should be regularly evaluated, and this change of the FRM is a result of such an evaluation.

# Appendix

Table 1: All identified learning points with their respective timelines during weeks 50/2022 – 52/2023.

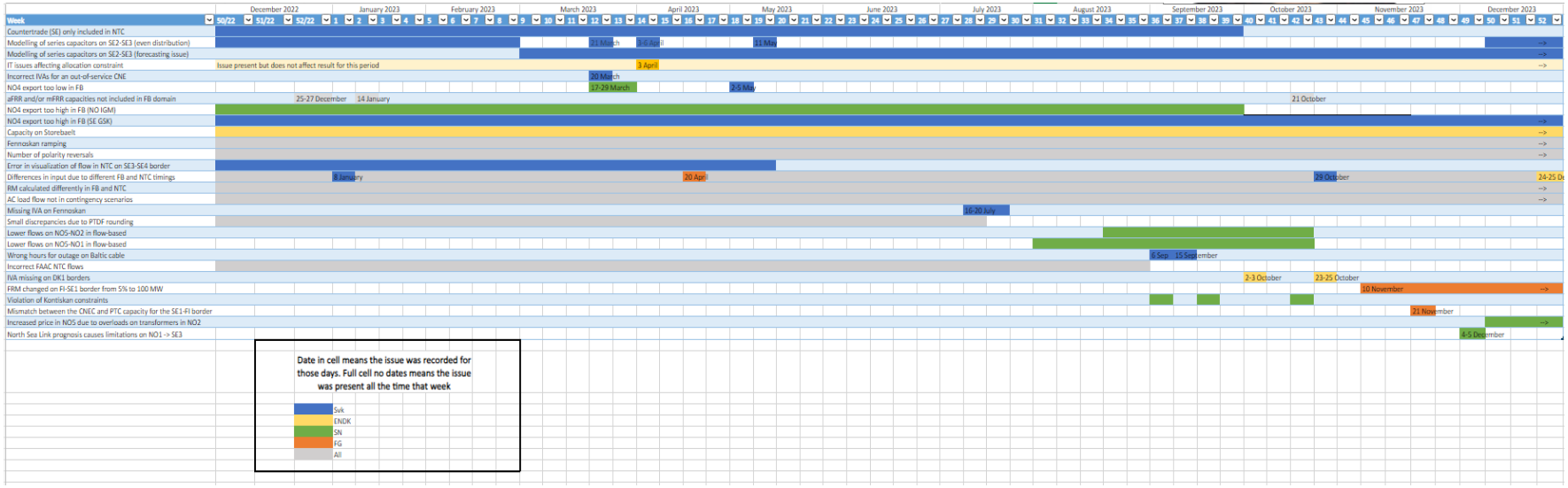

Table 2: All identified learning points with their respective timelines during weeks 1/2024 – 9/2024.

| | January 2024 | | | | February 2024 | | | | March 2024 | | | | | | | April 2024 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Week** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | | | |
| Modelling of series capacitors on SE2-SE3 (forecasting issue) | <-- | | | | | | | | --> | | | | | | | | | | | |
| IT issues affecting allocation constraint | | | | | | | | | --> | | | | | | | | | | | |
| NO4 export too high in FB (SE GSK) | | | | | | | | | --> | | | | | | | | | | | |
| Capacity on Storebaelt | | | | | | | | | --> | | | | | | | | | | | |
| Fennoskan ramping | | | | | | | | | --> | | | | | | | | | | | |
| Number of polarity reversals | | | | | | | | | --> | | | | | | | | | | | |
| RM calculated differently in FB and NTC | | | | | | | | | --> | | | | | | | | | | | |
| AC load flow not in contingency scenarios | | | | | | | | | --> | | | | | | | | | | | |
| FRM changed on FI-SE1 border from 5% to 100 MW | | | | | | | | | --> | | | | | | | | | | | |
| Increased price in NO5 due to overloads on transformers in NO2 | | | | | | | | | --> | | | | | | | | | | | |
| Outage in Finland on cut P1 handled differently in NTC than in FB | | 8-9 | 17-18 | | | | | | | | | | | | | | | | | |
| FRM changed to 10% for certain Swedish CNECs | | | | | | | | | --> | | | | | | | | | | | |

Date in cell means the issue was recorded for those days. Full cell no dates means the issue was present all the time that week

- Svk
- ENDK
- SN
- FG
- All