Transitional solution for calculation and allocation of intraday cross-zonal capacities for continuous trading in the Intraday timeframe

17.10.2024

Abbreviations:

AAC	Already Allocated Capacity
AAF	Already Allocated Flow
ATC	Available Transfer Capacity
ATCE	ATC Extraction
BZ	Bidding Zone
CC	Capacity Calculation
CCM	Capacity Calculation Method
CNE	Critical Network Element
CNEC	Critical Network Element with Contingency
D-1	1 Day before delivery date
D-2	2 Days before delivery date
DA	Day-Ahead
FB	Flow-Based
ID	Intra-Day
MC	Market coupling
NEMO	Nominated Electricity Market Operator
NP	Net position
NTC	Net Transfer Capacity
PTDF	Power Transfer Distribution Factor
RAM	Remaining Available Margin
SDAC	Single Day-ahead Coupling
SE1-SE2	Swedish border between bidding zone SE1 and bidding zone SE2, containing both directions of SE1→SE2 and SE2→SE1
SE1→SE2	Direction from bidding zone SE1 to bidding zone SE2
TP	ENTSO-E Transparency Platform
TSO	Transmission System Operator
XBID	Intra-Day continuous trading platform
z2z	Zone-to-zone
z2s	Zone-to-slack

Version Control			
Version	**Author**	**Date**	**Changes**
0.1	Nordic CCM project MET WG	13.04.2022	First version
0.2	Nordic CCM project MET WG	29.02.2024	Detailed explanation of relaxation parameters and various enhancements for better readability
0.3	Nordic CCM project MET WG	24.04.2024	Updated relaxation parameters
0.4	Nordic CCM project MET WG	Xx/10/2024	Improved explanation of delta compensation and more clarifications RAM relaxation on allocation constraints

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1 Background and purpose

Article 20 of the Nordic DA CCM, approved on October 14, 2020, describes a transitional solution for the calculation and allocation of cross-zonal capacities for the intraday timeframe. Article 20(1) states the need of calculating ATC-values based on the FB domain for the intraday market until the single intraday coupling is able to support FB parameters[1]. Article 20(2) prescribes an optimization approach to facilitate this calculation. Article 20(3) requires the Nordic TSOs to publish the optimization approach and the parameters used, including their descriptions, purpose, and effect two months before the application of this transitional solution (i.e. two months before the Nordic DA FB go-live). The NRAs and stakeholders shall be informed along the development process of the optimization formulation, and they may provide comments duly to be taken into account in development work.

This document aims at fulfilling the article 20(2) and 20(3) by elaborating the optimization formulation that is currently being investigated in the Nordic CCR and is intended to be used at the start of the parallel runs. As such, this document is a living document that is aligned to the latest development of the ATC extraction (ATCE) along the Nordic CCM parallel runs.

Article 20 requires the calculation of 'ATC' values from the 'final DA FB domain'. The calculation is referred as the ATCE method. Because the final DA FB domain is used as input to the ATCE, the outcome of this calculation is 'ATC' values, corresponding to the NTC values that are calculated based on the DA FB domain. Chapter 3 elaborates more on the terminology of the ATCE in the Nordic context.

2 High level comparison between FB and NTC

This chapter illustrates the relationship between the FB and NTC given the same grid topology and conditions for the two approaches. Considering the following example depicted in Figure 1, a power grid consisting of three bidding zones (BZs), and three identical lines with the physical capacity of 1000 MW each. Each line is considered a Critical Network Element (CNE).

The physical characteristics of this grid can be linearized and represented by a matrix of "zone to slack" PTDFs (z2sPTDFs) and Remaining Available Margins (RAMs). Each BZ has a specific z2sPTDF for each CNE that tells us how much of one MW injected in this BZ shows up on a particular CNE. Each RAM shows the maximum allowed flow on each CNE. In this simplified case, the capacity of each connecting line (or CNE) is the RAM for that CNE, and C is the chosen "slack zone"[2] in the system. The matrix of RAMs and z2sPTDFs are shown in figure 3 below[3].

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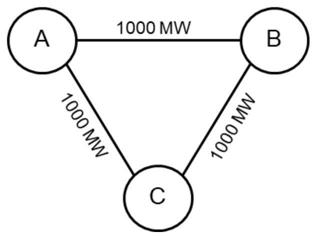
[1] 'Until the single intraday coupling in accordance with Article 51 of the CACM Regulation is able to support the allocation of cross-zonal capacities based on FB parameters, the CCC shall transform the final FB parameters as referred to in Article 19 into available transmission capacity ('ATC') values on bidding zone borders of the Nordic CCR and bidding zone borders of neighbouring CCRs if the latter are included in capacity calculation pursuant to Article 18. For each market time unit, one set of ATC values shall be calculated.'

[2] The slack zone is the reference point in the z2sPTDF matrix in the sense that all power injections is extracted in this zone. Thus, all z2sPTDFs for the slack zone are zero (see Figure 1 and Footnote 3 for details). The slack zone is a necessary mathematical construct, but the choice of slack zone has no influence on the results.

[3] The z2sPTDF of BZ A on the CNE (A->B) can be interpreted/computed by the following. First, run a load flow calculation, on the grid without any modification, to obtain the power flow on the CNE (A->B), denoted as



Line (CNE)	Max flows	PTDFs for BZ A	PTDFs for BZ B	PTDFs for BZ C (slack)
A -> B	1000 MW	33 %	- 33 %	0
B -> C	1000 MW	33 %	67 %	0
A -> C	1000 MW	67 %	33 %	0

Figure 1. 3-bidding zone example and its z2sPTDFs

There are two approaches to calculate capacity for the market coupling based on this linearized modelling of the grids, NTC and FB. In FB, the capacity is provided to the market directly in the form of the z2sPTDF matrix above, in addition to the 'Max flows', being remaining available margin (RAM) in the FB terminology. The market algorithm determines prices and Net Positions (NPs) of the bidding zones as market coupling outcome. Essentially, the FB market coupling algorithm tries to increase NPs (with an objective/intention to maximize the socio-economic welfare of the market coupling bidding zones in Europe) until a limit on one (or several) of the CNEs are reached. The domain of all possible combinations of NPs allowed in the FB market complying to the matrix above, defines the "FB domain". The FB domain for the matrix above is illustrated in Figure 2 (in two dimensions only).

In NTC, capacities are provided as values for each direction for each individual bidding zone border. These values can be extracted from the linearized grid description above in such a way that the resulting NTC domain respects the linearized grid description and its limits. As for the FB domain, the NTC domain includes all possible combinations of NPs that are allowed in the NTC market, complying to the physical limits of the grid. The NTC domain is illustrated in Figure 2.

In NTC, the physical limitation of CNE (A->C) being 1000 MW with a z2sPTDF of 67%, causing the export capacity of BZ A to be limited to 1500 MW (i.e. 1000 MW / 0.67 = 1500 MW) (see Figure 2). The import capacity for BZ A, will equally have to be limited to 1500 MW due to the physical limitation of CNE (A->C) being 1000 MW as well with a z2sPTDF of –0.67 (-1000/-0.67). Similar arguments also hold for BZ B and bidding zone C, which also will face import- and export limits at 1500 MW. In this manner, NTC is a

'F_AB_original'. Second, modify the grid condition by injecting 100 MW power at A, and consuming the 100 MW power at C (i.e. being the slack). Run the load flow again in this modified setup to obtain the power flow on the CNE (A->B), denoted as 'F_AB_new'. The z2sPTDF of BZ A is then computed by (F_AB_new – F_AB_original)/100, where the 100 in the denominator refers to the 100 MW power injection. Similarly, to compute z2sPTDF of BZ B, the logic remains the same except that the modification in the second step injects 100 MW at BZ B. Finally, to compute z2sPTDF of BZ C, the injection and the consumption both happen at BZ C. Thus, the 'F_AB_original' and 'F_AB_new' in this case are the same, resulting z2sPTDF of BZ C on CNE (A->B) being 0.

capacity calculation and market approach that limits the import- and export capacity for each bidding zone.

The way the limits are implemented, is by distributing the import/export limits to the different borders. However, the distribution itself can be done in a multitude of different ways, only requiring that the correct export and import limitations for each bidding zone are maintained. Returning to our 3-BZ example above, the 1500 MW limitations may for example cause the TSOs to ex-ante decide 750 MW in each direction for border A->B and A->C and B->C equally. A different, but equally valid distribution of NTCs, is to put NTCs for A->B at (1500,0), B->C at (1500,0) and A->C at (0, 1500). This capacity arrangement also provides 1500 MW as import and export limits for all 3 bidding zones. Thus, the two distributions are only two different representations of the same NTC domain. In fact, all distributions of NTCs resulting in the 1500 export/import limits are different representations of the same NTC domain.

Although the equal split of the 1500 MW export capacity on CNE (A->C) and CNE (A->B) is a valid NTC solution to facilitate the trades in the market, one may also observe that the FB method/domain can offer more capacities in terms of trading possibilities. With FB, one potential market outcome is 1000 MW export in BZ A and B at the same time, allowing C to import 2000 MW. This market outcome is at the 'edge/intersection' of the FB domain but still within FB. Consequently, by providing the FB domain to the market (i.e. asking the market allocation algorithm to find an optimal solution within the FB domain for the European market coupling), the market allocation outcome may end up at this market point. On the contrary, this 'FB feasible' market outcome is not within the previously described NTCs. Consequently, by providing the NTC domain to the NTC market allocation (i.e. asking the market allocation algorithm to find an optimal solution within the NTC domain for the European market coupling), the market allocation outcome can never find this 'FB feasible' market point as a market coupling solution.

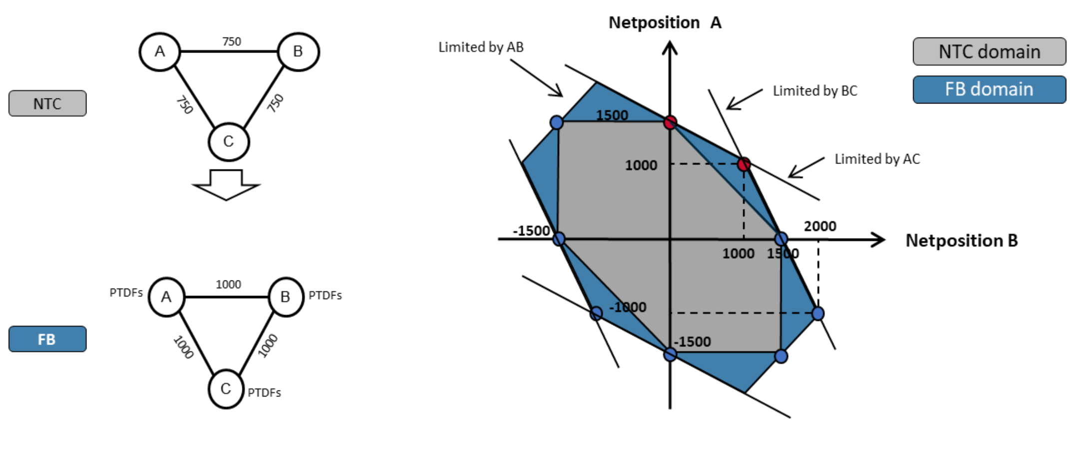


Figure 2 FB and NTC domain comparison

Note that BZ C is not explicitly shown in Figure 2. Because the 3-BZ example is considered a balanced and closed system, the sum of export of BZ A and B must equal to the import of BZ C.

3 ATCE in the Nordic context

3.1 Background

After the DA market clearing at 13:00 and before 14:00 D-1 (one day before the energy delivery date), the TSOs need to calculate ID capacities for the ID gate opening at 15:00 on D-1.

At the time of DA FB go-live in the CCR Nordic, XBID is technically not yet able to process the FB format (i.e. PTDFs and RAMs on the CNEC level), but the NTC/ATC-format (i.e. the capacities between bidding zones on the cross-zonal border level). The ATCE method is designed as a transitional solution to solve this compatibility issue[4]. Specifically, the required inputs of the XBID platform, foreseen at the DA FB go-live in the Nordic CCR, are DA NTC and DA AAC (AAC=Already Allocated Capacity), corresponding to the equation below.

$$ID\ ATC = DA\ NTC - DA\ AAC$$

To facilitate the ID trading activities, the TSOs shall provide the capacities corresponding to the DA NTC term and the DA AAC term, as inputs for the ID timeframe to the XBID platform, such that XBID automatically generates the ID ATC for the ID trading. In a nutshell, the ATCE optimization method computes the capacity that corresponds to the DA NTC values in the equation above from the DA FB domain, together with the DA AAC (i.e. not computed by the ATCE optimization but computed by the TSOs based on DA MC results), as input to the ID trading platform for the ID gate opening. For the sake of simplicity and explanation, from this point on the DA NTC in this document refers to the outcome of the ATCE (i.e. extracted NTC), if not specified otherwise.

3.2 DA AAC in ATCE

For the ID gate-opening capacity computations, the DA AAC refers to the DA market outcome of already allocated flows (i.e. DA AAF). In other words, the DA AAC is a more general terms being used within the current NTC world. In the ATCE method, the content of the DA AAC is (represented by) DA AAF. Appendix I elaborates the consideration of adopting the DA AAF to represent the DA AAC.

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[4] Based on a given FB domain (PTDF and RAM on the CNEC level), the ATCE method provides an 'optimal' set of NTC values (capacities on the cross-zonal border level).

On D-1 around 12:45, the EU market coupling algorithm (known as Euphemia) provides the market coupling outcome, in terms of price and net position per bidding zone. The DA AAF is computed using the formula[5] below,

$$DA\ AAF = z2sPTDF \times NP$$

The z2sPTDF refers to the zone-to-slack PTDF, which forms the DA FB domain together with the RAM. The NP term is the balanced net positions of the Nordic bidding zones, as the market results from Euphemia[6]. In other words, the DA AAF is the physical flow on each CNEC that is induced by the DA market clearing point. In general, one can compute the DA AAF for every CNEC if their z2sPTDFs and the DA market clearing point are available.

DA AAF of border CNECs

Of all CNECs nominated to the FB CC and MC process, some CNECs are border CNEs and others are 'internal' CNECs within the bidding zone. In the ATCE context, not all the computed DA AAFs per CNEC are used. Instead, only the AAFs of border CNECs are of relevance. They are the physical flows flowing on the cross-border network elements. In other words, although the DA AAF term is on the CNEC level by default, the DA AAF in the ATCE context is a border level term.

Again, for the sake of simplicity and explanation, from this point on the DA AAC in this document refers to the DA AAF (of the borders) and is interchangeable, if not specified otherwise.

3.3 DA NTC in ATCE

To ensure there is sufficient ID ATC at the gate opening, ID ATC is designed to be always greater or equal to 0. This further implies that the DA NTC term needs to be always greater or equal to the DA AAC term according to the equation of ID ATC = DA NTC – DA AAC. In other words, the DA AAC term is the DA already allocated capacity from the market coupling. The DA NTC term, as an output of the ATCE, should at least guarantee the DA AAC, such that there is always 'sufficient' ID ATC at the ID gate-opening[7].

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[5] The AAF is also used in the Congestion Income Distribution Methodology in Article 4. link: https://documents.acer.europa.eu/Official_documents/Acts_of_the_Agency/Individual%20decisions%20Annexes/ACER%20Decision%20No%2016-2021_Annexes/ACER%20Decision%2016-2021%20on%20CIDM%20-%20Annex%20I.pdf

[6] In terms of matrix multiplication, for a CNEC defined for a single border A→B, the dimension of its z2sPTDF is 1-by-n, where n is the number of the bidding zones, including the virtual bidding zones. The Nordic BZ NPs should be a n-by-1 vector, such that the dimension of the cross-product of the z2sPTDF and the BZ NPs is 1-by-1 (i.e. 1-by-n by n-by-1). This implies that the DA AAF for a border CNEC is a 1-by-1 value.

[7] The TSOs are developing a suitable method and the associated business process to cope with the situation when an unplanned outage occurs between the MC starts and the ID gateopening.

3.4 Conceptual example

Suppose SE1→SE2 DA AAC is 4000 MW[8] (being the physical flow computed by z2sPTDF of the SE1→SE2 border CNE * NP of all Nordic BZs). This implies that the minimum-guaranteed capacity of the DA NTC of SE1→SE2 border is 4000 MW. Mathematically speaking, this 4000 MW value is the lower bound of the 'to-be-extracted' DA NTC of this border. Suppose that the optimization program obtains 4300 MW DA NTC on this direction, in this case the TSOs shall provide 4300 MW as DA NTC and 4000 MW as DA AAC to XBID. The XBID platform further determines the ID ATC of this SE1→SE2 direction, using the equation ID ATC = DA NTC – DA AAC = 4300 – 4000 = 300 MW. Similarly, the SE2→SE1 direction DA AAC is -4000 MW (as input to the ATCE) and let's suppose the DA optimal NTC is 1500 MW (from ATCE as optimization outcome). The TSOs shall provide DA NTC of 1500 MW and the DA AAC of -4000 MW to XBID. The XBID platform computes the ID ATC of this direction, being 1500 - (-4000) = 5500 MW.

4 General implementation description of ATCE algorithm

This chapter describes the optimization formulation, including the description, purpose and effect of the parameter(s) used in the optimization. Mathematically, constrained optimization is the process of optimizing an objective function with respect to some variables in the presence of constraints on those variables.

Figure 3 show the schematic overview of the ATCE prototype tool. Essential building blocks are

- objective function (see section 4.1)
- constraints (see section 4.2)
- mathematical solver/problem overview (see section 4.3)
- threshold parameter (see section 4.4)

[8] The numbers in the example are fictitious and only for illustration purposes.

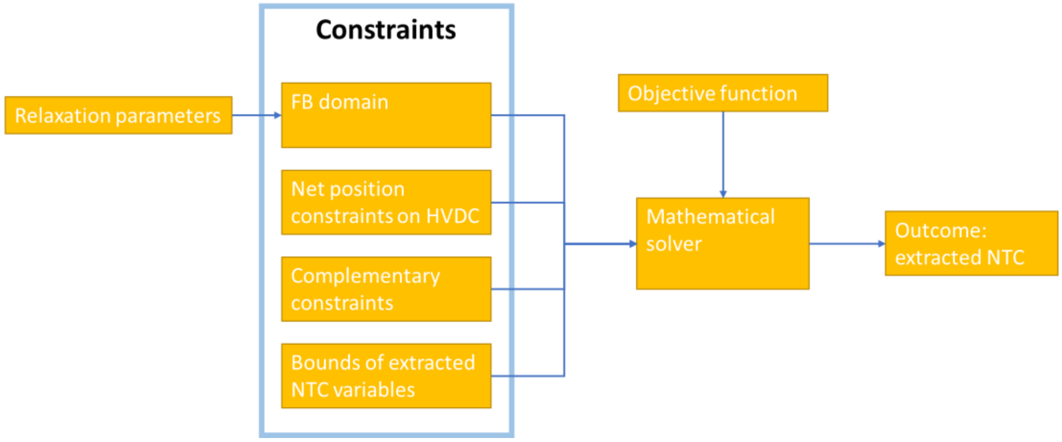

Figure 3 Overview of the ATCE

4.1 Objective function

In general, an optimization problem consists of an objective function that is a means to maximize or minimize something. In the Nordic ATCE context, the objective function maximizes the total Nordic bidding zone border capacities by multiplying all individual Nordic bidding zone border total capacity. The mathematical formulation is given in the equation below.

$$O = \prod_{n} C_n \,, \qquad where\ C_n = \hat{C}_n + \hat{C}_{n,o}$$

For each bidding zone border, there are two transfer capacities (i.e. NTCs to be extracted) representing the two opposite directions, denoted as $\hat{C}_n\ and\ \hat{C}_{n,o}$, where 'n' is the number of borders and 'o' refers to 'opposite'. Each of the directional capacities is a variable in the optimization formulation. The sum of the two opposite capacities of the same border forms the 'total' capacity of the border, denoted as C_n in the equation above, e.g. the SE1-SE2 total border capacity is (NTC(SE1→SE2) + NTC(SE2→SE1)), reflecting $\hat{C}_n + \hat{C}_{n,o}$[9]. Again, the objective function maximizes the total Nordic bidding zone border capacities by multiplying all individual Nordic bidding zone border total capacity. To write it more explicitly, the objective function looks like Maximize[(SE1-SE2 total capacity) * (NO1-NO5 total capacity) * (other AC borders total capacity…) * (FennoSkan total capacity)] * (other DC borders total capacity…)].

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[9] One of the $\hat{C}_n\ or\ \hat{C}_{n,o}$ could be a negative number. The sum of the two is always a positive number. Conceptual example: DA AAF of one direction is 1000MW. The extracted DA NTC of this direction must be greater or equal to 1000. Meanwhile, the extracted DA NTC of the opposite direction must be greater or equal to -1000. Thus, one of the extracted DA NTCs of the same border may end up being negative, but the sum of these two extracted DA NTC values is always positive.

The $\hat{C}_n$ *and* $\hat{C}_{n,o}$, are the exogenous variables in the ATCE optimization. The ATCE optimization respects the FB constraints, which are on the CNEC level. The extracted NTCs (i.e. $\hat{C}_n$ *and* $\hat{C}_{n,o}$, being the results of the ATCE optimization) are on the bidding zone border level. The formula z2zPTDF * capacity variable (i.e. $\hat{C}_n$ *or* $\hat{C}_{n,o}$ exogenous variables) ≤ RAM links the CNEC level z2zPTDF to the bidding zone border level exogenous capacities variables.

4.2 Constraints

A constraint in the optimization formulation is a condition that the solution must satisfy. In the context of the Nordic ATCE approach, the constraints can be classified as below,

- FB constraints: the physical flows on the CNECs and combined dynamic constraints induced by the extracted NTC must be less than or equal to the DA FB RAM of these elements. Please see more information in section 4.5.4
- Net position constraints: If net position constraints are present on the HVDC links to limit the import and export of the HVDC links as part of the DA FB capacity calculation (CC) inputs to the DA FB market coupling (MC), they are also considered in the ATCE.
- Complementary constraint: The HVDC capacity at the sending end of an HVDC cable (i.e. the extracted DA NTC at the sending end of an HVDC cable) should be equal to the capacity at the receiving end of the cable (i.e. the extracted DA NTC at the receiving end of the cable) plus the losses[10].
- Bounds of NTC variables: The optimization variables contain DA NTC of AC borders and the DC borders.
    - AC border: Using the AC border SE1-SE2 as an example, the variables are NTC(SE1→SE2) and NTC(SE2→SE1). The upper bound of the variable NTC(SE1→SE2) in the optimization formulation is infinity. 'Infinity' implies that the TSOs do not explicitly set the upper boundary to the DA NTC on this direction. The lower bound of DA NTC(SE1→SE2) is the DA AAC of this direction as the minimum-guaranteed capacity.
    - DC border: Using FennoSkan as an example, the upper bound of FennoSkan(SE3→FI) is not infinity, but the capacity defined by the TSOs, either as its nominal capacity or explicitly defined in the net position constraints. The lower bound of this directional capacity is the DA AAC of FennoSkan(SE3→FI).

[10] The Skagerrak HVDC has an implicit loss factor at 2.9% currently. The loss factor is aligned among TSOs, NRAs and NEMOs on a regular basis.

4.3 Non-linear optimization problem

Given the objective function of the optimization formulation, being the product of the total cross-zonal transfer capacity of each bidding zone border, the optimization problem of the ATCE is a non-linear problem, which requires a non-linear solver to solve it.

4.4 Introduction to PTDF and filter

4.4.1 Forms of PTDF and FB domain

The FB parameters, or FB domain, in this document refer to the PTDFs and RAMs. PTDF, the power transfer distribution factor, has two forms, namely the zone-to-slack PTDF[11] (z2sPTDF) and the zone-to-zone PTDF[12] (z2zPTDF).

The translation between the two forms of PTDFs is straightforward, using the equation below.

$$z2zPTDF(A \rightarrow B) = z2sPTDF(A) - z2sPTDF(B)$$

z2zPTDF(A->B) denotes the z2zPTDF from bidding zone A to bidding zone B. Physically, it describes the impact of power flow on a CNE, when there is an exchange from bidding zone A to bidding zone B.

Example: Suppose that A, B, and C are three fictitious bidding zones connecting each other. Let's assume the z2sPTDFs of CNEC X are shown below.

	z2sPTDF(A)	z2sPTDF(B)	z2sPTDF(C)
CNEC X	0.3	0.28	-0.2

Correspondingly, the z2zPTDFs of CNEC X are shown below, applying the equation above,

	z2zPTDF(A->B)	z2zPTDF(B->A)	z2zPTDF(A->C)	z2zPTDF(C->A)	z2zPTDF(B->C)	z2zPTDF(C->B)
CNEC X	0.02	-0.02	0.5	-0.5	0.48	-0.48

Because of the two forms of PTDFs, a FB domain can also be described in two different equations/forms, namely,

$$\boldsymbol{z2sPTDF} \times NP \leq \boldsymbol{RAM}, \text{ and}$$

$$\boldsymbol{z2zPTDF} \times Exchange \leq \boldsymbol{RAM}$$

These equations/forms reflect the PTDF definition in the footnotes 11 and 12. Again, the FB domain is the same, but with two forms of expression and application. Specifically, the single day-ahead coupling

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[11] 'zone-to-slack $PTDF$' means the PTDF of a commercial exchange between a bidding zone and the slack

[12] 'zone-to-zone $PTDF$' means the PTDF of a commercial exchange between two bidding zones

(SDAC) algorithm, commonly known as Euphemia, takes the form of z2sPTDF and RAM as inputs to perform the DA market coupling. For the ATCE purposes, the form of z2zPTDF and RAM, transformed from z2sPTDFs, is needed.

4.4.2 Positive z2zPTDF filter

From the example above, the z2zPTDFs of the CNEC X appear to be both positive and negative with the same magnitude.

The same z2zPTDFs are shown below,

	z2zPTDF(A->B)	z2zPTDF(B->A)	z2zPTDF(A->C)	z2zPTDF(C->A)	z2zPTDF(B->C)	z2zPTDF(C->B)
CNEC X	0.02	-0.02	0.5	-0.5	0.48	-0.48

Suppose a trade A->B is 100MW and the z2zPTDF of A->B is 0.02, the impact of this trade on the CNEC X is computed by 0.02 * 100 MW = 2 MW.

Because the direction is A->B with 100MW, this also implies that the opposite direction of the same trade (i.e. B->A) is -100MW, i.e. the same magnitude with an opposite sign. The impact of the opposite direction but the same trade, i.e. B→A, is -0.02 * -100 = 2 MW

Because these 'two' directions are the same trade and its actual impact on the CNEC X is only 2MW, it would be double counting, if we consider the two directions separately.

Numerically, to avoid the double counting, this positive z2zPTDF filter is applied by identifying 'z2zPTDFs with a negative sign' and setting them to 0. Note: numerically, we would avoid the double counting effect by setting the positive z2zPTDFs to 0.

Note that the application of the positive z2zPTDF filter is a methodological implementation in the ATCE algorithm and is not adjustable by the TSOs.

After applying the positive z2zPTDF filter, the z2zPTDFs are shown below,

	z2zPTDF(A->B)	z2zPTDF(B->A)	z2zPTDF(A->C)	z2zPTDF(C->A)	z2zPTDF(B->C)	z2zPTDF(C->B)
CNEC X	0.02	0	0.5	0	0.48	0

4.5 Introduction to Relaxation parameters

4.5.1 Background

The primary purpose of the ID market is to allow market participants to balance supply and demand close to the time of energy delivery, considering the variability and unpredictability in production and consumption. Furthermore, having sufficient ID capacities allows the market participants to manage their risks and optimize their portfolios, contributing to the overall efficiency of the electricity market more effectively.

Process-wise, the ID market opens after the closure of the DA market. The capacity available in the ID market can be seen as the 'leftover' or remaining capacity after the DA market clears. In other words, after the Day-Ahead market allocations, the remaining transmission capacity is made available for Intraday trading. It is often presumed that because the Single Day-Ahead Coupling (SDAC) algorithm allocates transmission capacities optimally, there would be limited capacity left for the ID market.

The TSOs implement two types of mathematical relaxations to expand the FB domain, aiming to meet market needs for substantial ID capacities. However, as with most things, there is another layer to consider. In this scenario, these mathematical relaxations bring along operational implications.

According to the DA CCM Article 20(3), the Nordic TSOs will publish the relaxation parameters used in the optimization approach including their descriptions, purpose and effect, two months before the Nordic FB go-live.

The following sections elaborate the so-called ‘RAM relaxation’ and the ‘PTDF relaxation’ and the TSO choice of the relaxation setting associated operational implications.

4.5.2 RAM relaxation parameter

The DA FB domain serves as a key input for the ATCE engine to compute the ID ATCs. This DA FB domain is formed by PTDFs and RAMs. In this context, the RAM relaxation specifically refers to the addition of a certain number of megawatts (MW) to the existing DA FB RAM of CNECs only (not to allocation constraints), while maintaining their PTDFs unchanged.

The RAM relaxation is a manageable setting. For example, by adding an extra 10 MW of RAM as to the existing RAM on a CNEC, we create a larger FB domain for the ATCE engine to work with. This expansion allows for the computation of a ‘larger’ set of ID ATCs. However, it is important to note that if this enhanced ID ATC is fully utilized in the ID market, it could potentially lead to an overload of the same magnitude – in this case, an additional 10 MW on the relaxed CNEC.

The TSOs agreed to manage the overload caused by the RAM relaxation using available measures, such that the application of the RAM relaxation does not compromise the operational security of the transmission grids (after applying the security measures).

4.5.3 z2zPTDF relaxation parameter

Next to the RAM relaxation parameter, the ATCE method also introduces another parameter, namely the z2zPTDF relaxation parameter. In other words, any ‘small’ z2zPTDF value less than or equal to the parameter are set to zero. Using the PTDF example above, suppose the z2zPTDF relaxation parameter = 0.05 or 5%. Before applying the z2zPTDF parameter, the z2zPTDFs are shown below,

	z2zPTDF(A->B)	z2zPTDF(B->A)	z2zPTDF(A->C)	z2zPTDF(C->A)	z2zPTDF(B->C)	z2zPTDF(C->B)
CNEC X	0.02	-0.02	0.5	-0.5	0.48	-0.48

After applying the positive z2zPTDF filter, the z2zPTDFs are shown below[13],

	z2zPTDF(A->B)	z2zPTDF(B->A)	z2zPTDF(A->C)	z2zPTDF(C->A)	z2zPTDF(B->C)	z2zPTDF(C->B)
CNEC X	0.02	0	0.5	0	0.48	0

After applying the z2zPTDF relaxation parameter, the filtered z2zPTDFs are shown below.

	z2zPTDF(A->B)	z2zPTDF(B->A)	z2zPTDF(A->C)	z2zPTDF(C->A)	z2zPTDF(B->C)	z2zPTDF(C->B)
CNEC X	0	0	0.5	0	0.48	0

The z2zPTDF relaxation parameter is introduced to filter out the following two scenarios:

- The z2sPTDF and z2zPTDF are computed by power system analysis tools and contain decimal numbers by nature. Due to rounding or computational accuracy, it may happen that 'on paper' the z2zPTDF is 1 % and 'in reality' the effect of such 1 % z2zPTDF is not observed by the TSOs. Such small z2zPTDFs should not limit the cross-border exchanges. By applying the z2zPTDF threshold, the effect of such small z2zPTDFs is eliminated from the ATCE.
- The TSOs may have sufficient remedial actions to alleviate certain overloads, without limiting the cross-border exchanges. Thus, the TSOs decide not to consider these 'minor overloads' being potential reasons to limit the cross-border capacities. By applying the z2zPTDF threshold, such 'minor overloads' become acceptable in the ATCE.

4.5.4 Implementation

4.5.4.1 Compensation on DA RAM

Consider the following equation, the ATCE optimization problem is only feasible when delta is positive (i.e. the DA RAM of border CNEs are greater or equal to the induced border flow). To ensure the total RAM is sufficient to cover the induced border flows, all negative delta values are compensated to zero[14],

$$delta = DA\_RAM - (z2zPTDF_{thres}+) * border\ AAF$$

[13] The sequence of applying the positive z2zPTDF filter and applying the z2zPTDF threshold does not impact the results.

[14] If the delta before the compensation is -1 MW, (as results of the DA_RAM being 50MW and the DA AAF being 51 MW in this conceptual example), the compensated DA RAM becomes 50 – (-1) = 51 MW, with the DA AAF remains at 51 MW. The delta after the compensation is zero.

where the z2zPTDF_thres+ refers to the z2zPTDFs after applying the positive PTDF filter and the z2zPTDF threshold as elaborated in section 4.5. The delta compensation is applied before solving the optimization problem.

4.5.4.2 General overview of implementation

Referring to the implementation, the FB domain in the ATCE is modelled as follow,

z2zPTDF_relaxation+ * capacity variable (i.e. $\hat{C}_n$ or $\hat{C}_{n,o}$ exogenous variables) ≤ DA_RAM + RAM_relaxation + (delta compensation, if needed[15])

On the left-hand side (i.e. the left-hand side of the ≤ sign), z2zPTDF_relaxation+ refers to the z2zPTDF applying the positive PTDF filter and the PTDF relaxation parameter. The capacity variable refers to $\hat{C}_n$ or $\hat{C}_{n,o}$.

On the right-hand side, the two terms refer to the original DA RAM and the RAM relaxation parameter.

In the mathematical terms, the inequality constraints are modelled as A * x ≤ b.

A is a matrix containing z2zPTDF+

x is a vector containing $\hat{C}_n$ and $\hat{C}_{n,o}$

b is a vector containing DA RAM and the RAM relaxation together

Corresponding to the matrix implementation, the z2zPTDF_thres+ is a m-by-n matrix, m is the number of constraints, e.g. the number of presolved[16] CNECs, n is the number of directional borders. Thus, the C_n is an n-by-1 vector consisting of $\hat{C}_n$ and $\hat{C}_{n,o}$, and the DA RAM and the RAM relaxation are both also n-by-1 vectors.

In a more explicit form, the above equations can be written out, using the 3-node example, as

z2ZPTDF_relaxation+(A->B) * Cn(A->B) + z2zPTDF_relaxation+(B->A) * Cn,o(B->A) +
z2ZPTDF_relaxation+(A->C) * Cn(A->C) + z2zPTDF_relaxation+(C->A) * Cn,o(C->A) +
z2ZPTDF_relaxation+(B->C) * Cn(B->C) + z2zPTDF_relaxation+(C->B) * Cn,o(C->B)

≤ DA_RAM + RAM_relaxation + (delta compensation)

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[16] 'Presolved' refers to the mathematical step to remove the redundant constraints from the optimization problem without affecting the mathematical optimal solution. Conceptual example: suppose the solver looks for an optimal solution that must fulfil constraint 1, being x ≤ 5 and constraint 2, being x ≤ 10. The presolve, mathematically, removes the constraint 2 before performing the optimization, given the consideration that if a solution is less than 5, it must be less than 10.

5 ATCE settings during EPR and at go-live

In the current implementation as of week 13 2024, the PTDF relaxation parameter is set to 2%. The RAM relaxation parameter is set to 10 MW on CNECs, excluding allocation constraints[17]. These allocation constraints are comprised of both combined dynamic constraints[18] and HVDCs. In this context, the RAM relaxation is applied exclusively to the thermal limits of the transmission grid elements. It is not applied to the combined dynamic constraints as these are computed by the TSOs to ensure dynamic stability of the grids. The dynamic constraints are harder limits than the thermal limits. In other words, the thermal overloads may be manageable if remedial actions exist, but the dynamic stability limits must never be exceeded. Furthermore, HVDCs are excluded from the RAM relaxation because they are controllable devices that are adhere to specific allocation schedules.

Initially, the TSOs set the PTDF relaxation parameter to 0.05 and the RAM relaxation to 0 at the start of the external parallel run (EPR). During the EPR, the TSOs observed large potential overloads resulting from this combination of parameters. Such potential overloads, in terms of magnitude and frequency of occurrence, impose heavy operational risks that the TSOs are not able to manage. To address the operational risks, the TSOs decided to use a more controlled and balanced relaxation combination, opting for increased RAM relaxation and a carefully chosen PTDF relaxation to ensure that operational risks remain manageable.

6 Summary

This document describes the ATCE method to be applied for the ID capacity calculation at gate-opening, as a transitional solution until XBID can support FB parameters.

This document is aligned to the latest development of the ATCE implementation along the Nordic CCM parallel run, and subject to feedback from the NRAs and stakeholders towards Nordic CCM DA FB go-live. The Nordic TSOs' aim is to apply the described ATCE method at DA FB go-live to calculate the ID cross-zonal capacities at gate-opening. The TSOs will publish the exact values and parameters of the ATCE method two months before DA FB go-live in accordance with approved CCM methodology.

[17] A 0.01 MW relaxation is strategically implemented on the allocation constraints. This deliberate margin allows the optimization solver to discover feasible solutions, without compromising the quality of the outcome.

[18] Combined dynamic constraint is modelled as 'Power Transfer Corridors' (PTCs) limitations in the FB world.

Appendix I: Using DA AAF instead of DA scheduled exchanges as the lower bound of the capacity variable C_n

To ensure the extracted NTC values greater or equal to the DA AAC in the FB context, it is essential to determine the DA AAC in the FB context, such that it is applied as the lower bound in the ATCE method.

The Nordic CCM project explored the different possibilities determining the DA AAC, e.g. DA scheduled exchange (SE) vs. DA AAF.

DA SE: Applying the current SDAC algorithm on the FB domain inputs, the direct outcome of the SDAC is a set of net positions. The DA SE is a set of 'post-processed' market outcome based on this set of net positions and the pre-aligned linear cost coefficients (among TSOs and NEMOs) of bidding zone borders to determine the exchanges. By default, such conversion from NPs to SEs is not unique. Because of the linear cost coefficients being applied, the conversion returns one set of SEs guaranteeing the least cost. However, this conversion from NPs to SEs does not reflect the physical flows on the bidding zone borders.

The DA AAF represents the physical flows that are induced by the resulting NPs from SDAC algorithm. The physical border flows are computed using the linearized z2sPTDFs of the border elements and the market outcome NPs, with no abovementioned conversion involved. Thus, the DA AAF is considered a better physical representation of the grid situation, being the DA already allocated (physical) flows. Considering the lower bounds of the ATCE method, the (border) DA AAF is clearly a better choice to be guaranteed when extracting the DA NTC, such that the resulting ATC for ID gateopening based on the linearized physical reality, shall always have (greater or equal to zero) capacities to start off with.