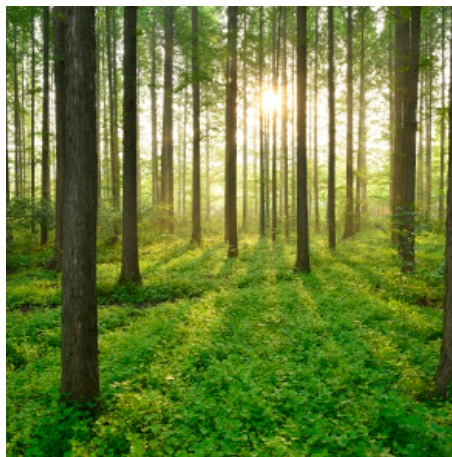
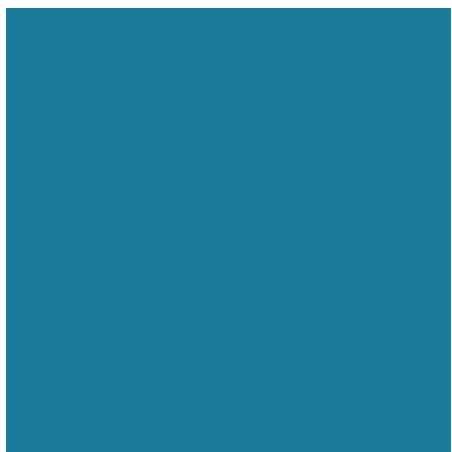


IMPACT OF FLOW-BASED ON THE INTRADAY MARKET

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FRAMTIDENS ELMARKNADS-
DESIGN, FEMD



IMPACT OF FLOW-BASED ON THE INTRADAY MARKET

Impact of changes to the capacity calculation
methodology on the intraday market

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Foreword

The electricity market is in a state of fast changes. Electricity demand is expected to grow, and electricity generation capacity are expected to be increased and built in new places. To better be able to handle new and somewhat changing flows in the transmission grid the Nordic system operators are planning to introduce a new calculation method for cross (electricity) borders, the flow-based calculation method. In this report we are within Energiforsk's Future electricity Market Design program, FemD, investigating what impact this can have on the Nordic intraday market.

The Nordic system operators are currently (spring 2023) doing tests and are weekly reporting data and market outcomes. Using this data this project has performed simulations for the first 10 weeks and are discussing the outcome for the intraday market. One conclusion is that we need further understanding of how interconnectedness between different markets in different time frames are affected. For the intraday market itself, further understanding of the impact of flow based is needed. Finally, the report concludes that the use of non-intuitive flows (forcing flows from high price areas to low price areas) require additional investigations with respect to the socio-economic and operational security impacts.

Energiforsk

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Summary

Changes to the capacity calculation and allocation methodology for the day-ahead and intraday markets are expected to be implemented in the near future in the Nordics. Nordic TSOs are currently running external parallel runs in which the impact of these changes on both day-ahead and intraday markets are analyzed. The focus of these external parallel runs has very much been on the day-ahead market. In this report, the analysis of the Nordic TSOs is complemented by an extended evaluation of the impacts on the intraday market.

Two main changes are expected to drive the impacts on the intraday market: the introduction of the flow-based market coupling methodology for day-ahead and a new methodology to compute intraday net transfer capacities.

A quantitative evaluation has been performed in this report on the first 10 weeks of 2023 using data from the external parallel runs. The results of the evaluations show that, for all Swedish domestic borders except in the direction SE3>SE4, available capacities for intraday trading systematically decrease. For SE3>SE4, available capacities for intraday trading increase in half of the time. For other Nordic borders, the results are mixed with some borders getting in average increased available capacities for intraday and some others getting in average decreased capacities.

A large share of intraday trading takes place between bidding zones. Cross-border intraday trading is not only important for adjustment of market participants' positions but also for reacting to unexpected changes such as the sudden disconnection of generators. Reduction in cross-border capacities on some borders may result in lower intraday trading and, therefore, in larger real-time imbalances that must be handled by other measures such as activation of ancillary services.

One main conclusion of this report is therefore that there is a need to analyze how the proposed changes to the capacity calculation and allocation method will impact the overall economic efficiency and operational security considering effects on multiple markets.

The evaluation also reveals that changes in available capacities for intraday trading are driven by different factors on different borders. On some borders, changes can be mostly explained by the introduction of flow-based in day-ahead while on some other borders, changes can be mostly explained by the new methodology to compute intraday net transfer capacities. On yet some other borders, these two factors are equally important.

Another main conclusion of this report is therefore that the introduction of flow-based only explains part of the differences in available trading capacities for intraday, and more analysis of the proposed methodology for computing intraday net transfer capacities should be performed. This has received very little attention so far in the work done by the Nordic TSOs and during stakeholder interaction where this work is presented. In particular, it was shown in this report that the new methodology implicitly prioritizes giving capacity to borders with lower day-ahead flows.

In addition to the changes to the available capacities for intraday trading, so-called non-intuitive flows occurring in the day-ahead flow-based market outcome and their impact on intraday trading have been described. It was illustrated how these non-intuitive flows can lead to arbitrage possibilities between the day-ahead and intraday markets that will most likely result in changes in the market participants' trading strategies not only for intraday but also for day-ahead. This can then have an impact on the day-ahead price formation and, consequently, on the day-ahead socioeconomic welfare gains of the proposed changes to capacity calculation and allocation. **A third main conclusion from this report is therefore that there is a need to further analyze the specific impact of non-intuitive flows on the socioeconomic welfare and operational security.**

Overall, this report highlights the importance to evaluate the combined overall effects of the proposed changes on all trading markets and real-time operations instead of focusing only on the day-ahead market. Only then can the consequences of the proposed changes in terms of social welfare and operational security be adequately analyzed.

Keywords

Intraday market, day-ahead market, flow-based, non-intuitive flows, capacity calculation.

Intradagmarknad, dagen före-marknad, flödesbaserad metod, icke-intuitiva flöden, kapacitetsberäkningar.

Sammanfattning

De nordiska TSO:erna genomför just nu externa parallellkörningar för att testa föreslagna ändringar i metoderna för kapacitetsberäkning och -allokering till dagen före- och intradagmarknaderna. Fokus på rapporteringen från dessa körningar har legat mycket på hur dagen före-marknaden påverkas. I denna rapport analyseras i detalj vilka effekter de föreslagna ändringarna har på intradagmarknaden.

Två huvudförändringar förväntas ha effekter på intradagmarknaden: införandet av den flödesbaserade metoden för kapacitetsberäkning och -allokering till dagen före-marknaden och användningen av en ny metod för att räkna fram intradagkapaciteter.

I denna rapport har en kvantitativ analys gjorts baserat på publicerat data från de första 10 veckorna i 2023 i de externa parallellkörningarna. Resultaten av denna analys visar en generell minskning av kapaciteter tillgängliga för intradaghandel på alla svenska snitt förutom på snitt 4 i södergående riktning. I denna riktning ökar i stället kapaciteterna i hälften av tiden. Resultaten för andra nordiska budområdesgränser varierar: vissa gränser får ofta högre kapacitet i snitt medan andra ofta får lägre kapacitet.

En stor andel av intradaghandeln i Norden sker över budområdesgränserna. Gränsöverskridande intradaghandel är av betydelse inte bara för att möjliggöra justeringar i marknadsaktörernas positioner, utefter ny information såsom uppdaterade prognoser, utan också för att kunna reagera på stora oförutsedda händelser såsom plötsliga bortkopplingar av stora produktionsenheter. En minskning av intradagkapaciteterna på vissa gränser kan därmed begränsa intradagmarknadens roll i hanteringen av dessa händelser. Detta skulle i så fall skapa större realtidsobalanser som måste hanteras på ett annat sätt, till exempel genom avrop från balansmarknaden. **En huvudsaklig slutsats av denna rapport är att det finns ett behov av att analysera vad de föreslagna metodändringarna har för övergripande ekonomisk nytta och effekt på driftsäkerheten med hänsyn till flera marknader, i stället för att begränsa analysen till dagen före-marknaden.**

Analysen visar också att förändringarna i intradagkapaciteterna beror på olika faktorer i olika delar av nätet. På vissa budområdesgränser härstammar dessa förändringar från införandet av den flödesbaserade metoden på dagen före-marknaden. På andra budområdesgränser härstammar de i stället från den nya metoden för att räkna fram intradagkapaciteterna. På vissa budområdesgränser bidrar dessa två faktorer lika mycket.

En annan huvudsaklig slutsats av denna rapport är därmed att införandet av den flödesbaserade metoden bara förklarar till viss del skillnaderna i intradagkapaciteterna och att mer detaljerad analys krävs för att bättre förstå effekterna av den nya metoden för beräkning av intradagkapaciteter. Analysen av denna nya metod har fått väldigt lite uppmärksamhet hittills i rapporteringen från de externa parallellkörningarna. Denna rapport visar i synnerhet att det sker

en inneboende prioritering av intradagkapaciteter till fördel för budområdesgränser med lägre dagen före-handel.

Slutligen har så-kallade icke-intuitiva flöden och dessa möjliga effekter på intradagmarknaden beskrivits i denna rapport. Dessa flöden uppstår på dagen före-marknaden och kan leda till arbitragemöjligheter mellan intradag- och dagen före-marknaderna. Dessa arbitragemöjligheter kommer sannolikt leda till anpassningar av marknadsaktörernas budstrategier, vilket i sin tur kan påverka prissättningen på dagen före-marknaden och, därmed, elmarknadsnyttan på dagen före-marknaden med de föreslagna ändringarna för kapacitetsberäkning och -allokering. **En tredje huvudsaklig slutsats från denna rapport är därmed att det behövs vidareanalyser av effekterna av de icke-intuitiva flödena.**

Sammanfattningsvis betonar denna rapport vikten av att analysera de kombinerade effekterna av de föreslagna ändringarna på alla marknader och på driften av kraftsystemet i stället för att endast fokusera på dagen före-marknaden. Enbart genom en sådan analys kan de socioekonomiska och driftrelaterade effekterna kvantifieras på ett lämpligt sätt.

List of abbreviations

AAC	Already Allocated Capacity
ATC	Available Transfer Capacity
CCM	Capacity Calculation Methodology
CNEC	Critical network element and contingency
DA	Day-ahead
EPR	External Parallel Runs
FB	Flow-based
FB MC	Flow-based Market Coupling
ID	Intraday
NRA	National Regulatory Authority
NTC	Net Transfer Capacity
NTC MC	Net Transfer Capacity Market Coupling
PH	Power Hour
PTDF	Power Transfer Distribution Factors
RAM	Remaining Available Margin
RCC	Regional Coordination Center
SEW	Socioeconomic welfare
TSO	Transmission System Operator

List of content

1	Changes in capacity calculation and allocation	10
1.1	Current intraday trading volumes	10
1.2	Current capacity calculation and allocation methodology	12
1.3	Flowbased methodology for the day-ahead market	13
1.4	Methodology for extraction of intraday capacities	14
1.5	External parallel runs	15
2	Qualitative analysis of the impacts on intraday	17
2.1	Impacts on intraday capacities	18
2.2	Non-intuitive flows in day-ahead	21
3	Quantitative analysis of the impacts on intraday	25
3.1	Data sources	25
3.2	Impact on available capacities for intraday trading	25
3.3	Borders with zero ATC	27
3.4	Impact of the introduction of FB MC in DA	30
3.5	Impact of the new methodology to compute ID NTC	34
3.6	Analysis of arbitrage possibilities due to non-intuitive flows	37
4	Conclusions	39
5	References	40

1 Changes in capacity calculation and allocation

1.1 CURRENT INTRADAY TRADING VOLUMES

The intraday market is a physical market for continuous electricity trading that opens after the day-ahead market outcome has become available and remains open until one hour before the delivery hour. The intraday market plays an important role for resource optimisation in several ways. Intermittent generation resources with intrinsically large day-ahead forecast errors, such as wind power, use the intraday market to adjust their day-ahead position as better forecasts become available the closer to the delivery period. Market participants also use the intraday market to re-balance their day-ahead commitments following e.g. updates on temperature forecasts and unexpected changes in production availability (for example following unexpected contingencies). A thorough description of the function and roles of the intraday market in the Nordics can be found in [1] (in Swedish).

Figure 1 shows the yearly intraday trading volumes (sell and buy volumes) together with the yearly wind power production in Sweden. It can be seen that intraday trading volumes have become larger with a 50% increase between 2013 and 2020, thus showing the increased importance of the intraday market. This trend is expected to continue as larger amounts of variable renewable energy sources such as wind power are installed in the system.

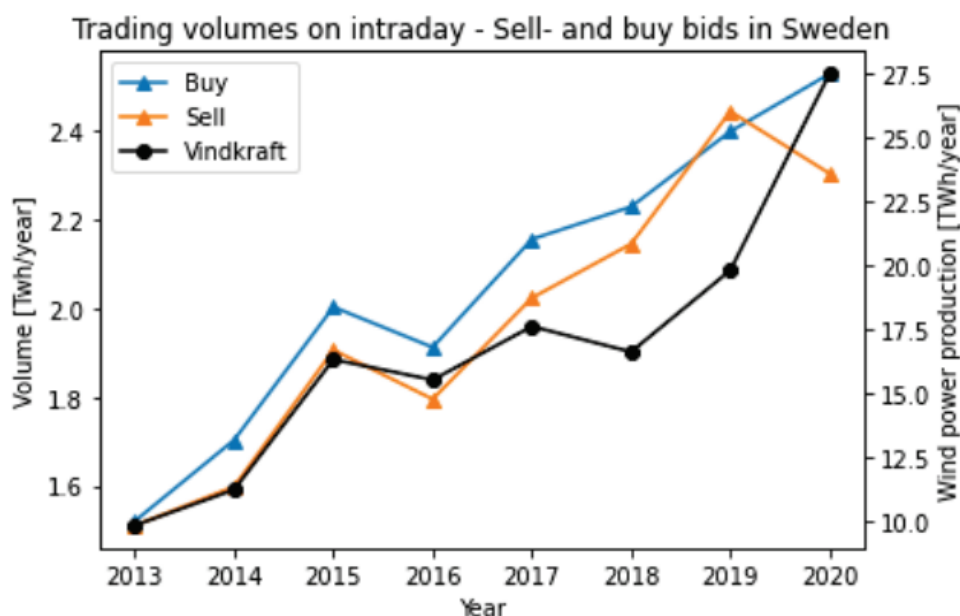


Figure 1: Intraday trading volumes in Sweden and wind power production from 2013 to 2020.

Intraday trading occurs within the SIDC region which interconnects a large part of Europe as shown in Figure 2. Market participants have therefore the possibility to trade with other bidding zones. Figure 3 shows the share of intraday trading from Swedish bidding zones to other bidding zones within the SIDC region in 2020.

About 80 % of all trades were made with other bidding zones. This underlines the importance of cross-border intraday capacities to support intraday trading.

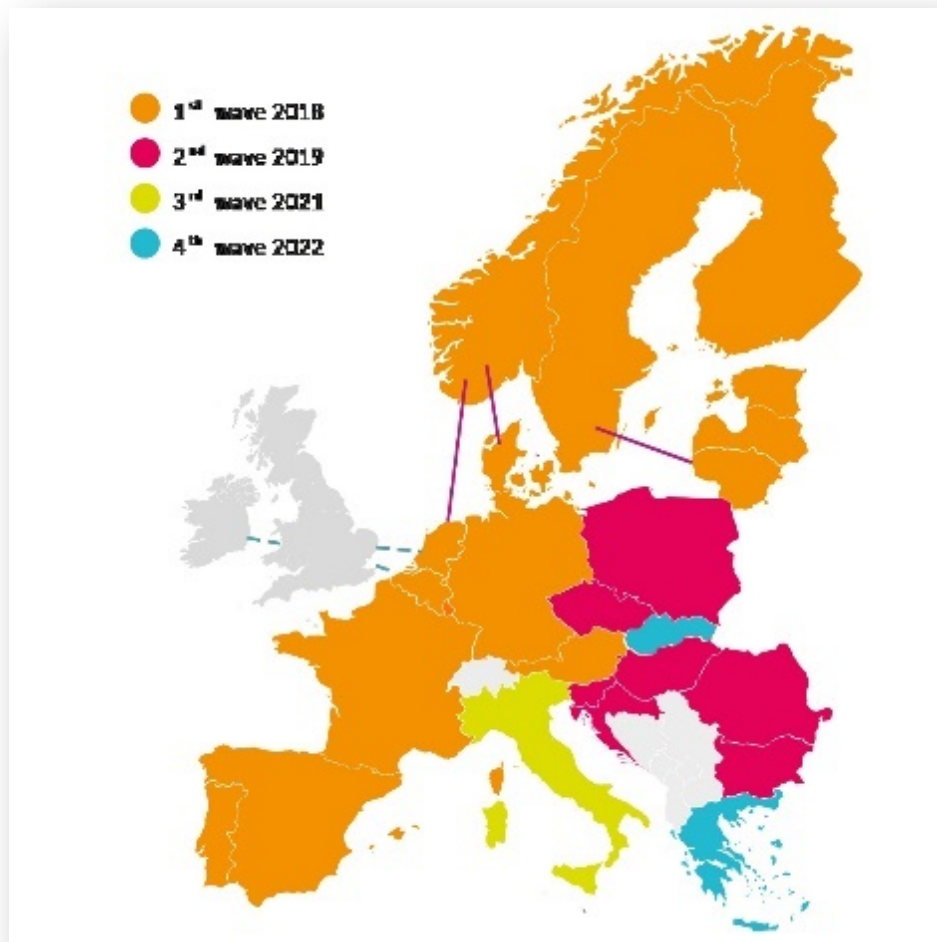


Figure 2: SIB region as of 2022, Source: ENTSO-E.

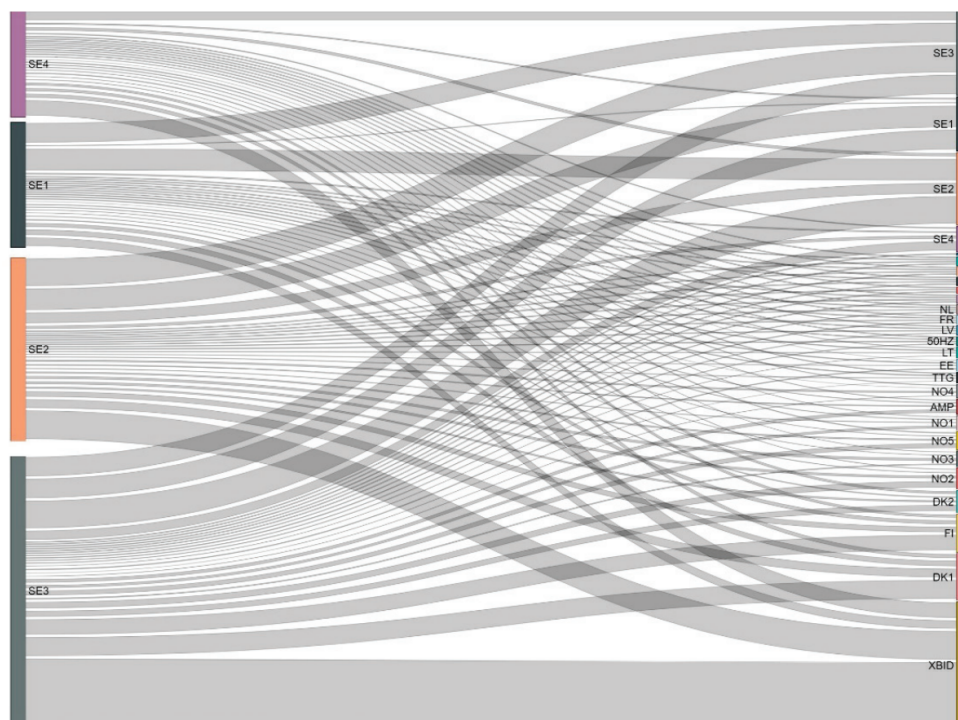


Figure 3: Share of intraday trading between Swedish bidding zones and other bidding zones in 2020. “XBID” refers to trading with actors that do not have NordPool as their nominated electricity market operator. Source: Nordpool.

1.2 CURRENT CAPACITY CALCULATION AND ALLOCATION METHODOLOGY

Capacity calculation refers to determining the amount of capacity available for power trading between different bidding zones in the transmission network, while ensuring that the operational security of the network is not compromised.

Currently in the Nordics, despite a highly interconnected transmission network spanning the entire Nordic region and the European continent, the network capacities on the bidding zone borders are calculated by the individual Transmission System Operators (TSOs), largely from their own grid constraints. As shown in Figure 4, the TSOs identify a set of critical network elements with associated contingencies (CNECs) and forecast the state of the grid, considering production and consumption scenarios along with other operational uncertainties with respect to future system conditions [2] [3]. The result of this analysis is translated into a maximum capacity called the Net Transfer Capacity (NTC), on the bidding zone borders. When these capacities are determined on a day-ahead timeframe and sent to the Nominated Electricity Market Operators (NEMOs) by the TSOs, the NEMOs solve the day-ahead market coupling problem using the Euphemia algorithm. Euphemia seeks to maximize the socio-economic welfare of the European day-ahead market and matches energy supply and demand for all time periods of a given single day in one-shot, while incorporating the network limits of TSOs [2]. The outcome of this day-ahead market coupling then includes among others (such as clearing prices, net positions, etc.), the traded volumes between different bidding zones, which result in an ‘already occupied’ part of the

NTC in the day-ahead timeframe, called the Already Allocated Capacity (DA AAC in Figure 4). When the DA AAC is subtracted from the NTC value, the remaining capacity available for trading in the intraday (ID) market at ID gate opening is named as the Available Transfer Capacity (ATC) for intraday, denoted by ID ATC in Figure 4. It is important to note here that the TSOs have the possibility to update the NTC values based on new forecasts before the opening of the ID market, so that the NTC values considered for calculating intraday capacity, denoted by ID NTC in the figure, can be different from the DA NTC values determined initially.

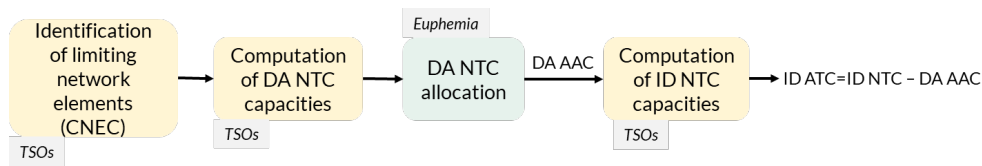


Figure 4: Current capacity calculation and allocation methodology.

1.3 FLOWBASED METHODOLOGY FOR THE DAY-AHEAD MARKET

A drawback with the NTC method is that it does not facilitate the optimal utilization of the transmission capacity in the network. While determining the NTCs, the capacity of the different critical network elements (CNE) is distributed between the different borders impacting the flows on these CNEs. However, in this forecast stage, the cross-border exchanges that will provide the most socioeconomic benefit (as an outcome of the subsequent market coupling problem) cannot be effectively prioritized. Also, the ongoing transition to renewable generation, which is highly intermittent in nature and difficult to predict, makes it even more challenging to forecast the grid condition and provide capacities within the operational security limits. In this context, the Flow-Based (FB) method for capacity calculation becomes a solution.

In the FB method, the grid constraints are directly integrated into the market-coupling problem instead of pre-calculating a maximum capacity (NTC) on the bidding zone borders. The NEMOs are provided with a list of critical network elements and contingencies (CNECs), the maximum allowed trading flow considering operational security (called Remaining Available Margin or RAM in FB context), and Power Transfer Distribution Factor (PTDF) matrices that indicate how a change in the production or consumption of a bidding zone impacts the flows on the CNECs [2]. These PTDFs and RAMs constitute the FB parameters as specified in Figure 5. The Nordic Regional Coordination Centre (NRCC) functions as a coordinated capacity calculator in the Nordic region, supporting the Nordic TSOs in this process.

The process of capacity calculation using FB, as shown in Figure 5, can then be summarized as follows. For each market time unit, the TSOs provide data to the NRCC that includes the CNECs, along with their operational limits and other dynamic constraints [2]. The NRCC calculates the FB parameters from this data and after validation by the TSOs, sends them to the NEMOs to solve the day-ahead market coupling with the FB parameters and constraints. Once again, as explained

in section 1.2, the day-ahead market coupling results in traded volumes between different bidding zones in the form of Already Allocated Capacity (AAC) in the day-ahead timeframe. However, the computation of ID ATC, i.e., the remaining capacity available for trading in the ID market is not straightforward in this case and includes additional steps, as explained subsequently in section 1.4.

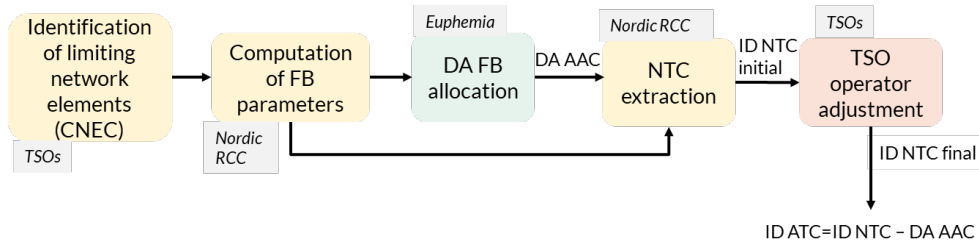


Figure 5: New capacity calculation and allocation methodology.

1.4 METHODOLOGY FOR EXTRACTION OF INTRADAY CAPACITIES

The ID trading platform cannot yet support FB parameters, but only the current NTC or ATC format where cross-border capacities are determined as a MW-value. This is partly owing to the complexity associated with incorporating the FB model into a continuous trading framework, as is the case for the intraday market. To overcome this issue, the Nordic TSOs have designed an interim solution called the ATC Extraction (ATCE) method to derive NTC-like values for the bidding zone borders from a given FB domain (PTDFs and RAMs at the CNEC level) [4]. The ATCE method uses an optimization approach such that the objective function maximizes the product of total capacities on all bidding zone borders in the Nordic region, while the constraints consist of the FB constraints on the CNEC level among other constraints. One important constraint is that the extracted ID NTC values should accommodate the day-ahead outcome, i.e., $ID\ NTC > DA\ AAC$ for each border and direction. The total capacities of the bidding zone borders in the objective function consist of two transfer capacities representing both directions of the border and are the exogenous variables in the optimization, also becoming the result in the form of extracted NTCs. A detailed description of the ATCE method can be found in [4]. The extracted ID NTCs are then subjected to some adjustment by the TSOs to give the final ID NTCs as shown in Figure 5, following which the capacity available for trading at ID gate opening (ID ATC) is calculated as the difference between this final ID NTC and the Already Allocated Capacity (AAC) during DA market coupling with FB.

The flow-based domain that is used by the methodology to extract ID NTC values is based on the flow-based domain from the day-ahead capacity calculation, with some exceptions:

- All negative PTDF values are set to zeros. This is a requirement to ensure operational security of the extracted ID NTC values.
- All PTDF values under a certain (small) threshold are set to zero. This is to avoid that CNECs impacted only to a small extent by trades can have an effect on the computed ID NTC.

- The RAM values are adjusted to ensure that the day-ahead flows are feasible on all CNECs. Indeed, these day-ahead flows are by construction feasible in the original day-ahead flow-based domain but may not be due to the above changes to the PTDF values done by the NTC extraction methodology.

The impact of each of these adjustments on the ID NTC are not analysed in this report. Rather, the impact of the overall methodology to compute the ID NTC is studied by comparing the new ID NTC with the current ones.

1.5 EXTERNAL PARALLEL RUNS

The Nordic TSOs' proposal for the new day-ahead and intraday capacity calculation methodology (CCM) was first approved by the Nordic national regulatory authorities (NRAs) in 2018 and further amended and approved in 2020. The approved methodology can be found at [5]. The go-live of the new CCM depends on successful parallel runs (EPR) and final confirmation by the Nordic NRAs. External parallel runs shall be performed for at least one year. An intermediary checkpoint was introduced where Nordic NRAs will perform an analysis of three months of results from the EPR. If Nordic NRAs approve the 3-month period, EPR will continue for another 6 months before go-live. If the 3-month period is not approved, EPR will be extended and TSOs requested to take actions. The timeline valid at the time of writing (June 2023) is presented in Figure 6.

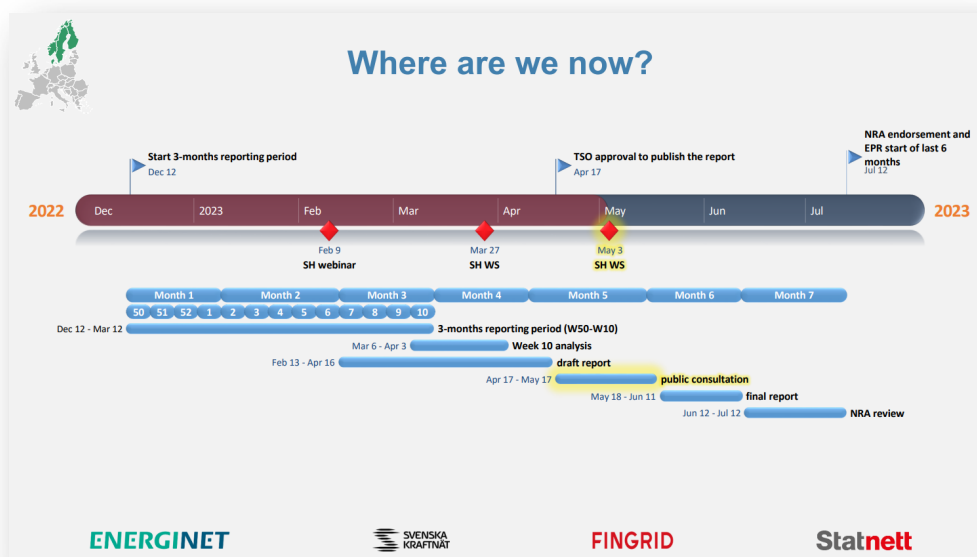


Figure 6: Timeline of the external parallel runs. Source: [6].

External parallel runs are a test period during which capacity calculation and allocation for day-ahead is performed using both the current (NTC) and the new (FB) method. In practice, the valid DA market outcome is the usual NTC market outcome and TSOs perform offline computations to get the FB market outcome

using the same orderbooks. Although called parallel runs, the capacity allocation process (i.e. market clearing) is not performed in parallel. Due to a two-week grace period, orderbooks are only available two weeks after the NTC market coupling has occurred. Hence, the FB market clearing is simulated at the earliest two weeks after the NTC market clearing for the same day.

As far as the intraday market is concerned, TSOs have included available transfer capacities (ATC) for the opening of intraday market using the new methodology. These ATC for the opening of ID are computed based on the FB market outcome.

The evaluation performed in this report are based on the results of these external parallel runs.

2 Qualitative analysis of the impacts on intraday

As discussed in the previous sections, the intraday market will be impacted due to two main changes to the current capacity calculation and allocation methodology:

1. Introduction of the flow-based market coupling methodology in the day-ahead market.
2. New methodology to compute intraday NTC capacities [4].

Note that the new methodology to compute intraday NTC capacities is termed an ATC extraction method by the Nordic TSOs in [4]. We choose in this report to emphasize that this method really computes NTC capacities, which is why we use another terminology for it. Furthermore, in the external parallel runs, TSOs denote the net transfer capacities that apply for intraday trading at gate opening as DA NTC. This is because these NTC values are computed based on the flow-based parameters computed during the day-ahead capacity calculations. In this report, we denote these NTC values as ID NTC instead of DA NTC, to make it clear that (1) they are for the intraday market and (2) modifications were made to the original DA flow-based domain by the NTC extraction method as described in Section 1.4.

Looking at Figure 4 and Figure 5, capacities available for ID trading at the opening of the ID market are ID ATC (Available Transfer Capacities) and are equal to ID NTC – DA AAC, that is to the difference between the Net Transfer Capacities that apply for ID and the Already Allocated Capacities during DA trading. The introduction of FB on DA entails differences in DA AAC, while the new methodology for computing intraday NTC capacities entails differences in ID NTC.

The changes to the current capacity calculation and allocation methodology have two impacts on intraday trading:

1. Capacities available for intraday trading will change. This is a result of both changes.
2. Non-intuitive flows will occur on some borders in day-ahead trading. Non-intuitive flows are trading flows from high- to low-price areas which naturally occur in the flow-based market coupling, especially in a meshed grid with small bidding zones like the Nordic one. The occurrence of these non-intuitive flows in day-ahead lead to the possibility of arbitrage possibilities between day-ahead and intraday (if arbitrage is allowed) or to lower intraday capacities in some directions (if arbitrage is not allowed by TSOs through setting some ID capacities to zero).

The following subsections will give more detail about these two impacts.

2.1 IMPACTS ON INTRADAY CAPACITIES

For each bidding zone border and direction, the available transfer capacity for intraday trading at ID market gate opening is computed as: $ID\ ATC = ID\ NTC - DA\ AAC$.

That is, the difference between the computed net transfer capacities (representing limits to cross-border exchanges that are safe in terms of operational security) and the already allocated capacities during DA. The term ID NTC is a result of a computation performed by the TSOs or the RCC (Regional Coordination Center), while the term DA AAC is an output of the DA market coupling and corresponds to day-ahead trading flows.

The introduction of the flow-based market coupling (FB MC) methodology in the day-ahead market will entail changes to the term DA AAC, since the trading pattern will be different with FB MC compared with the current NTC-based market coupling. The flow-based methodology is often said to optimize the use of the grid to a further extent compared to the current NTC methodology. What is meant by this is that the FB MC algorithm has a better representation of the physical grid than the NTC MC algorithm. The FB MC algorithm uses a grid model which captures the impact of the network elements' impedance on the active power flows. In contrast, the NTC MC algorithm represents the grid as bidding zones interconnected with cross-border capacities. This often entails that NTCs computed by TSOs (or RCCs) are more restrictive to trades than what a FB model is. Simply put, FB MC is less constrained than NTC MC, and, therefore, results in a greater utilization of the grid. This fact is often misinterpreted as saying that trading flows will be greater with FB MC than with NTC MC, which is not true. Instead, FB MC will result in a (sometimes very) different market outcome compared to NTC MC. This different market outcome will often be characterized by higher trading flows on some borders and directions, whereas trading flows will decrease on some other borders and directions. In some cases, trading flows are higher because of less restrictions in the FB MC (that is, these trading flows would not be possible with NTC MC). In other cases, higher trading flows are just a result of other model differences (that is, these higher trading flows would be possible with NTC MC). Market coupling is a maximization of social welfare and results in an optimal market outcome that is constrained by some limitations captured in the market coupling constraints. NTC and FB constraints are among these constraints. Therefore, it is expected that FB MC will naturally lead to market outcomes for which some trading flows on some borders and directions would not be possible with a NTC MC (because of the tighter constraints of the NTC MC). In particular, if some bidding zone borders are particularly and structurally important for social welfare, the FB MC will most likely result in a higher utilization of these borders. This is what is usually meant by "The flow-based methodology optimizes the use of the grid to a further extent compared to the current NTC methodology".

The reasoning above implies that changes in day-ahead trading flows will occur when switching from the NTC MC to the FB MC on the day-ahead market and that it is expected that some changes will be systematic in the sense that some bidding zone borders will often see higher trading flows with FB MC than with NTC MC.

Everything else being equal, this will in turn result in decreased capacities available for ID. That is, even if the ID NTC do not change (i.e., new ID NTC are equal to current ones), the ID ATC will change as a result of changes in DA AAC.

For a specific border, the impact will be opposite in opposite directions. That is, if ID ATC decreased because of higher DA AAC in one direction, ID ATC will increase in the opposite direction. As we will see in the results of the analyses performed in this project (see Section 3.2), there are many bidding zone borders on which we do not see this symmetrical effect, which implies that changes in ID ATC are also driven by other factors.

Another factor impacting the ID ATC is the computation of ID NTC, that are limits to cross-border exchanges computed by TSOs (or RCCs) to avoid operational security issues. Since the NTCs that apply at the gate opening of the intraday market are computed by different methodologies today and in the future when the new CCM will go live, this will also have an impact on the ID ATCs. Today's methodology is the result of (1) power system analyses performed by TSOs, (2) coordination between the TSOs and (3) educated operational judgement by TSOs to distribute capacity between different bidding zone borders when these borders impact common elements in the grid. In the proposed future methodology, parts of (2) and (3) will be replaced by an automated optimization-based methodology performed by the Nordic RCC and that takes as inputs the results of (1) to compute the NTC on each bidding zone border and direction. TSOs then have the possibility to adjust the automatically computed values and, therefore, to apply their operational experience as in (3) today. This new methodology will result in new ID NTCs and hence impact the ID ATCs by itself (that is, it will have an impact even if the DA AAC did not change).

As presented in Section 1.4, the new methodology seeks to maximize the product of the Nordic net transfer capacities while ensuring (1) operational security through a modified flow-based domain and (2) feasibility of the day-ahead trading flows. Maximizing the product of the net transfer capacities results implicitly in prioritizing giving more capacity to borders with lower DA flows. This is illustrated in the following simplified fictitious example.

Suppose that, after the day-ahead market clearing, day-ahead trading flows are equal to 6000 MW on border A and 700 MW on another border B. Suppose that these two borders both impact one same critical network element (CNEC) that is close to its limit in the day-ahead market outcome. The NTC extraction algorithm can give more capacity to border A (i.e., set the NTC of that border A to be more than 6000 MW), give more capacity to border B (i.e., set the NTC of border B to be more than 700 MW) or give more capacity to both. Suppose that there is enough remaining capacity on the CNEC for increasing either border capacity by 100 MW on top of the day-ahead flows. We can compare three cases:

- Case 1: More capacity (100 MW) to border A only. ID NTC of border A becomes 6100 MW. ID NTC of border B is equal to the day-ahead flow, i.e., 700 MW. The product of both capacities is $6100 \times 700 = 4\,270\,000$.

- Case 2: More capacity (100 MW) to border B only. ID NTC of border A is equal to the day-ahead flow, i.e., 6000 MW. ID NTC of border B becomes 800 MW. The product of both capacities is $6000 \times 800 = 4\,800\,000$.
- Case 3: More capacity to both, split as 50 MW on each border. ID NTC of border A becomes 6050 MW. ID NTC of border B becomes 750 MW. The product of both capacities is 4 537 000.

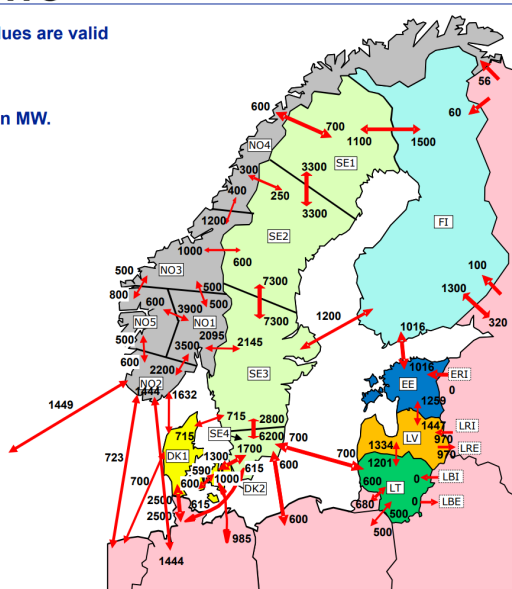
It can be seen that the product of the capacities is maximum where all the available capacity is given to the border with lower day-ahead flow, i.e., border B. In reality, other factors impact this result. Borders A and B in the example will most likely have different impacts on the critical network element in the form of different PTDFs. There may also be other limitations that may constrain the optimization in a different direction.

The fact remains, however, that everything else being equal, borders with smaller DA flows are prioritized. Since the grid is dimensioned on the need for capacity, the more important the bidding zone border for the overall socioeconomic welfare, the more important the maximum capacity. Figure 7 shows the current maximum NTC values of the Nordic borders. It can be seen that some important transmission corridors, such as the bidding zone border between SE2 and SE3, may be given less intraday capacity by the new NTC extraction methodology than smaller bidding zone borders.

MAXIMUM NTC

The maximum NTC values are valid from May 25th, 2022.

NTC values are given in MW.



entsoe
Reliable Sustainable Connected
Regional Group Nordic

NTCs can deviate up to 100 MW before there will be any change in the capacity reduction codes

Organisation for the Nordic Transmission System Operators

Figure 7: Maximum cross-border NTC values in the Nordics. Source: Nordpool.

Since both changes (introduction of FB MC for DA and new methodology for computing ID NTC) will be implemented at the same time at go-live, the effects on ID will be due to a combination of these two changes. There is also a dependency

between the two changes in the new methodology for computing ID NTC itself. The optimization formulation of this new methodology ensures that the computed ID NTC are always larger than DA AAC, so that ID ATCs are always positive.

These changes and their effects are analyzed in later sections.

2.2 NON-INTUITIVE FLOWS IN DAY-AHEAD

Non-intuitive flows are trading flows from high- to low-price bidding zones. They do not occur naturally in NTC MC. The only exception is if some NTCs are set to be negative by TSOs to force the trading flow in a particular direction, but this situation happens very seldom. With FB MC, however, these flows can occur more often because FB MC is informed by grid physics in the form of a simplified grid model instead of relying on a model limited to bidding areas connected by cross-border NTCs. Considering grid physics will, in some cases, make it economically efficient to have non-intuitive flows if that can allow the market coupling algorithm to relieve certain congestions to increase social welfare (measured as the sum of consumer surplus, producer surplus and congestion rents). The same possibility is not open to NTC MC because of the lack of knowledge of the corresponding algorithm when it comes to the interdependency of flows in different parts of the grids.

The benefit of non-intuitive flows is therefore a potential increase in social welfare. However, they are conceptually difficult to understand for market participants used to the NTC MC, which has been a barrier for stakeholder interaction.

Figure 8 shows the number of hours with and without non-intuitive flows during the analyzed 10-week period on some selected Nordic bidding zone borders (see Section 3.1 for more information about data sources). It can be seen that non-intuitive flows occur often on some borders. In particular, SE1 > SE2 has non-intuitive flows in 80% of all hours of the 10-week period.

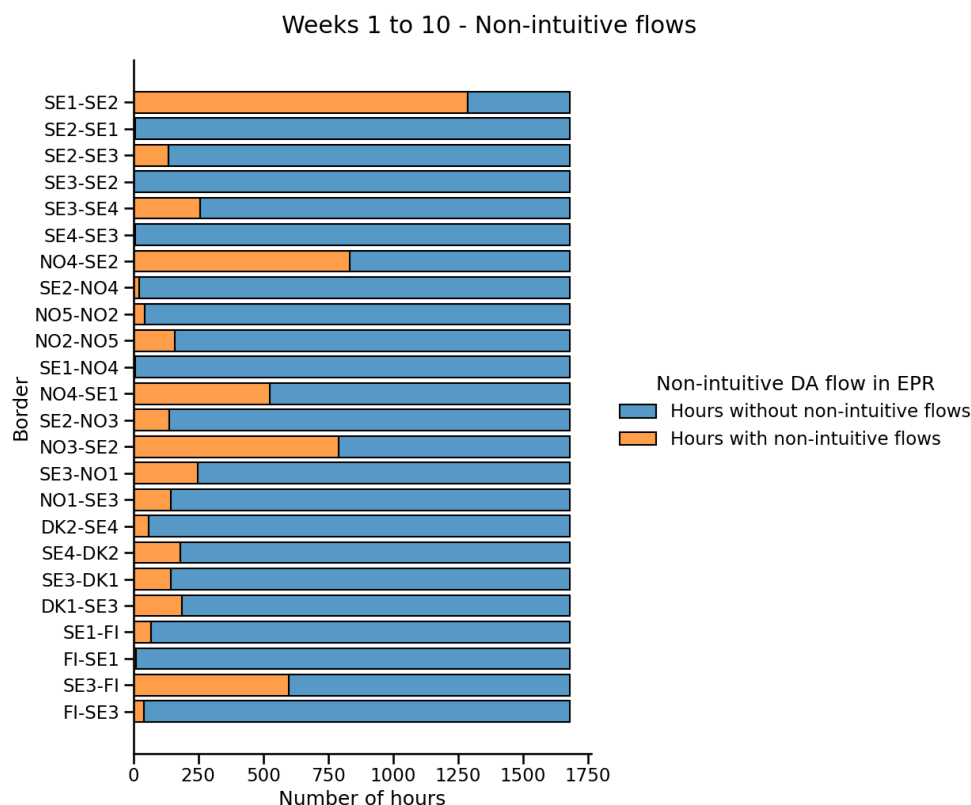


Figure 8: Number of hours with non-intuitive flows.

When non-intuitive flows from a price area A with high price to a price area B with low price occur in day-ahead, an arbitrage possibility between DA and ID arises if ID ATC from B to A are not zero due to the price difference between A and B in ID. Market actors can now trade on intraday from the low-price area B to the high-price area A.

There are two ways in which the ID ATC from B to A can be zero:

1. ID ATC is the result of the new methodology for computing NTC. The methodology is based on the same set of critical network element constraints as the one used during the FB MC. If a non-intuitive flow from A to B has arisen in the FB market outcome, it entails that some of these constraints are at their limit and that the non-intuitive flow is needed to ensure operational security (in terms of all constraints in the set to be satisfied). Therefore, the output of the methodology to extract ID NTC should not allow the possibility for ID trades from B to A (i.e., it should set ID NTC = DA AAC in the direction B to A so that ID ATC = 0), which would otherwise lead to some constraint violation. However, the new extraction methodology performs relaxation prior to computing the NTC capacities, which opens up the possibility for this effect to disappear, i.e., for ID ATC from B to A to be nonzero. The impact of this relaxation is that ID trading is allowed outside the security domain defined by the CNEC constraints, which must be handled by TSOs using some remedial actions.
2. If the automatically computed ID ATC from B to A is nonzero according to the reasoning in the previous point, TSO operators have the possibility to set it to

zero during the validation step (see Figure 5) if they wish to prevent arbitrage possibilities.

TSOs have indicated that they would not prevent arbitrage possibilities, thus rendering point 2 not applicable.

An illustration of how non-intuitive flows in DA give rise to arbitrage possibilities is given in Figure 9.

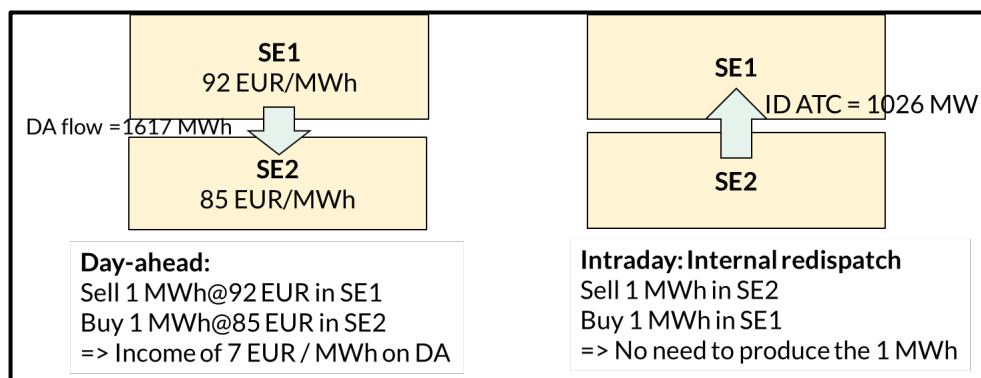


Figure 9: Illustration of arbitrage possibilities due to non-intuitive flows in DA. Figures taken from the external parallel runs for 3 January 2023, 05:00.

The figure shows, on the left, the DA market outcome when using FB MC (data from the Nordic external parallel runs) for 3 January 2023 05:00. The DA prices are 92 EUR/MWh and 85 EUR/MWh in SE1 and SE2, respectively. The DA trading flow goes from the high-price area SE1 to the low-price area SE2, i.e., it is an example of a non-intuitive flow. On the right-hand side of the figure, it can be seen that the ID ATC with the new methodology is 1026 MW from SE2 to SE1, i.e., it is possible to trade on ID in the direction opposite to that of the non-intuitive flow in DA. As explained below, this gives rise to arbitrage possibilities which will naturally lead to market participants trading back from SE2 to SE1.

An example of how a market participant that has assets in both price areas can use this as an arbitrage possibility is described in the figure. First, it can sell production in SE1 and buy consumption in SE2 on DA, which, in this case, leads to an income of 7 EUR/MWh. Second, it can perform an internal redispatch of its portfolio by selling from SE2 to SE1 on the ID market. The costs for this intraday trading are limited to the trading fees of its NEMO, well under 7 EUR/MWh. The results of this are:

- The market participant's positions are zero in both SE1 and SE2, i.e., it does not need to produce or consume anything.
- The market participant's profit is equal to 7 EUR/MWh minus the trading fees for DA and ID. The trading fees being well below 7 EUR/MWh, the market participant makes a net profit.
- The DA positions and trading flows are not representative of the actual positions and flows after ID trading.

The above is just one example of many ways to use the arbitrage possibility arising from non-intuitive flows. This arbitrage possibility will naturally be used by market participants. As market participants adapt their bidding strategies to this

arbitrage possibility, these strategies will change for both the day-ahead market and the intraday market. This may result in an impact on the price formation in SDAC. Therefore, by creating new trading possibilities in intraday, non-intuitive flows can indirectly also have an impact on day-ahead prices. This has not been accounted for so far in the analysis performed during the external parallel runs.

Since the new methodology for ID will only be implemented for trading at go-live (i.e. at the earliest Q1 2024), it is difficult to quantify this effect with reasonable accuracy. Instead, it is possible to look at how often these arbitrage possibilities have arisen during the period covered by the external parallel runs (EPR) and at the theoretical net profits that market participants could have made during this period. This analysis is described in detail in Section 3.6 and results in a total maximal theoretical arbitrage value of 87.9 MEUR during the first 3 months of 2023 in the EPR-period. This can be compared to the total change in day-ahead socio-economic welfare (SEW) during this period (as computed by the TSOs in their evaluation report) which is 63.3 MEUR for the simulated SDAC region and 73.4 MEUR for the Nordic region. Therefore, the arbitrage value created by non-intuitive flows can be higher than the SEW gains achieved in SDAC by the proposed changes.

In addition to this effect on trading strategies and prices formation, non-intuitive flows in day-ahead combined with the new NTC extraction methodology for intraday can also have an impact on operational security.

As mentioned above, allowing for ID trading in the direction opposite to the day-ahead flows may lead to operational security issues since it entails that ID trading is allowed to happen outside the security domain formed by the CNEC constraints (due to the relaxation of the operational security constraints in the NTC extraction methodology). One important aspect here is that, when the intraday market opens, this security domain is based on the same grid model as the one used for the day-ahead capacity calculations. Therefore, it does not include updates on, for example load or generation forecasts or grid topology. In light of this, TSOs may judge that it is operationally safe to allow ID trading, based on information not yet included in the automatic ID NTC extraction methodology. However, no quantitative analysis has been performed so far in the external parallel runs of this effect.

3 Quantitative analysis of the impacts on intraday

3.1 DATA SOURCES

For comparing the ID ATCs, i.e., the initial ID trading capacity at ID gate opening for the next day, the new ID ATCs (due to implementation of FB in DA MC) are available in the weekly 'ATCE results', under simulation results from the parallel runs on the NRCC website, accessed from [7]. These new ID ATCs have been determined based on the method described in section 1.4. Current ID ATCs, based on the operational NTC method for capacity calculation, are obtained from the ENTSO-E transparency platform, from the data under 'Implicit Allocations - Intraday - OC evolution'. Here, 'OC evolution' stands for 'Offered Capacity evolution', so the initial intraday capacities are obtained by querying the evolution update around 14:00 CET on the previous day (D-1), after the DA market clearing is complete and the intraday capacities for ID gate opening are available. Apart from ID ATCs, DA flows with FB and NTC are also analyzed to understand how they impact the available capacities for intraday. Data on DA flows with FB/NTC are taken from the 'Grid Constraint Matrix', also available in the EPR simulation results on the NRCC website and it contains the day-ahead market coupling results with FB/NTC for a given week. To understand the frequency and distribution of non-intuitive flows in the DA results with FB, DA prices due to FB market coupling, available in 'Market Simulation Results' in the EPR data are used.

3.2 IMPACT ON AVAILABLE CAPACITIES FOR INTRADAY TRADING

In this section, the results of the comparison between the current and new ID ATCs are presented. In addition, further analysis of the contribution of each of the two factors (introduction of FB MC in DA and new methodology for computing ID NTC) is presented farther down. The analysis focuses on a number of Nordic bidding zone borders that have been identified as important to the stakeholders participating in the reference group of this project.

Figure 10 shows, for some bidding zone borders and directions, the number of hours for which the new methodology gives higher ID ATC, lower ID ATC or identical ID ATC. It can be seen that some borders almost always receive higher ID ATCs (for example: NO2>NO5), some others almost always lower ID ATC (for example: SE1-SE2 in both directions) and some others sometimes higher and sometimes lower ID ATC (for example: SE2>NO4). Looking specifically at Swedish internal borders, new ID ATCs are lower on all borders and all directions most of the time, except for SE3>SE4 with a slightly higher number of hours with higher ID ATCs with the new method.

An interesting observation is that some borders see the same effect (increase or decrease in ID ATC) in both directions, for example SE1-SE2 and SE1-FI. This is not expected if the only factor impacting ID ATC would be the introduction of FB MC in DA. Indeed, this factor would entail larger DA trading flows in one direction and, therefore, lower DA trading flows in the other direction. Therefore, ID ATC

would decrease in one direction and increase in the other. Other factors will be analyzed in later sections of this report.

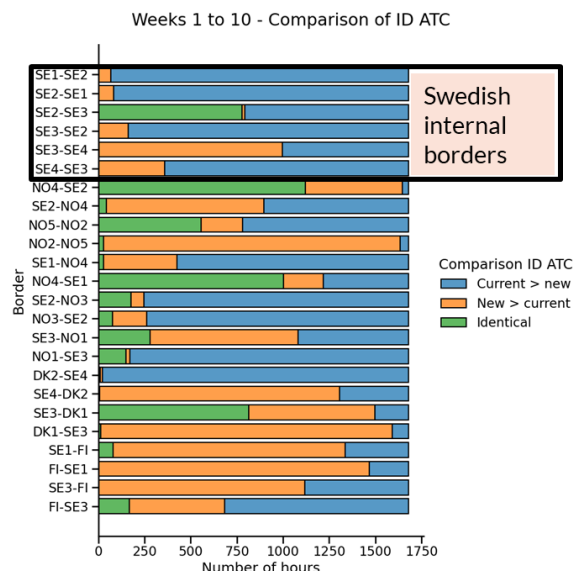


Figure 10: Number of hours when ID ATC are higher (respectively lower and identical) with the current methodology than with the new methodology. Swedish internal borders are marked for easier reference.

To complement the analysis of how often borders receive higher or lower ID ATCs, Figure 11 shows the differences between the new and current ID ATCs.

For Swedish internal borders, there is a clear trend of decreased ID ATCs with the new methodology, except for SE3>SE4. Part of this is due to what is today most probably unsecure high ID ATCs in the northbound direction. This is due to the fact that trading flows are not large in this direction today and, therefore, it has not been necessary to compute exact values for what secure ID ATCs should be. However, in the southbound direction, large decreases in ID ATCs can also be witnessed.

Some other borders and directions stick out. NO2>NO5 receives much higher ID ATCs with the new method and both NO1>SE2 and DK2>SE4 receive much lower ID ATCs.

It is important to note that all borders have different maximum capacities. It would be interesting to compare the magnitude of these differences with the maximum capacities. This is left as future work.

In the next sections, we will have a closer look at the special case of how often borders get zero ID ATCs. In addition, the two components of ID ATCs (ID NTC and DA AAC; $ID\ ATC = ID\ NTC - DA\ AAC$) will be studied individually to understand where the differences are coming from.

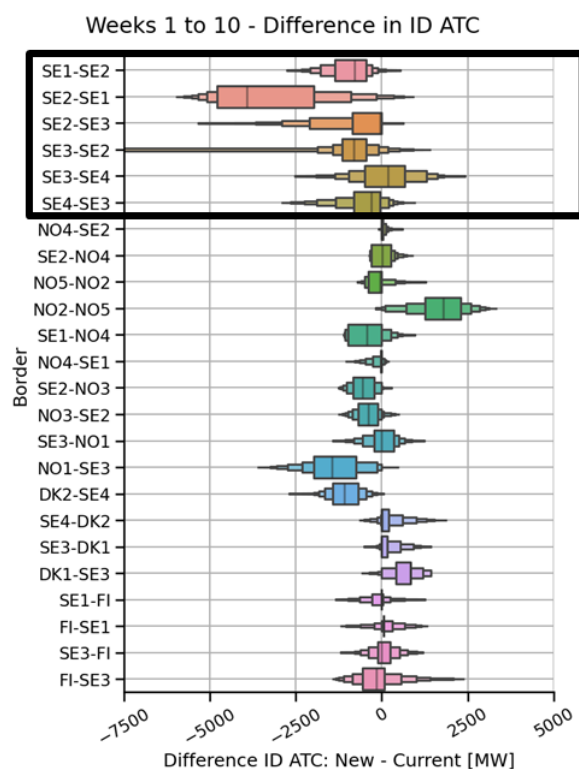


Figure 11: Distribution of differences in ID ATC between the new and the current method. The central box contains 50% of all hours around the median (the median is line in the central box). The next boxes contain 25% of the remaining hours. Reading example: For SE2>SE1, the median difference is about -4000 MW and 50% of the hours around the median witness differences between about -5000 MW and -2000 MW.

3.3 BORDERS WITH ZERO ATC

Figure 12 shows the number of hours with zero ID ATCs for the current and new methodologies. About half of the borders have more hours with zero ID ATCs with the new methodology and vice versa for the other half.

For Swedish internal borders, SE1-SE2 sees more hours with zero ATCs with the new method (there is not any with the current method) and SE2>SE3 receives zero ATC almost all the time with the new method (compared to about 75% of the time with the current method). On the other hand, SE3>SE4 receives zero ID ATC almost never with the new method, compared to more than 500 hours with the current method.

Other borders with important changes are NO5>NO2, SE2<>NO3 and NO1>SE3 with a sharp increase of the number of hours with zero ATCs with the new method; SE3>NO1, SE4>DK2, SE3<>DK1, SE1>FI and SE3>FI with a sharp decrease in the number of hours with zero ATCs.

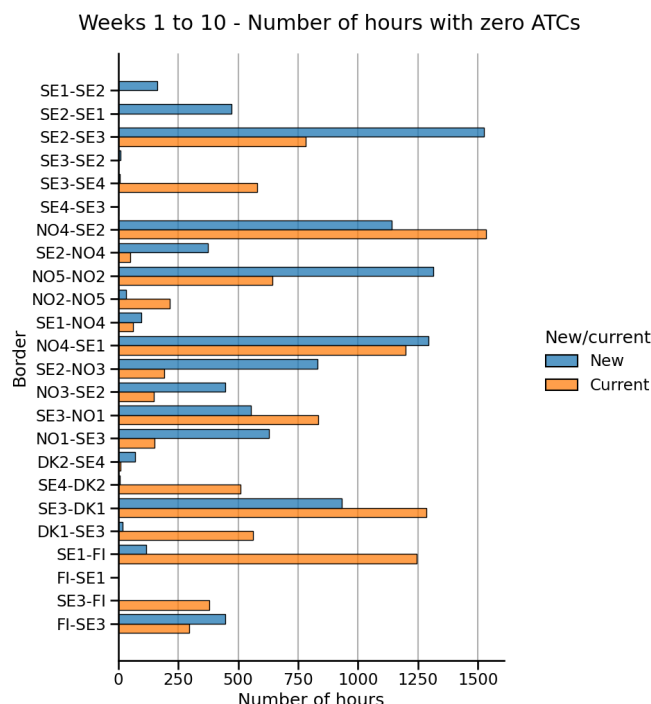


Figure 12: Number of hours with zero ATC with the current and new methodologies for each border.

Hours in which the new method gives zero ATCs while the current does not can occur due to different factors:

3. DA AAC increases with FB MC and hits the current NTC, thus leaving no capacity for ID trading.
4. DA AAC do not change significantly but ID NTCs value do. This can be due to the fact that the new methodology considers how allowing trading on one border can impact other borders. Another reason can be due to the objective function of the new methodology which guides the ID NTC computation towards a certain goal (maximizing the product of all Nordic capacities).
5. A sub-case of the previous point is non-intuitive flows which arise in DA to keep some network elements just at their flow limits to maximize social welfare. In that case, ID ATCs should be set to zero in the opposite direction because trading in that opposite direction would overload these grid elements, as discussed in Section 2.2. Note that this is not always the case that ID ATCs are set to zero by the new methodology because of some relaxations of some network element constraints.

Figure 13 shows the occurrence of zero ID ATC and non-intuitive flows depending on the DA flow direction.

For SE2>SE3 (the border and direction with the highest number of hours with zero ID ATC in Figure 12), it can be seen that almost all hours with zero ID ATC (light blue and light orange bars) occurs when the DA flows are in the same direction as the border, i.e., from SE2 to SE3. This indicates that the zero ID ATC is due to a full utilization of the cross-border capacity for DA trading, leaving no capacity for intraday. It is not possible from the figure to say whether the full utilization of the cross-border capacity in DA trading is a result of an increase of DA AAC or a

decrease of ID NTC. These two possibilities will be analyzed further in Sections 3.4 and 3.5.

On the contrary, for $SE2 > SE1$, it can be seen that all hours with zero ID ATC occur when the DA flows are in the other direction (i.e., from $SE1$ to $SE2$) and that most of these hours coincide with non-intuitive flows from $SE1$ to $SE2$ (light orange bar). This shows that, for $SE2 > SE1$, hours with zero ATCs are almost always a result of non-intuitive flows in the DA market.

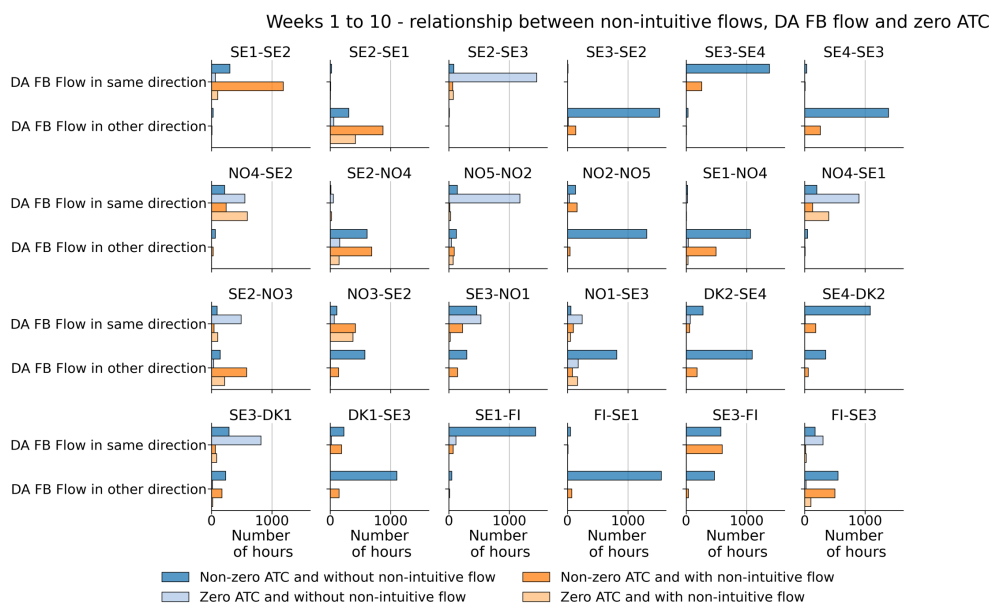


Figure 13: Relationship between non-intuitive flows, direction of DA flows and zero ID ATC with the new method. Reading guide: For $SE2 > SE3$, there were 1200 hours (light blue bar) with DA flows in same direction (i.e. $SE2$ to $SE3$) that resulted in zero ID ATCs.

The fact that some borders receive zero ATCs more often with the new methods can have consequences on operational security. Indeed, as was explained in detail in [1], a well-functioning intraday trading is key to reducing the impacts of unexpected events (such as unexpected trips of generators) on real-time operations. When for example a generator trip event occurs, this creates imbalances for the market participant with balance responsibility for this generator. This market participant can close this imbalance by trading it away on the intraday market. This is possible if trading possibilities exist either within the same bidding area or with another bidding area, in which case there needs to be sufficient ID ATCs. As was seen in Section 1.1, 80% of all intraday trading in the Nordics occur over bidding zone borders, which shows the latter case (closing imbalance through cross-border intraday trading) is especially important in the Nordic region. If the imbalance cannot be closed on the intraday market, it will result in real-time imbalances that must be handled by the TSOs, for example by activation mFRR reserves.

The sharp increase of the number of hours with zero ATCs with the new methodology on important corridors in the Nordics, such as $SE1 \rightarrow SE2$ and $SE2 \rightarrow SE3$, can therefore have important consequences on operational security. This has not been analyzed so far in the external parallel runs. Such an analysis could rely on the evaluation of cross-border intraday trading volumes following large

historical events, such as the 26 April event that led to the disconnection of two Forsmark reactors.

3.4 IMPACT OF THE INTRODUCTION OF FB MC IN DA

We now turn our attention to the component of ID ATC related to the introduction of FB MC in DA, namely DA AAC, which impacts the trading capacities in ID as follows: $ID\ ATC = ID\ NTC - DA\ AAC$.

As was noted earlier, if the only change to the current methodology was the introduction of FB MC in DA, this factor would explain all the differences in ID ATC. It has already been observed earlier that it is not the case.

Figure 14 presents the number of hours for which DA AAC is larger, lower, or identical with the new methodology than with the current one. Figure 15 presents the extent to which the new and the current methodologies differ in terms of DA AAC by visualizing the distribution of the differences new DA AAC – current DA AAC.

A larger DA AAC with the new methodology results from a higher utilization of a border in a certain direction by FB MC compared to NTC MC. For each border, the results are symmetrical in terms of direction, as can be seen in Figure 14. That is, the number of hours with larger DA AAC with the new methodology in one direction is equal to the number of hours with lower DA AAC in the other direction.

For Swedish domestic borders, DA AAC is higher with the new method in 75% of the hours for SE1>SE2, in 50% of the hours for SE2>SE3 and only for a few hours for SE3>SE4. Note, for SE2>SE3, that a change in modelling of series capacitors on this border has been made in week 9 by the TSOs¹. This change will better reflect the current way of operating these series capacitors and is expected to increase DA AAC from weeks 9 and onwards.

The magnitude of the differences in DA AAC between the new and the current method is shown in Figure 15. A few borders stick out: SE3>SE4 and SE4>DK2 with large decreases in DA AAC, SE3>NO1 and SE3>DK1 with large increases in DA AAC.

¹ See <https://nordic-rcc.net/wp-content/uploads/2023/03/5.-Result-elaboration-DA.pdf>

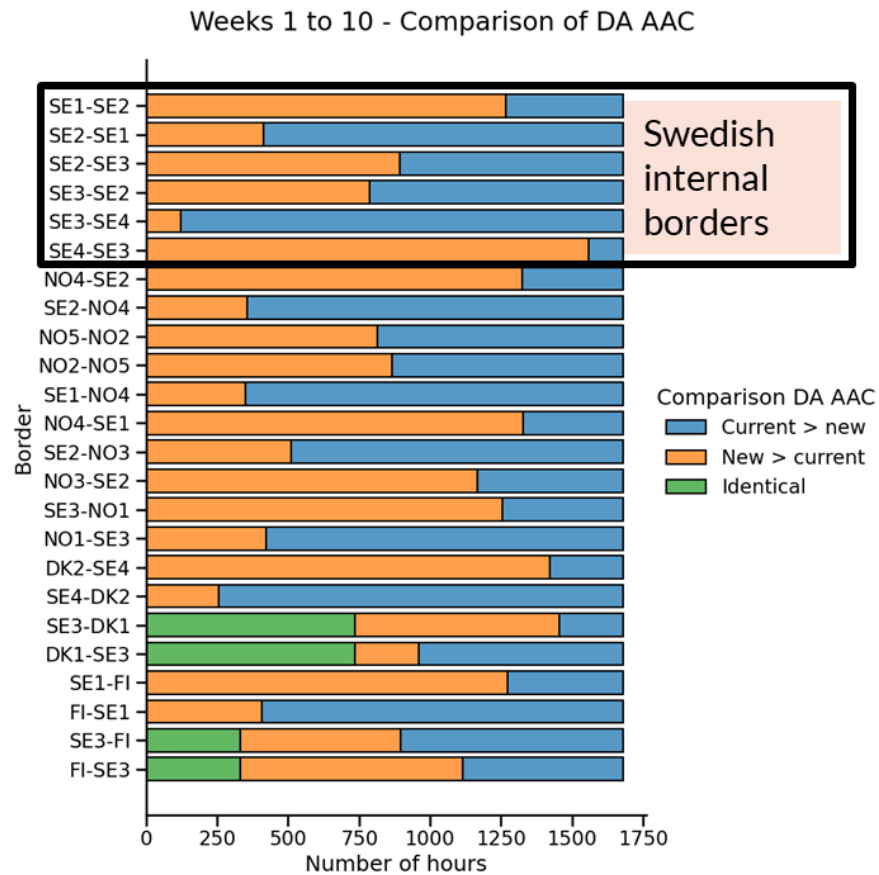


Figure 14: Number of hours when DA AAC are higher (respectively lower and identical) with the current methodology than with the new methodology.

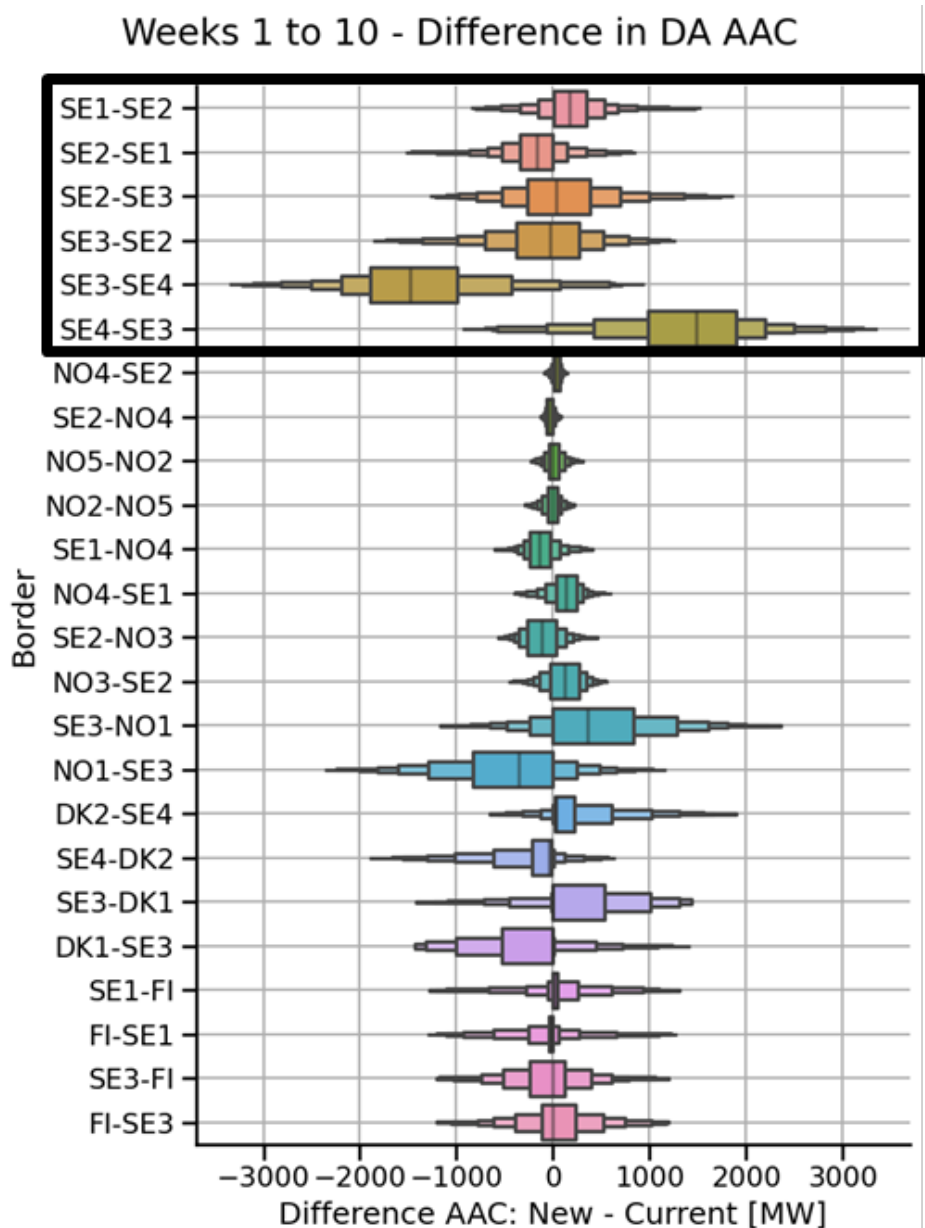


Figure 15: Distribution of differences in DA AAC between the new and the current method.

To explore how these changes in DA AAC due to the introduction of flow-based impact the ID capacities, Figure 16 shows the correlation between changes in DA AAC and changes in ID ATC. As explained above, the expected correlation is that increases in DA AAC should result in decreases in ID ATC. This trend is clearly seen on some borders, such as SE4>DK2, SE1<>FI and SE3>FI. However, it is much weaker on some other borders, such as NO5<>NO2. On the Swedish domestic borders, the trend can be seen but often with a lot of noise around it.

The analysis of this correlation reveals that change in DA AAC is seldom the only factors that impacts ID ATC. Therefore, changes in available trading capacities for intraday are only partly explained by the introduction of flow-based in DA.

In the next section, the effect of the new methodology to compute ID NTC will be analyzed.

Weeks 1 to 10 - Correlation between differences in DA AAC and in ID ATC

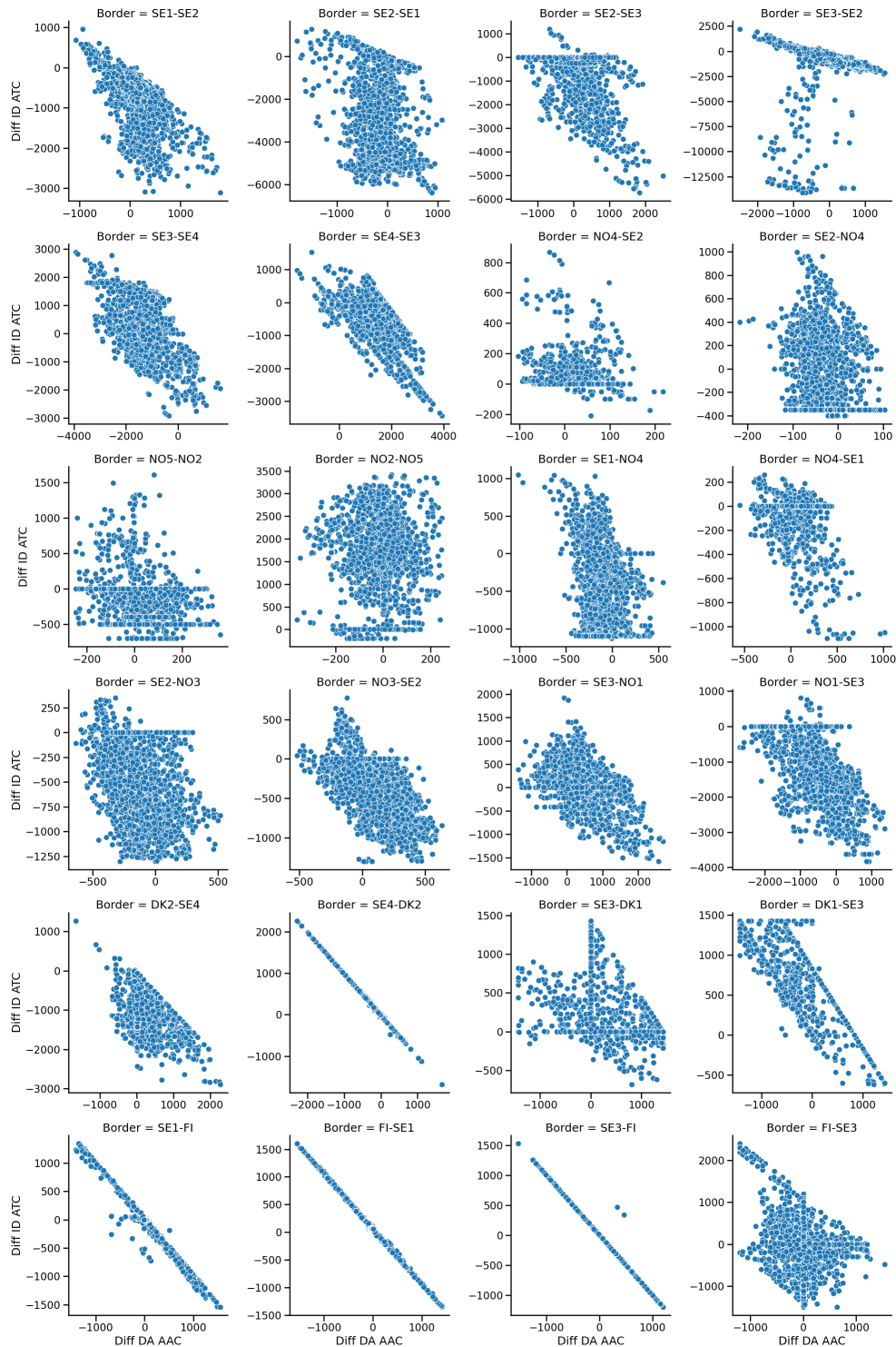


Figure 16: Correlation between changes in DA AAC and changes in ID ATC. Each datapoint corresponds to one hour in the analysed period.

3.5 IMPACT OF THE NEW METHODOLOGY TO COMPUTE ID NTC

In this section, we turn our attention to the second factor that has an impact of available trading capacities for intraday: ID NTC. Figure 17 shows the number of hours for which the new method gives higher ID NTC, lower, and identical. Figure 18 shows the extent of the differences between the new and the current ID ATC. Some systematic changes in ID NTC can be identified.

For Swedish domestic borders, a systematic decrease in ID NTC on all borders and all directions (except SE4>SE3) can be observed. Here, the effect is non-symmetrical, as opposed to differences in DA AAC in the previous section. That is, one border can see a decrease in ID NTC in both directions.

Other clear and systematic effects are systematic increases on NO4>SE2, NO2>NO5, SE3>NO1, SE3>DK1, SE1>FI and SE3>FI and systematic decreases on NO5>NO2, SE1>NO4, SE2>NO3, NO1>SE3 and DK2>SE4.

Looking at the magnitudes of the differences in Figure 18, the larger differences are observed on the Swedish domestic borders as well as on NO2>NO5 (large increases), NO1>SE3 (large decreases) and DK2>SE4 (large decreases).

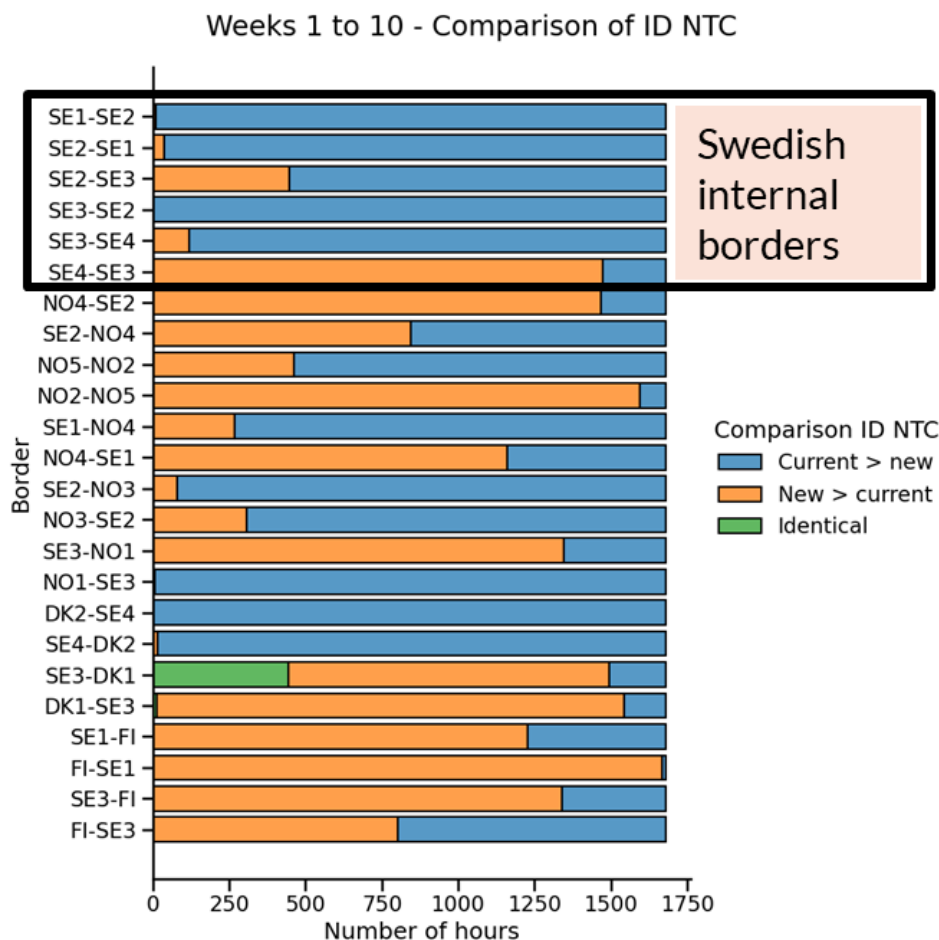


Figure 17: Number of hours when ID NTC are higher (respectively lower and identical) with the current methodology than with the new methodology.

Weeks 1 to 10 - Difference in ID NTC

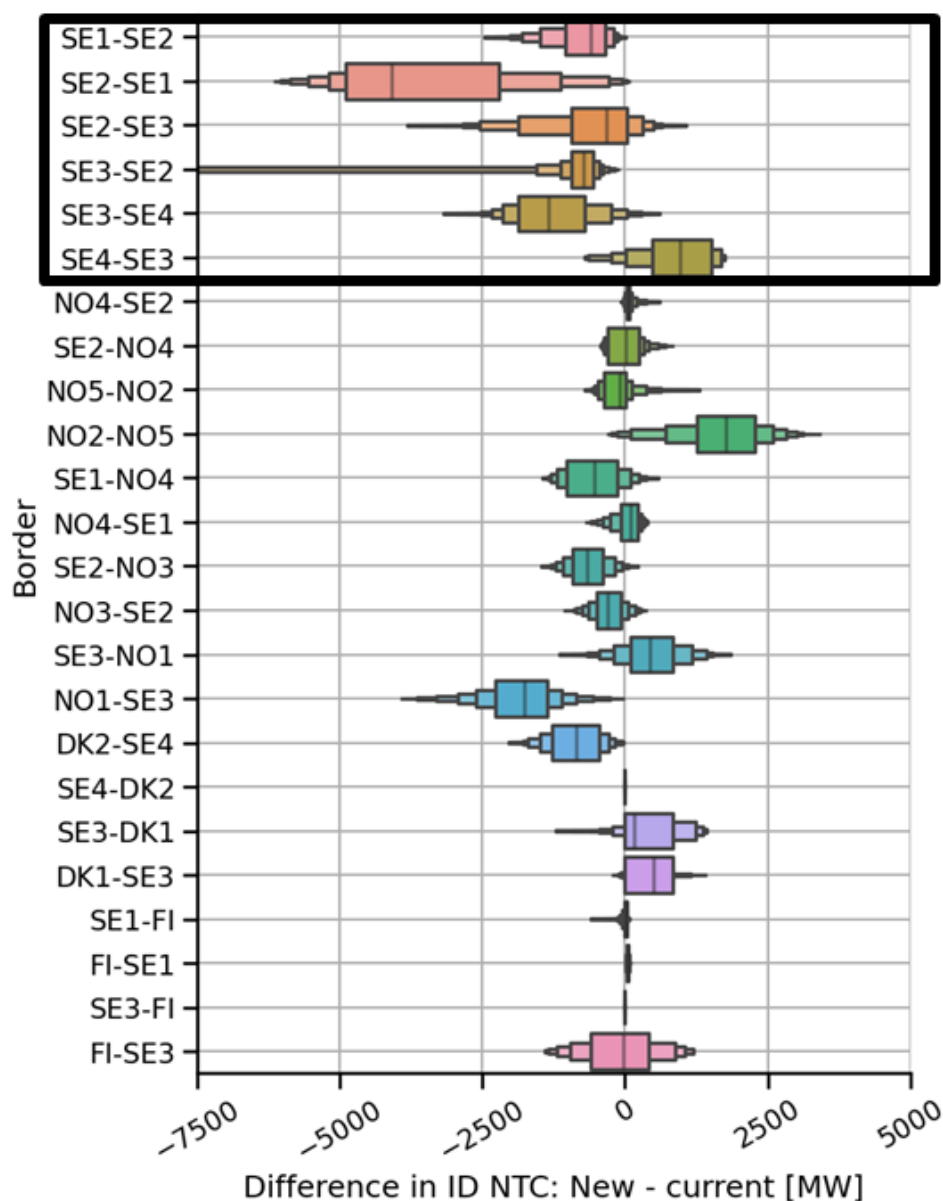


Figure 18: Distribution of differences in ID NTC between the new and the current method.

To analyze how changes in ID NTC impact ID ATC, Figure 19 shows the correlation between differences in ID NTC and differences in ID ATC. An increase in ID NTC should lead to an increase in ID ATC, everything else being equal. This trend is clearly seen on some of the borders. For example, this trend is much clearer on $SE1 \diamond SE2$ and $SE2 \diamond SE3$ than the correlation between DA AAC and ID ATC from Figure 16. This indicates that changes in ID ATC are mostly explained by changes in ID NTC, not by changes in ID AAC, for these borders. This is also the case for $NO4 \diamond SE2$ and $NO2 \diamond NO5$. For other borders, such as $SE2 \diamond NO3$, both trends are equally visible, indicating that changes in both ID NTC and DA AAC contribute to the changes in ID ATC.

Weeks 1 to 10 - Correlation between differences in ID NTC and in ID ATC

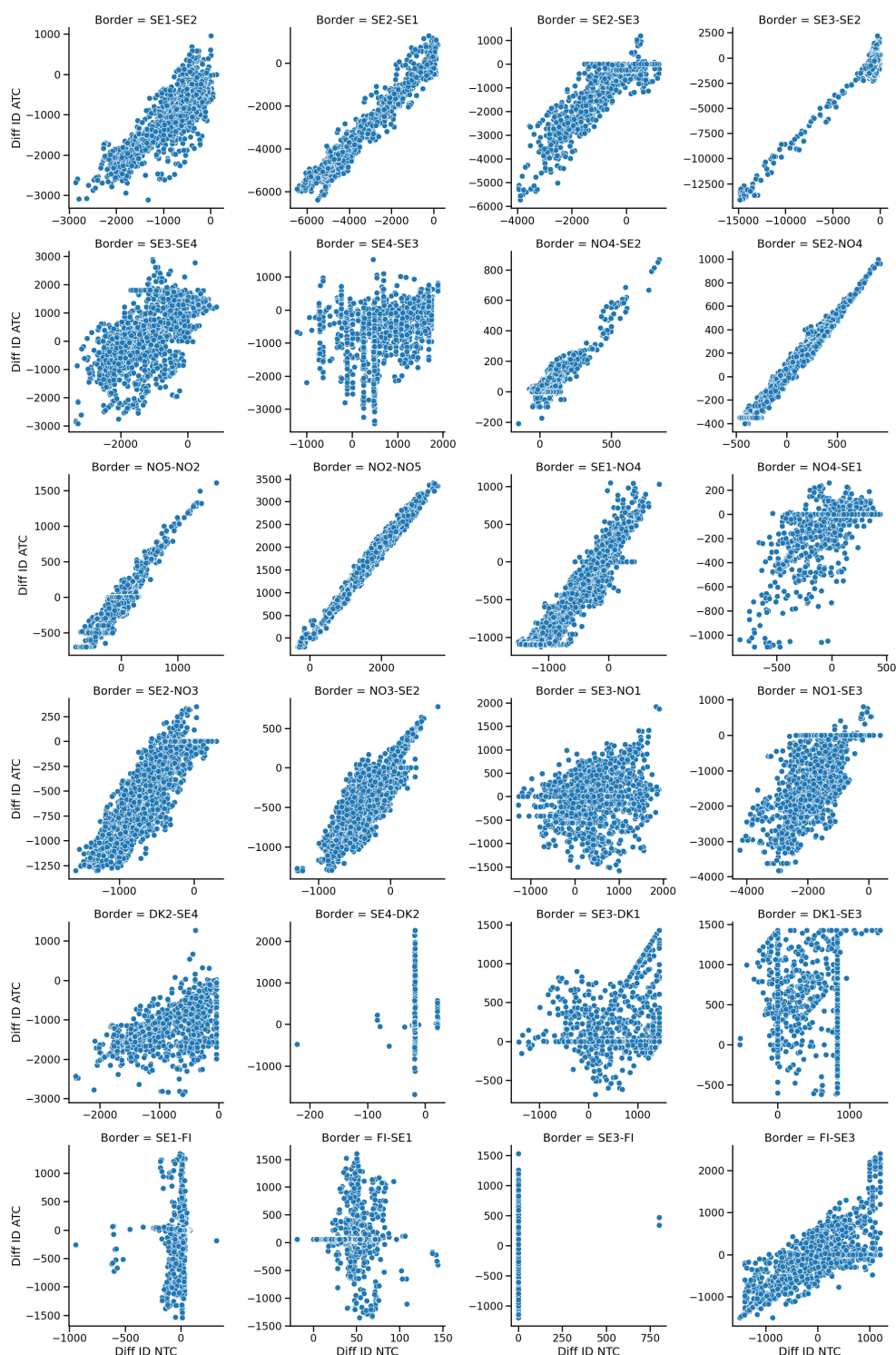


Figure 19: Correlation between changes in ID NTC and changes in ID ATC. Each datapoint corresponds to one hour in the analyzed period.

3.6 ANALYSIS OF ARBITRAGE POSSIBILITIES DUE TO NON-INTUITIVE FLOWS

As mentioned in Section 2.2, when explaining the theory and root cause behind arbitrage possibilities due to non-intuitive flows, it is difficult to quantify with high accuracy to what extent this phenomenon will be used by market participants after go-live. However, based on the theory behind the example explained in Figure 9, it is possible to quantify a “maximum theoretical arbitrage value” by calculating the hourly theoretical arbitrage value per PH (Power Hour) and per border (by multiplying the ID-capacity and DA price-spread between the two areas), and then aggregate these values for all internal Nordic borders and PHs with a non-intuitive flow and where there is ID-capacity given in opposite direction of the DA-flow.

This total max theoretical arbitrage value is shown in Table 1 below, summing to 87.9 MEUR during the EPR-period (which is then larger than the total DA SEW gain of 73.4 MEUR in the Nordic region for the same EPR-period).

Table 1: Maximum theoretical value during the EPR-period.

Border	Total possible profit from arbitrage trading (€)
DK1-DK2	58,420
DK1-NO2	1,527,812
DK1-SE3	2,182,700
DK2-SE4	1,635,097
FI-SE1	542,884
FI-SE3	5,865,009
NO1-NO2	7,039,300
NO1-NO3	436,975
NO1-NO5	6,418,160
NO1-SE3	9,130,523
NO2-NO5	1,283,793
NO3-SE2	6,228,816
NO3-NO4	2,018,289
NO3-NO5	865,864
NO4-SE1	1,988,562
NO4-SE2	3,879,344
SE1-SE2	15,339,366
SE2-SE3	7,006,094
SE3-SE4	14,432,205
Total	87,879,213

These figures numbers can be seen as the maximum theoretical arbitrage value, but as already mentioned, it is difficult to say exactly how and to what extent this will be utilized by market players. However, since profit maximizing opportunities are usually used in a well-functioning market, there is a high chance that the vast majority of this value (and thus also the available ID-capacity for those PHs/borders) will be used immediately when the ID-market opens at 15:00 D-1 – and thus not be available later in the ID-market when these capacities are needed for other purposes such as import/export of balancing energy.

When market participants start to adapt their bidding strategies (e.g., changing DA-pricing in order to capture ID opportunity value, including these arbitrage-values), this will have a direct impact on both DA-prices/flows and on the occurrence of these arbitrage-values. Thus, in reality, we will never see the exact same DA-prices and arbitrage-possibilities as during EPR, but it is reasonable to believe that the correlation or relationship between DA SEW gains and ID arbitrage values is fairly stable (lower DA SEW-value = lower ID arbitrage value). The detailed analysis of this correlation is left as future work.

ID opportunity value is of course considered in DA bidding strategies already today, with the current NTC-model. But where it's currently very difficult to foresee future mFRR-prices (which is currently the main price driver for Nordic ID-markets) 12-36 hours in advance, non-intuitive flows and arbitrage values caused by Flowbased will (according to EPR) be very structural and common – and thus also fairly easy to predict and use as a new key input in one's bidding strategies.

4 Conclusions

In this report, quantitative and qualitative analyses of the impact on the intraday market of the proposed changes to the capacity calculation and allocation methodology for the day-ahead and intraday markets in the Nordics have been performed. Two main changes have been shown to drive the impacts on the intraday market: the introduction of the flow-based market coupling methodology for day-ahead and a new methodology to compute intraday net transfer capacities.

The quantitative analysis is based on the first 10 weeks of data available for 2023 from the external parallel runs currently performed by the Nordic TOSs. It reveals some systematic decrease of intraday capacities on the Swedish internal borders, except on cut 4 in the direction SE3 to SE4. Other Nordic borders are impacted differently: some receive on average more capacity for intraday trading and some others less capacity. It is advocated to perform further analysis on the impacts that these changes in intraday capacities will have on the overall economic efficiency of the proposed changes as well as on operational security aspects. In particular, some concerns are raised about both the general decreased in intraday capacity on SE1->SE2 and SE2->SE3 and the increase of hours with zero intraday capacity on these same borders. This could have important consequences on the role of the intraday market to limit the impacts of unexpected events on real-time operations. It is advocated to analyze large historical events to better understand to what extent intraday trading mitigated the real-time impacts of these events and how this mitigation effect will be impacted by the proposed changes in capacity calculation and allocation.

The evaluation also reveals that changes in available capacities for intraday trading are driven by different factors on different borders. On some borders, changes can be mostly explained by the introduction of flow-based in day-ahead, while on some other borders changes can be mostly explained by the new methodology to compute intraday net transfer capacities. On yet some other borders, these two factors are equally important. It is advocated that this methodology is analyzed more thoroughly to fully understand its consequences on both the intraday market and, overall, on the economic efficiency of the proposed changes as well as on operational security aspects.

Finally, non-intuitive flows are shown to occur fairly often in the day-ahead market outcome with the flow-based methodology. They may create arbitrage opportunities between the day-ahead and intraday markets. These arbitrage opportunities will result in changes in trading strategies which may impact the day-ahead prices. These changes can in turn have an impact on the day-ahead socioeconomic gains when switching to flow-based. It is advocated that these effects are analyzed more thoroughly.

Overall, this report highlights the importance to evaluate the combined overall effects of the proposed changes on all trading markets and real-time operations instead of focusing only on the day-ahead market. Only then can the consequences of the proposed changes in terms of social welfare and operational security be adequately analyzed.

5 References

- [1] M. Brolin, C. Hamon and S. Nyström, "Intradagmarknaden : En generell beskrivning av intradagmarknadens funktion," Energiforsk, 2021.
- [2] [Online]. Available: https://nordic-rcc.net/wp-content/uploads/2023/03/CCM-EPR-handbook_V3.pdf.
- [3] [Online]. Available: https://eepublicdownloads.entsoe.eu/clean-documents/pre2015/ntc/entsoe_NTCUsersInformation.pdf.
- [4] Energinet; Fingrid; Statnett; Svenska kraftnät, "Transitional solution for calculation and allocation of intraday cross-zonal capacities for continuous trading in the intraday timeframe," 2022.
- [5] Energinet; Fingrid; Statnett; Svenska kraftnät, "Capacity calculation methodology," 2022. [Online]. Available: <https://nordic-rcc.net/flow-based/methodology/>.
- [6] Energinet; Fingrid; Statnett; Svenska kraftnät, "Consultation process evaluation," 2023. [Online]. Available: <https://nordic-rcc.net/wp-content/uploads/2023/05/3.-Consultation-process-elaboration.pdf>.
- [7] [Online]. Available: <https://nordic-rcc.net/flow-based/simulation-results/>.

IMPACT OF FLOW-BASED ON THE INTRADAY MARKET

Changes to the capacity calculation and allocation methodology for the day-ahead and intraday markets are expected to be implemented in the near future in the Nordics. Nordic TSOs are currently running external parallel runs in which the impact of these changes on both day-ahead and intraday markets are analyzed. The focus of these external parallel runs has very much been on the day-ahead market. In this report, the analysis of the Nordic TSOs is complemented by an extended evaluation of the impacts on the intraday market.

One main conclusion of this report is that there is a need to analyze how the proposed changes to the capacity calculation and allocation method will impact the overall economic efficiency and operational security considering effects on multiple markets. Another main conclusion of this report is that the introduction of flow-based only explains part of the differences in available trading capacities for intraday, and more analysis of the proposed methodology for computing intraday net transfer capacities should be performed.

A third main conclusion from this report is that there is a need to further analyze the specific impact of so-called non-intuitive flows on the socioeconomic welfare and operational security. Overall, this report highlights the importance to evaluate the combined overall effects of the proposed changes on all trading markets and real-time operations instead of focusing only on the dayahead market. Only then can the consequences of the proposed changes in terms of social welfare and operational security be adequately analyzed.

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