2. ATCE-methodology

Nordic CCM Stakeholder Meeting

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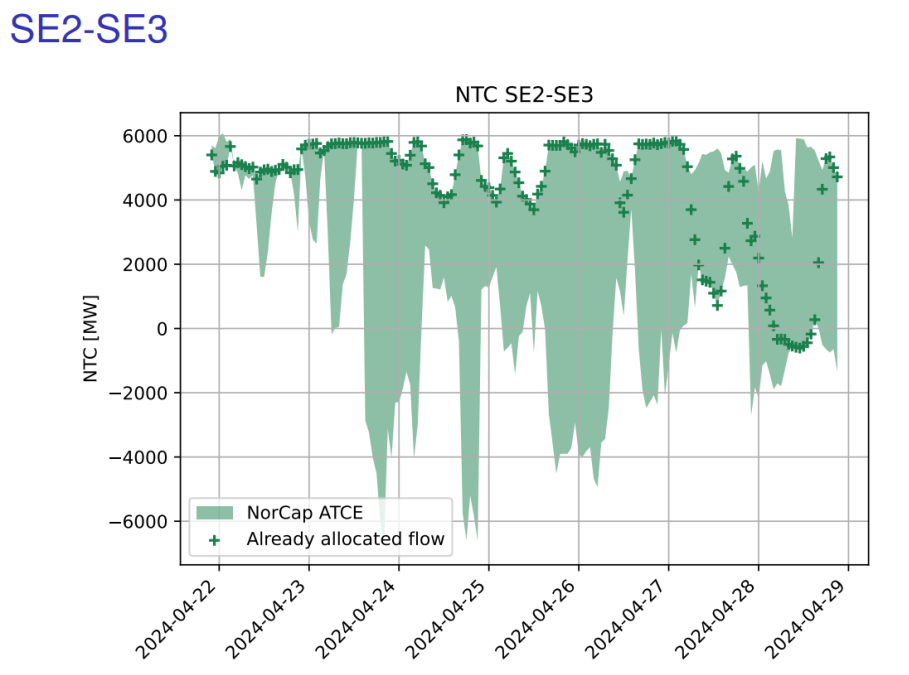
Agenda

- **Introduction: Difference between NTC and ATCE**
- Background: Flowbased capacity calculation
- Methodology: Review of the ATCE
- Arbitrage analysis

Introduction

Background

- Flowbased capacity allocation will be implemented for day-ahead market while the “left over” capacity will be allocated for intraday market with the **ATCE-method**
- The ATCE-method optimise the available transfer capacity as a CNTC (“**NTC-like**”) capacity based on the FB-DA result and distribute it among the included corridors (using relaxation on certain parameters)
- During the ongoing EPR the results are published weekly and available at the NRCC-website. The main result is that the capacities are more **varying** compared with the current NTC method.



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Introduction

ATCE-method is not the same as current NTC-method

Three main differences between ATCE and the current NTC-method for ID:

1. The ATCE will provide less capacity on some borders/directions for ID-market due to higher utilization on the FB DA-market. The capacities are dependent on the flow which might restrict the left over capacity on some borders to allow higher capacity in other borders.
2. The ATCE takes into account all flow-scenarios and provides more conservative capacities to manage all outcomes. The current NTC-method focus on probable flow scenarios and allocate capacities where it is needed with a higher but controllable risk.
3. The ATCE also takes into account loops-flow in neighbouring TSOs which can limit the possible trade in different direction. The current NTC-method don't consider affects and possible grid limitations in neighbouring grid in a sufficient way meaning that the ATCE result will in general be more operational secure.

Higher utilization FB-DA

All capacities are dynamic and depends on the flow direction

- For FB DA the market turnout optimise the capacities depending on the flow direction
- Example
  East-west flow through Sweden is limited by internal bottleneck within SE3, which affect several corridors
  - For MTU1 some corridors receive large capacities
  - For MTU2 some other corridors might receive large capacities
- To uphold the resulting capacity the flow must stay the same on the other borders which limit the left over/ID-capacity

East-west flow (MTU1)

SE2>SE3>NO1 flow has been prioritised, limiting the capacity on other borders

East-west flow (MTU2)

FI>SE3>SE4 flow has been prioritised, limiting the capacity on other borders

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Current capacities (NTC) are “forecast”-based

Capacities (NTC) are set dependent on forecast of possible flows

- The NTC-world considers the probable flow scenarios and optimise the capacities where its needed the most
- The smallest capacities of the possible scenarios will be allocated to the market in order to manage all possible outcomes
- After the DA-result, the ID-capacities can be updated to optimise the capacities in the most likely direction (thus limiting the capacity in other direction that probably won’t be used)

South-bound flow

East-west flow

West-coast flow

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New capacities (ATCE) are “model”-based

Capacities (ATCE) are set by an optimisation model without

- The ATCE-world considers ”all flows” to be possible and allocates capacities to manage all of these
- Capacities derived from one scenario can limit the flow in another scenario (even if the two will not happen at the same time)
- Example
  Export to NO1 could be possible in west-coast flow scenario but limited in a SE3 flow scenario (thus limited in the ATCE)
- Some scenarios are unlikely while others might be more and more likely in the future

South-bound flow

SE3 flow (?)

East-west flow

SE4 flow (?)

West-coast flow

North-bound flow (!)

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Loop-flows #1

The NTC-world

ATCE-world

⬅ The NTC world assumes trade from BZ to BZ in a straight line

- In reality the same trade will transfer through several bidding zones (as in the ATCE-world) ➡

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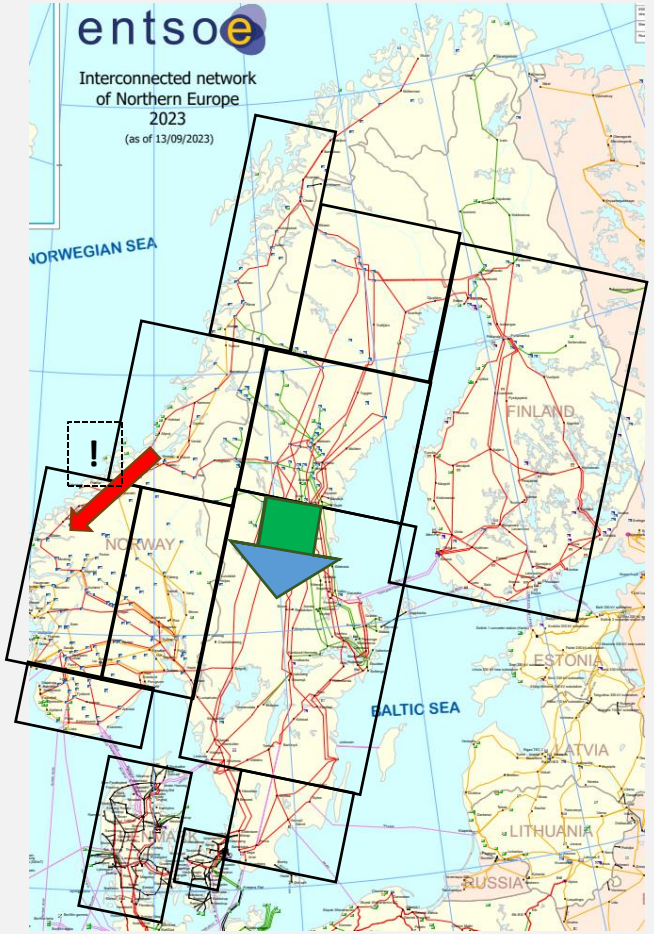
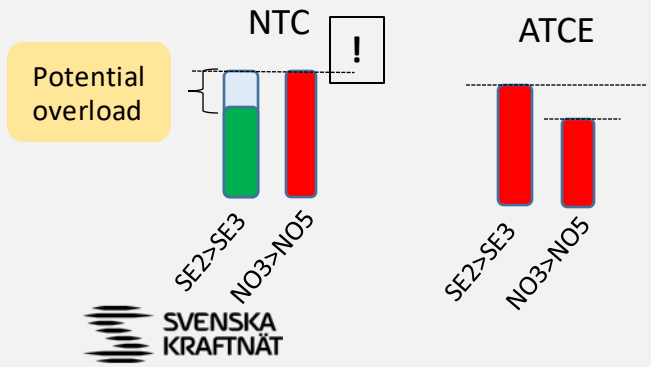
Loop-flows #2

The NTC-world

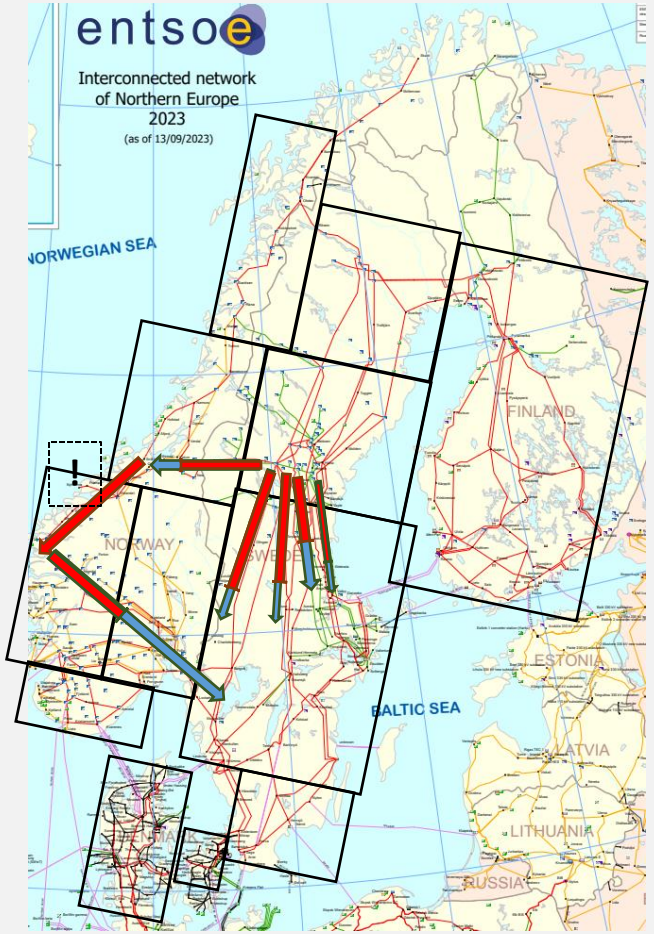


⬅ The NTC world assumes trade from BZ to BZ in a straight line

- In reality the same trade will transfer through several bidding zones (as in the ATCE-world) ➡
- Hence, trade in Sweden might be limited by bottlenecks in Norway (and vice versa)
  - In NTC: continues trade on SE2>SE3 would cause overload on parallel line
  - In ATCE: continues trade on SE2>SE3 will be limited to prevent this



ATCE-world



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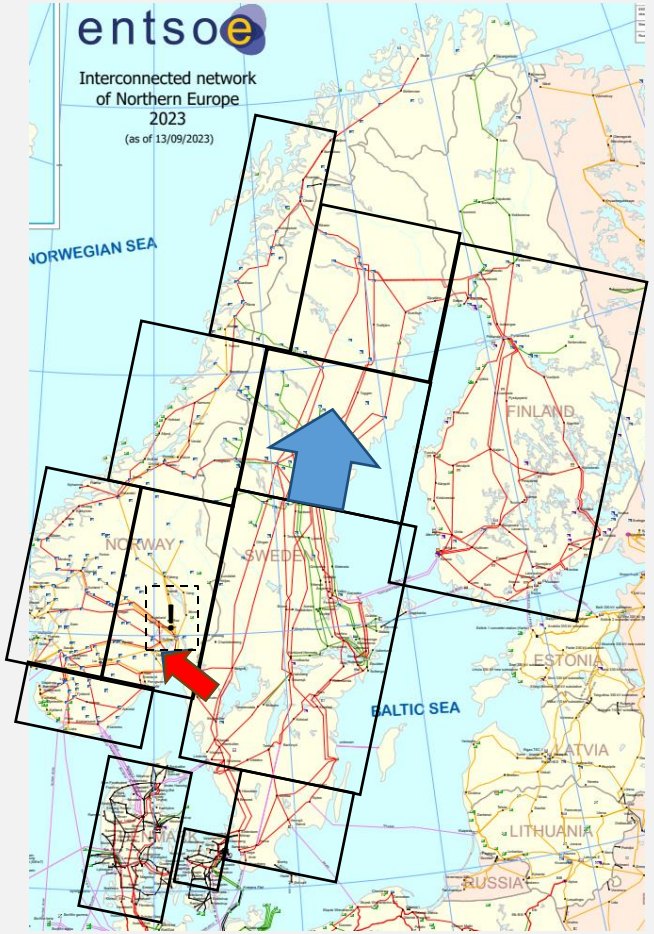
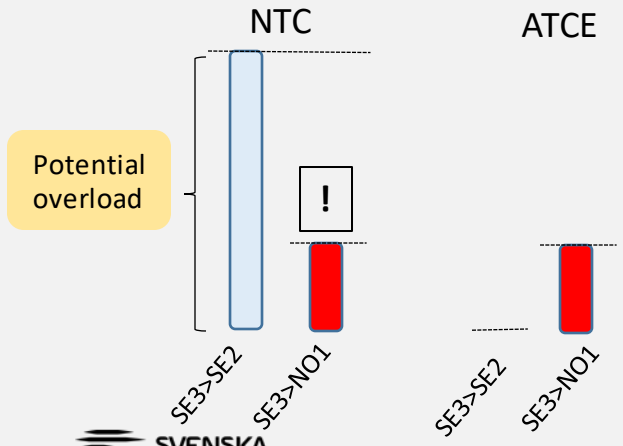
Loop flows #3

The NTC-world



- The NTC-world allocates often high capacity SE3>SE2
- But in reality a small portion of the ID-trade SE3>SE2 will flow through Norway and potentially overload SE3>NO1 border
- ATCE will thus limit SE3>SE2 capacity to prevent this overload

ATCE is a more coordinated and operational secure approach



ATCE-world

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Applied ATCE-relaxation

Applied relaxation in the ATCE-method to avoid unnecessary restrictions

- Capacites are more operational secure but also more conservative compared to current NTC-method → Motivate some relaxation to the ATCE-parameters to increase the capacities in a operational secure way
- Applied relaxation adjust for unrealistic loop-flows (less than 2 %) and takes a calculated risk that all 'loading' flows won't happen at the same time
- Relaxation leads to increased capacities but also opens up arbitrage possibilites

Relaxation: A trade-off between increased capacities and operational security

Summary and question-break

Three main differences between ATCE and the current NTC-method

Higher utilization and optimised flows on FB-DA result in less ID-capacities

ATCE takes into account all flow scenarios likely as well as unlikely resulting in more strict ID-capacities

ATCE takes into account loop-flows which increase operational security and limits ID-capacities

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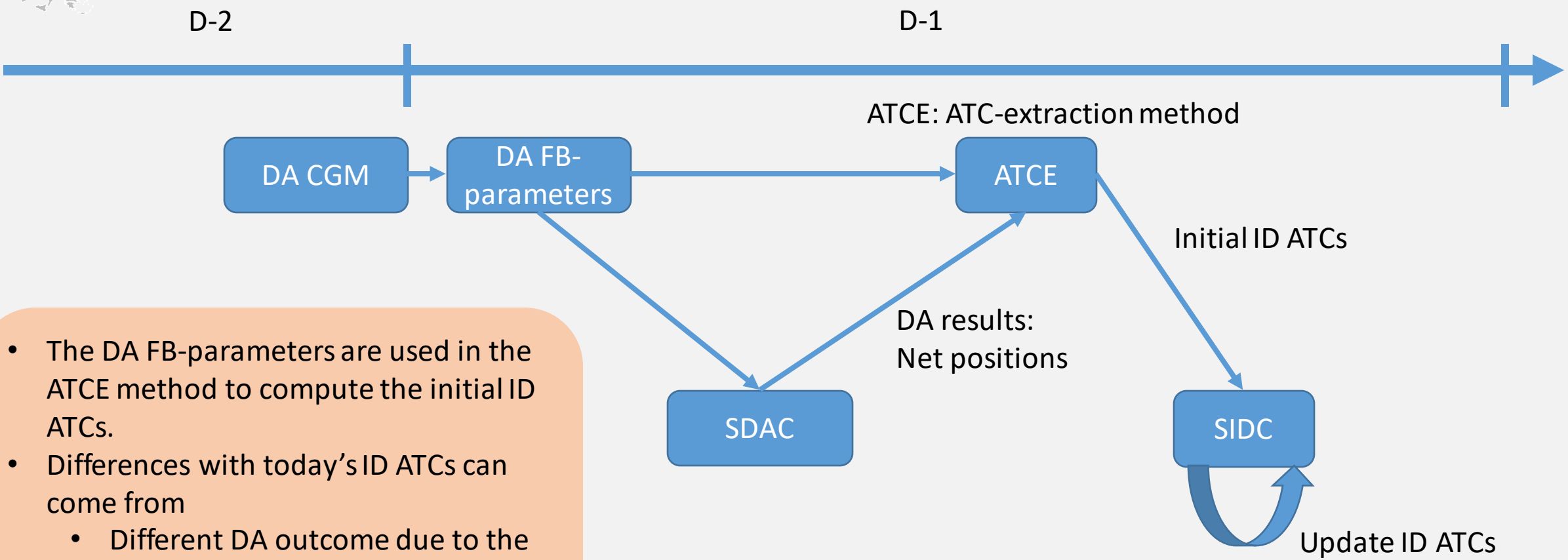
Capacity calculations from D-2 to ID



- The DA FB-parameters are used in the ATCE method to compute the initial ID ATCs.
- Differences with today's ID ATCs can come from
  - Different DA outcome due to the introduction of flowbased
  - New ATCE method

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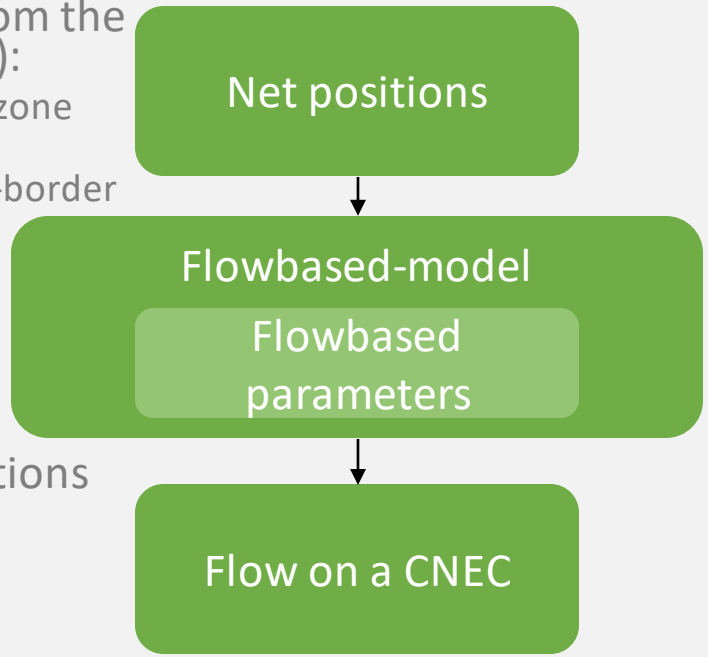
Flowbased model

- The flowbased model is a simplified model of the flow on CNECs (or CDCs).
- The FB model's parameters (F0, PTDF, RAM) are computed from the N-RCC from inputs from the TSOs (CNEC-list, GSK, RA, FRM, Fmax, IVA):
  - PTDF: how much of an export from a bidding zone transits through a CNEC.
  - F0: How much flows on a CNEC without cross-border exchanges
  - RAM: capacity available to the market)
  - RA: Relieving effect from remedial actions
  - FRM: Flow reliability margin
  - Fmax: Physical limit for the CNEC
- The FB model's variables are the net positions (net export) in the bidding zones.
- Market flow = sum(PTDF*NP)
- FB-flow = F0 + sum(PTDF*NP)
- RAM = Fmax + RA – FRM – AAC – IVA – F0
- CNEC-constraint: sum(PTDF*NP)<=RAM



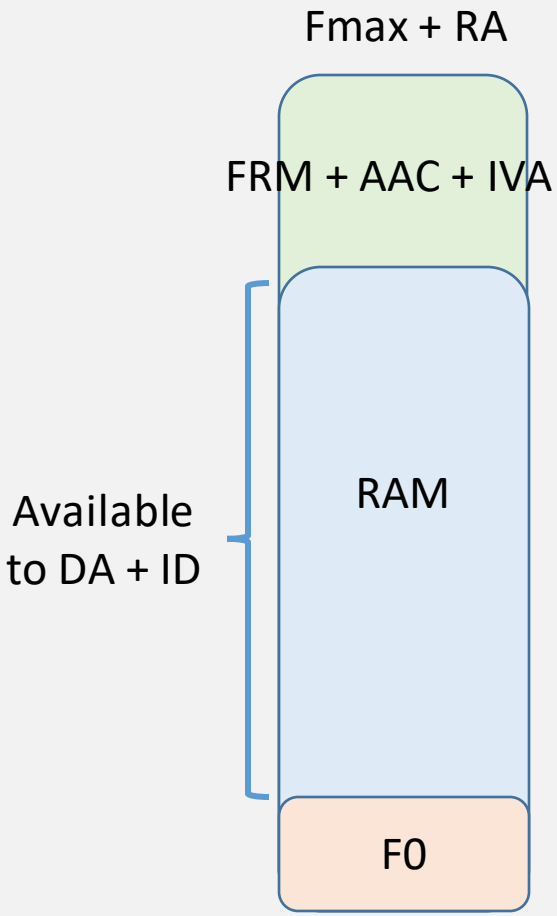


Illustration of one CNEC's components

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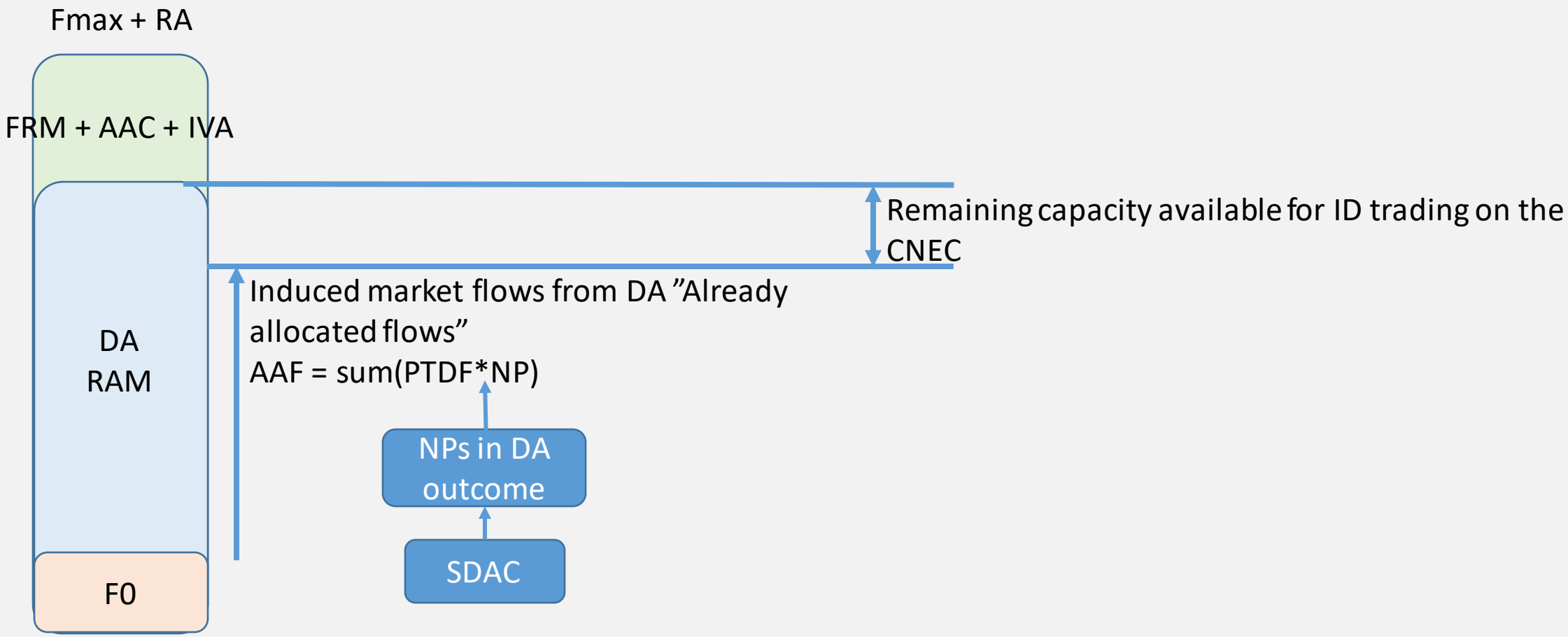
Remaining capacity available for ID



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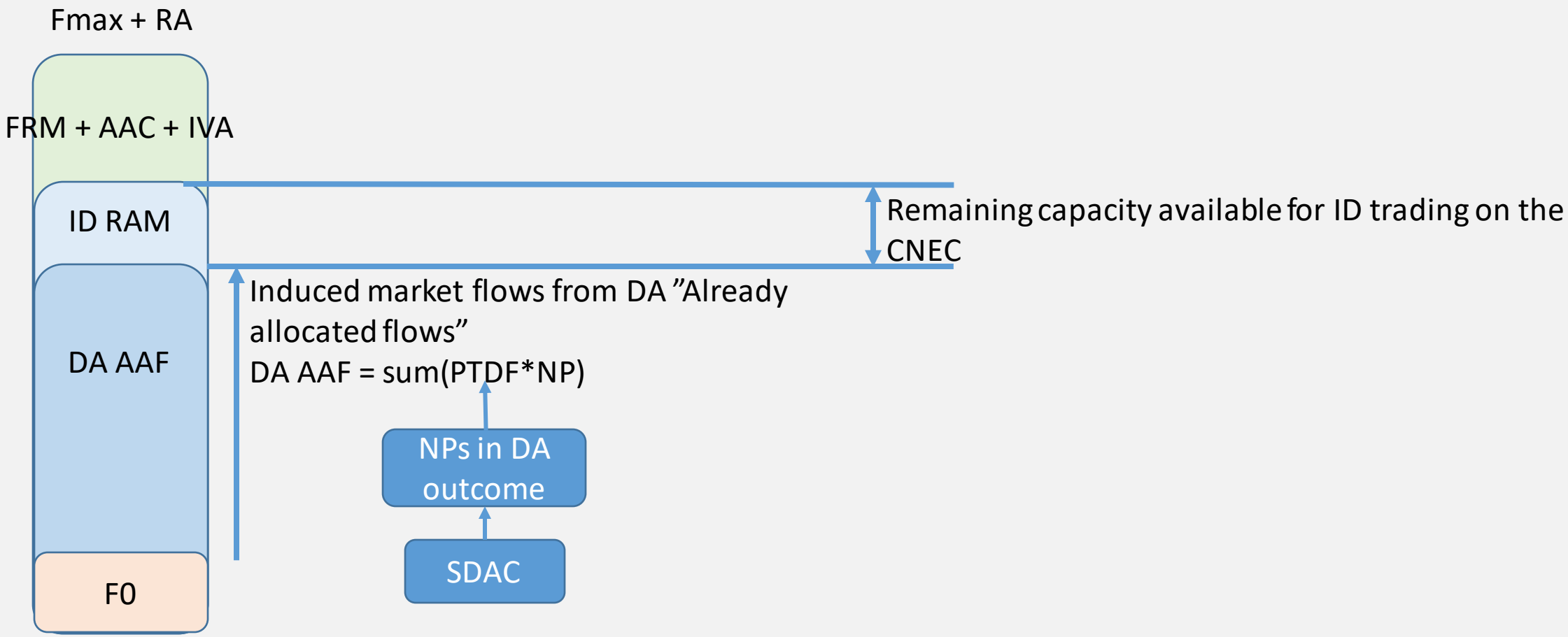
Remaining capacity available for ID



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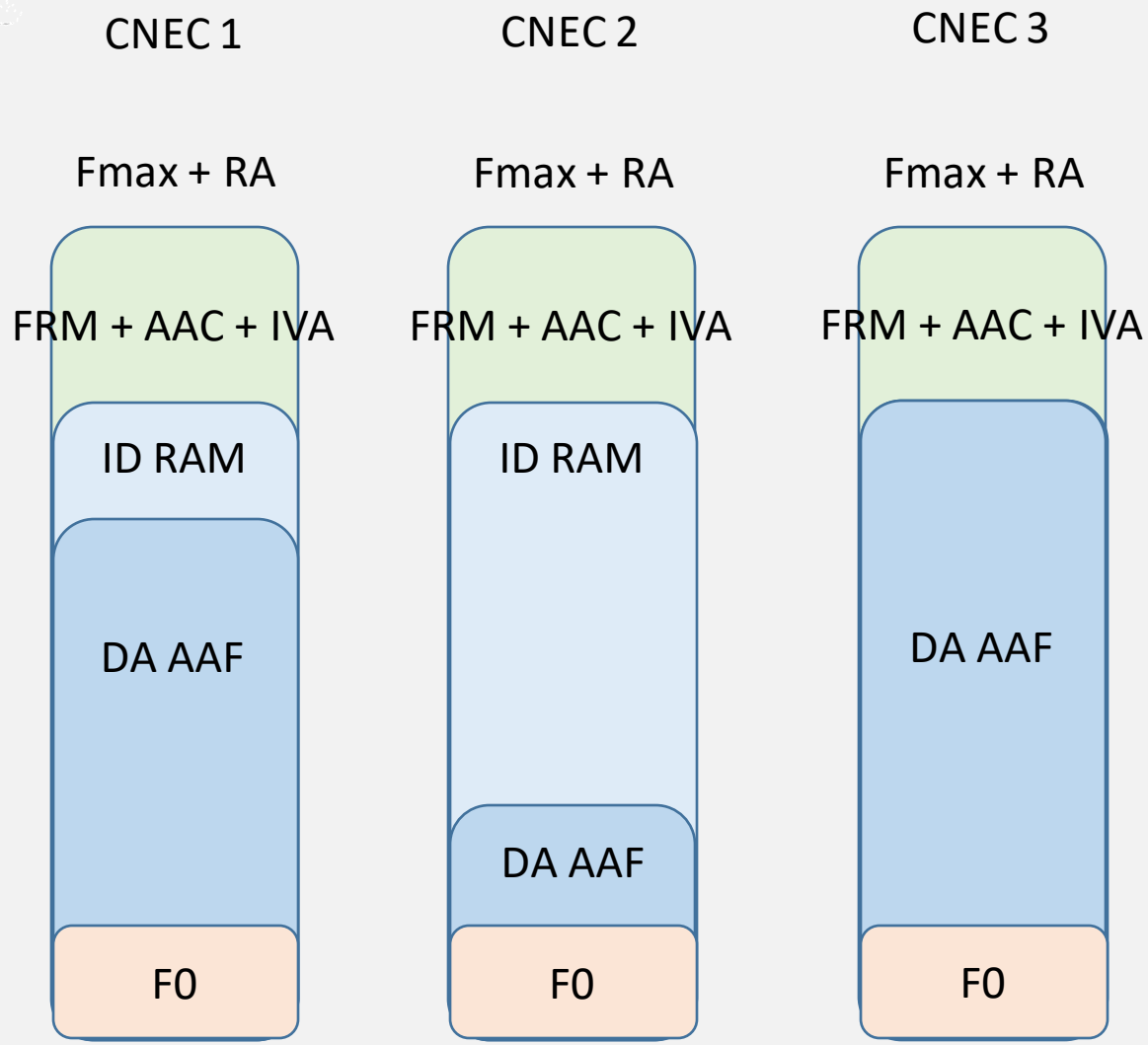
Remaining capacity available for ID



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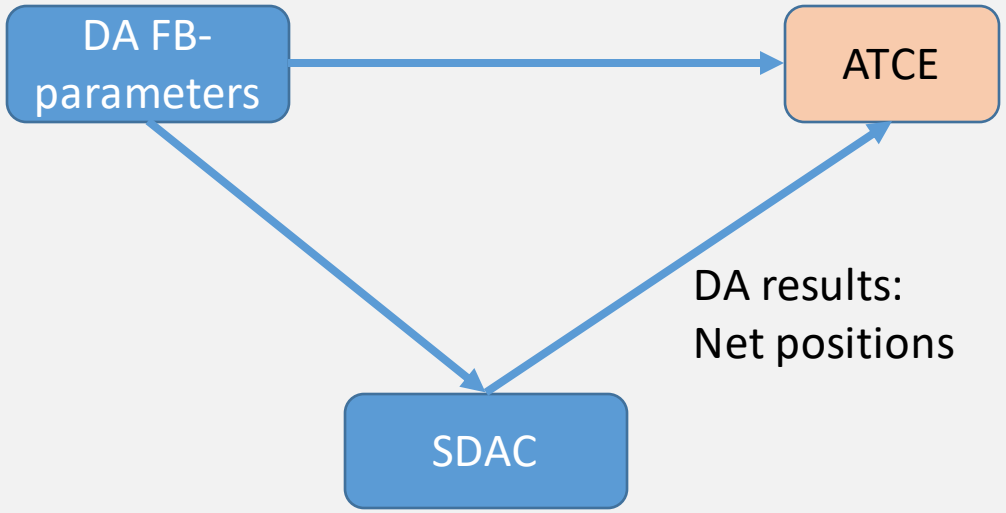
Remaining capacity available for ID

ATCE: ATC-extraction method



ATCE:
How to compute ATC capacities given the CNEC-constraints and the DA AAF?

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ATCE methodology

- Objective function = product of the NTC capacities on each border and direction:

  $(NTC_{SE1>SE2} + NTC_{SE2>SE1})$*…

- CNEC Constraints
  - Sum(z2zPTDF*NTC) <= DA RAM

  Where for example, $z2zPTDF_{SE2>SE3}$*$NTC_{SE2>SE3}$ is the flow on a CNEC due to already allocated DA capacities and extracted ID ATC between SE2>SE3.
- NTC > DA AAC, for all borders
- ATC = NTC – DA AAC, for all borders

ATCE

Maximizing the product of the cross-border capacities NTC
Such that the resulting CNEC-flows stay lower than the remaining available margin for ID on the CNECs.

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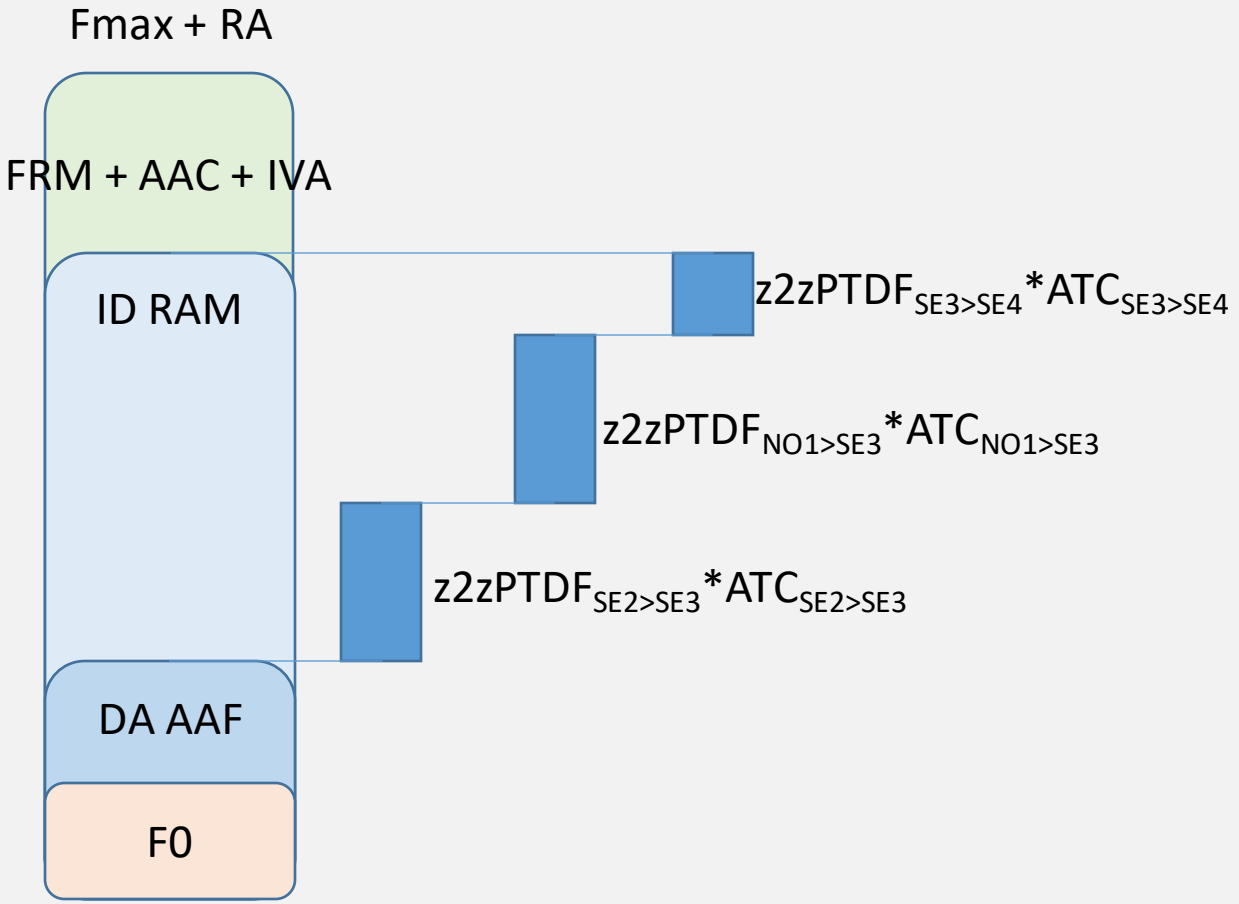
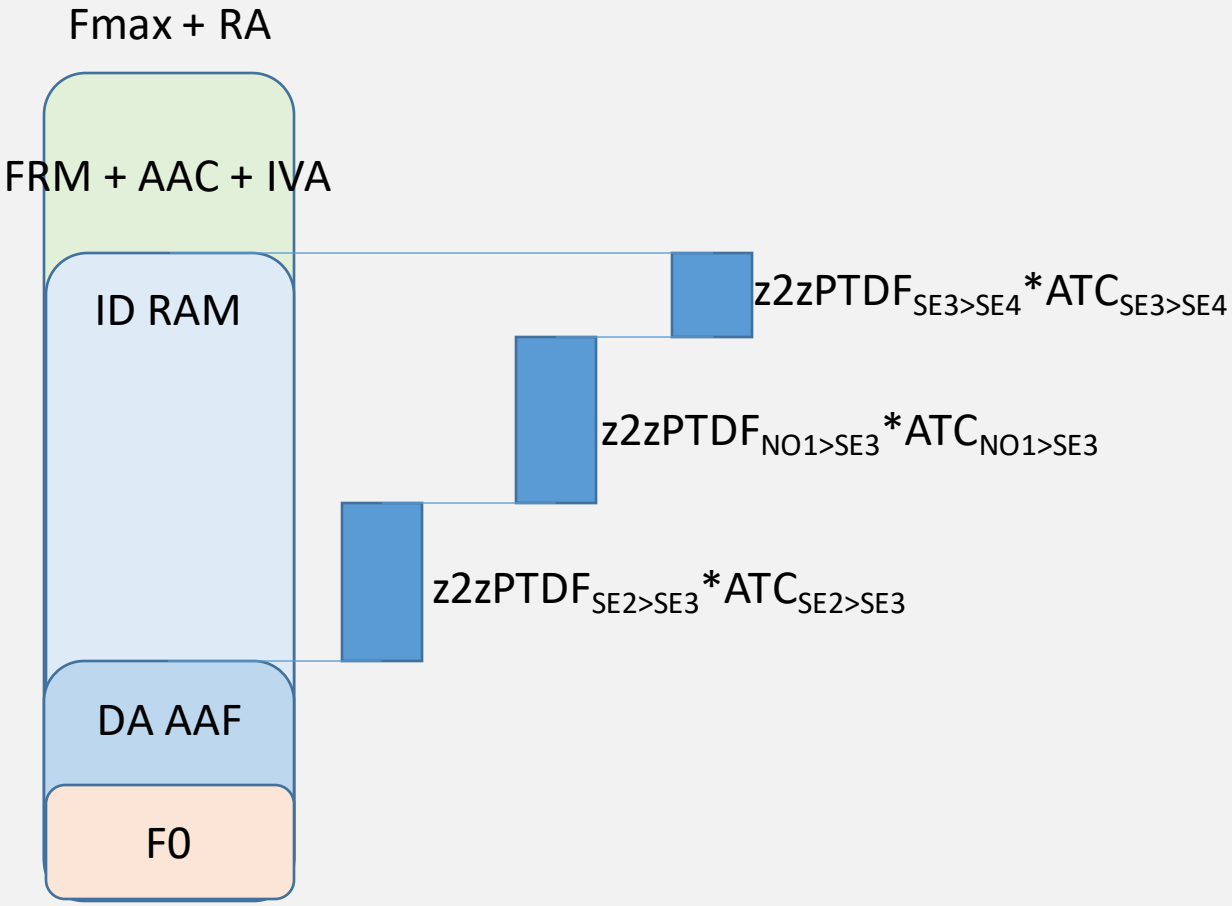
Limiting vs non-limiting CNECs

- The ATCE methodology allocates ID RAM on each CNEC between the borders impacting this CNEC (i.e. with nonzero PTDFs).
- Example: one CNEC with nonzero PTDFs for SE2>SE3, NO1>SE3 and SE3>SE4

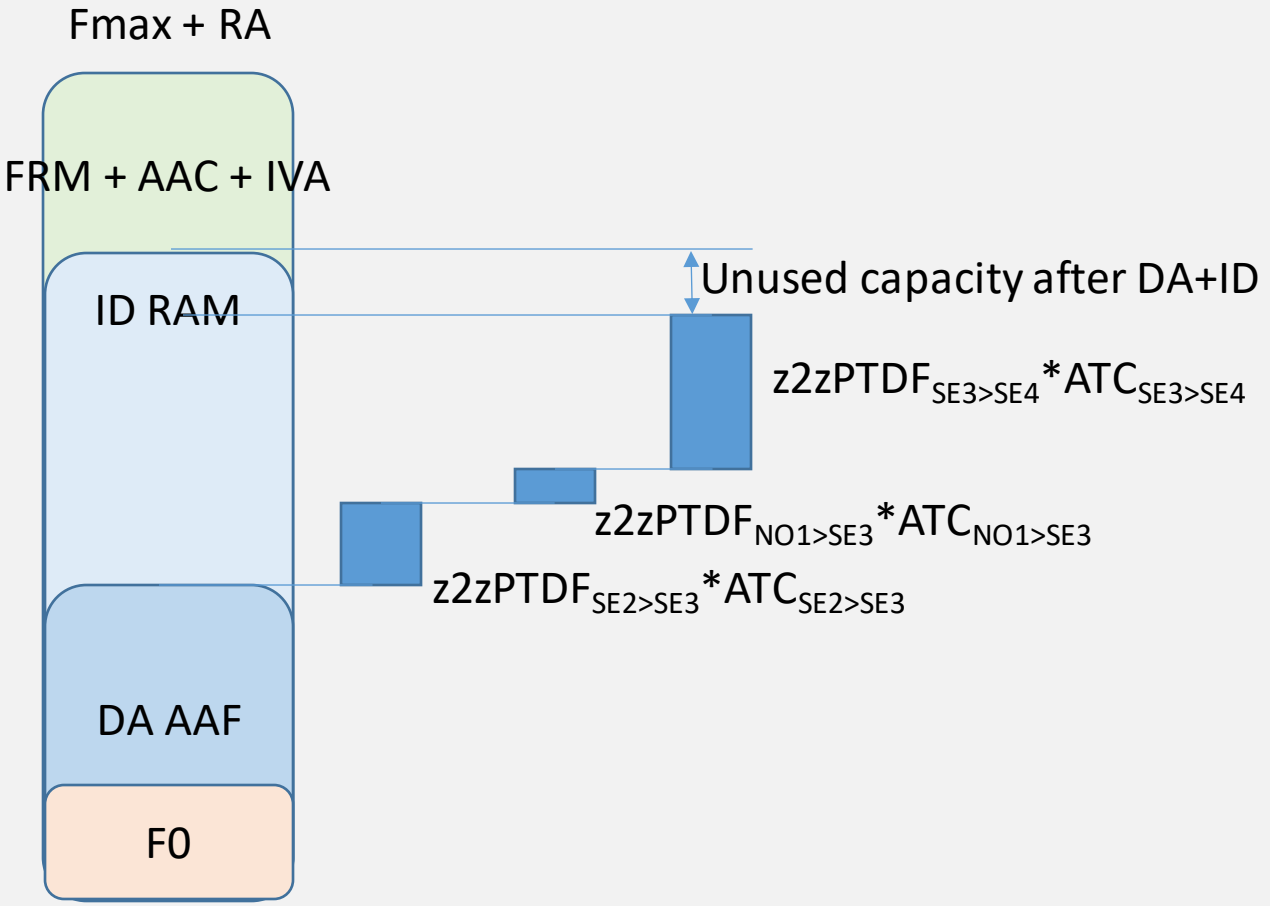


Limiting vs non-limiting CNECs

CNEC 1: limiting (=binding)



CNEC 2: non-limiting



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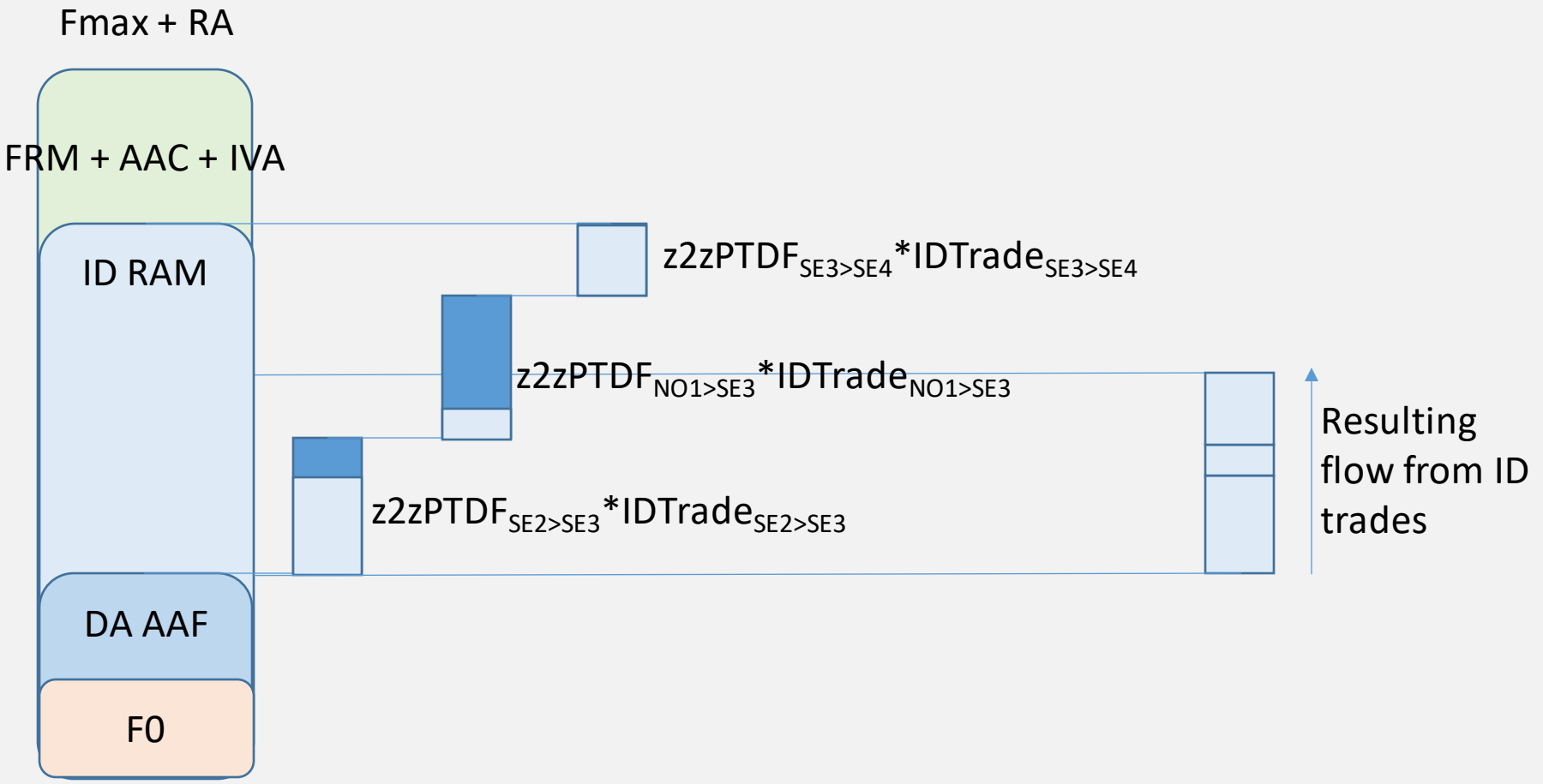
ID ATCs vs Actual ID trades



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Why this doesn't work as is.

Issue 1: negative PTDFs.

Induced flows due to ID ATC:
Sum(PTDF*ATC) <= ID RAM

Suppose

- $PTDF_{SE2>SE3} = -0.1$
- the solution to ATCE is $IDATC_{SE2>SE3}$ = 1000 MW.

Then $IDATC_{SE2>SE3}$ is relieving the flow on the CNEC by 100 MW, creating more space for other borders to use capacity on this CNEC. But if ID trades from SE2>SE3 do not materialize, this relieving effect will not either.

=> Risk for overloads

Solution: Set all negative PTDFs to zero.

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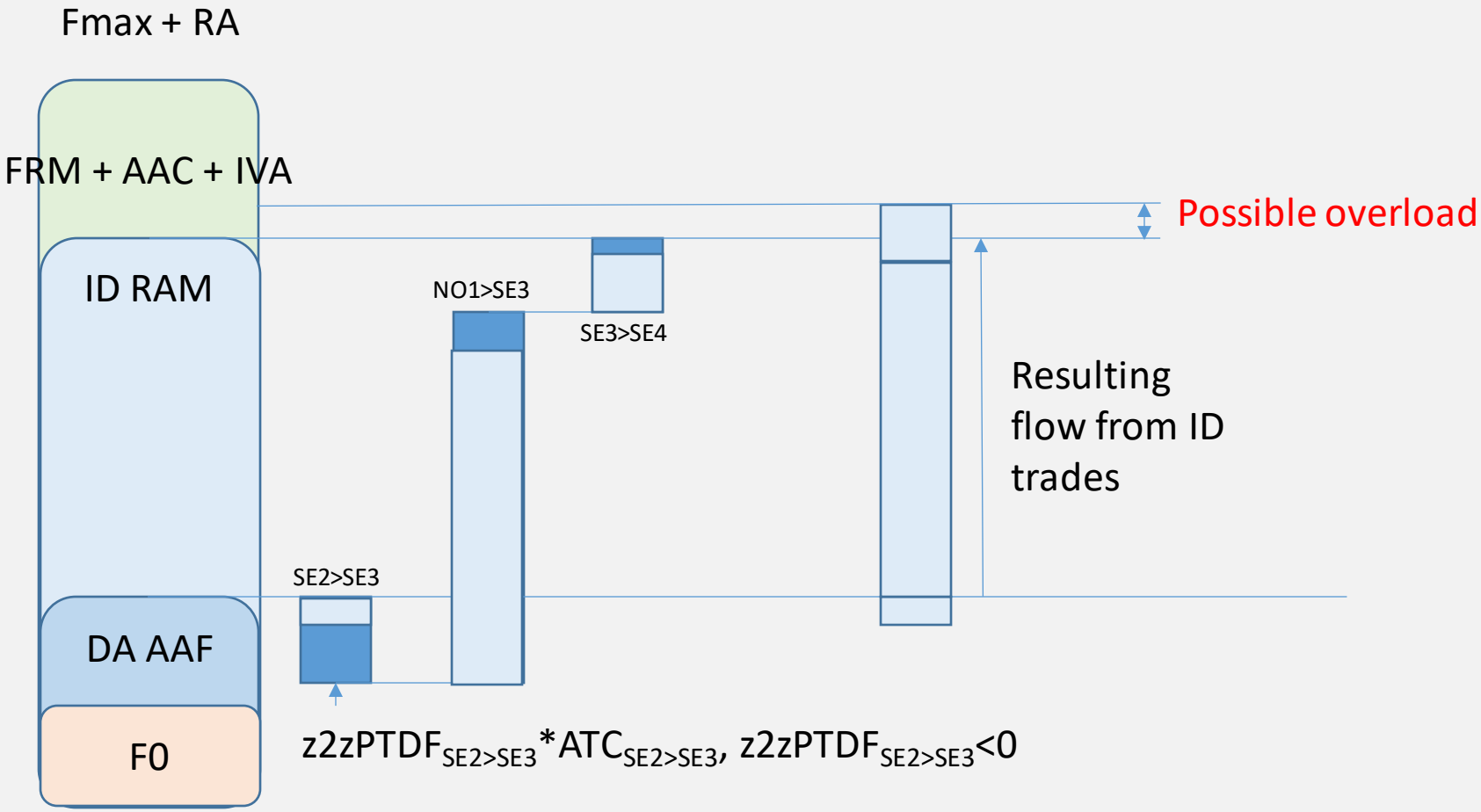
Issue 1: negative PTDFs



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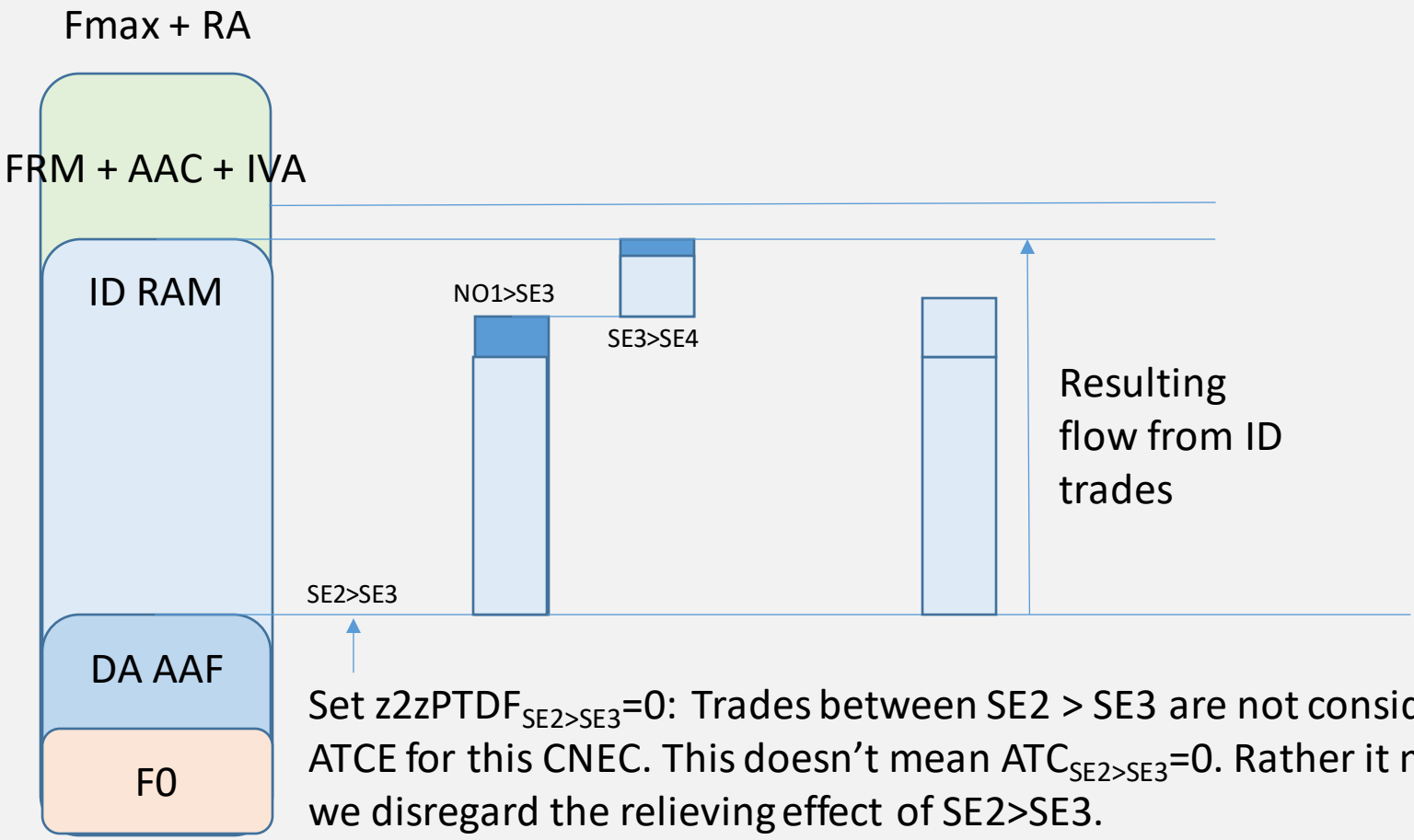
Issue 1: negative PTDFs



Set $z2zPTDF_{SE2>SE3}=0$: Trades between SE2 > SE3 are not considered in the ATCE for this CNEC. This doesn't mean $ATC_{SE2>SE3}=0$. Rather it means that we disregard the relieving effect of SE2>SE3.

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Tuning of some parameters

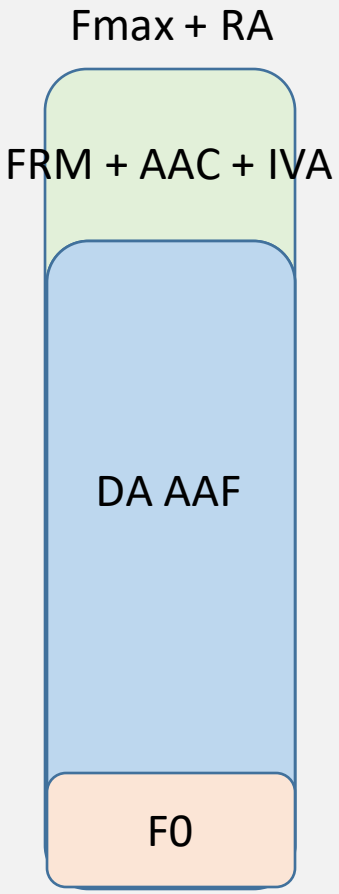
Issue 2: ID RAM = 0 for a CNEC

If all of the RAM was already allocated in DA, then ID RAM = 0. Any border with non-zero PTDFs for this CNEC will receive zero ID ATC.

=> Zero ID ATCs on some borders

Solution: Relax ID RAM with 10 MW on CNECs and with 0.5 MW on other combined dynamic constraints.

Issue 2: ID RAM = 0



- Suppose that DA AAF = RAM, i.e. ID RAM = 0.
- Suppose that $z2zPTDF_{SE2>SE3}$, $z2zPTDF_{NO1>SE3}$ and $z2zPTDF_{SE3>SE4}$ are all nonzero.
- This means that if we were to give some ID ATC to any of these borders (in these directions), this could potentially result in overloads.
- => $ATC_{SE2>SE3}$ =$ATC_{NO1>SE3}$ = $ATC_{SE3>SE4}$ =0

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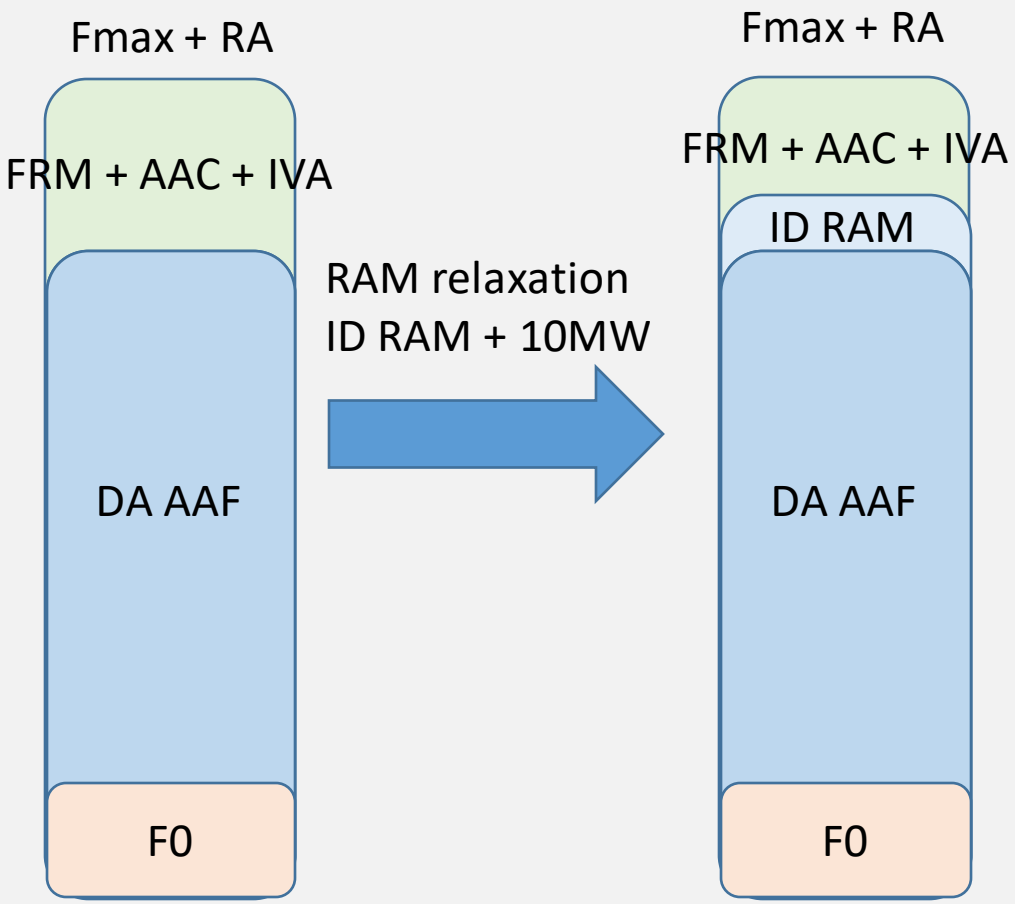
Issue 2: ID RAM = 0



- RAM relaxation entails a risk for overloads since it uses part of the reservations made for FRM and AAC.
- How large is the effect of relaxing RAM with 10 MW?
- Suppose all of this 10 MW were given to SE2>SE3
- Then $z2zPTDF_{SE2>SE3} * ATC_{SE2>SE3}$ = ID RAM = 10 MW
- This means that $ATC_{SE2>SE3}$ = 10 MW / $z2zPTDF_{SE2>SE3}$

$z2zPTDF_{SE2>SE3}$	0.1	0.25	0.5
$ATC_{SE2>SE3}$	100 MW	40 MW	20 MW

- Most importantly, it gives some room to the ATCE solver and avoids blocking any border.

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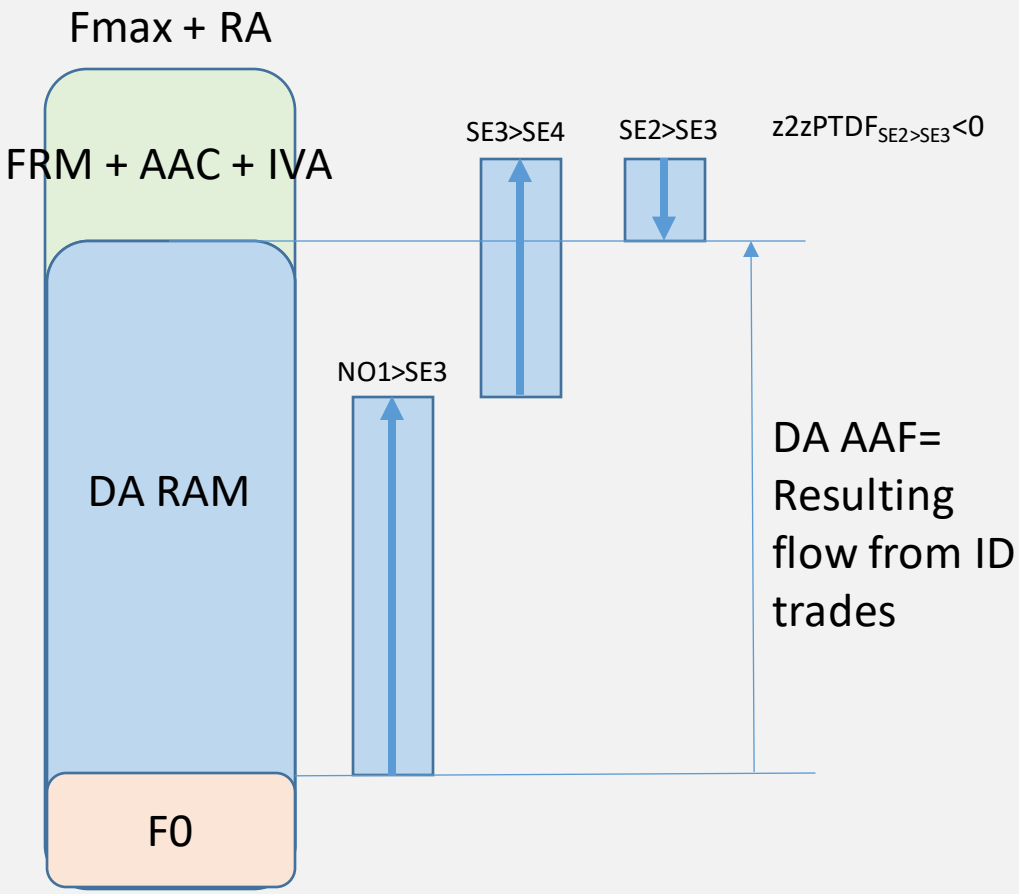
RAM relaxation and counter-intuitive flows



- Counter-intuitive flows occur in DA when flows from high- to low-price areas allows for an increased use of the grid capacity to increase SEW (despite these counter-intuitive flows)
- When counter-intuitive flows occur in DA, there will be some CNECs whose loading will be decreased by borders with counter-intuitive flows so that their loading can be increased beyond their capacity (RAM) by other borders
- The DA AAF for these CNECs is then equal to their RAM.
- No ID ATC can be given to borders that impact these CNECs.
- In the example on the left, NO1>SE3, SE3>SE4 and **SE3>SE2** would all receive 0 ID ATC.

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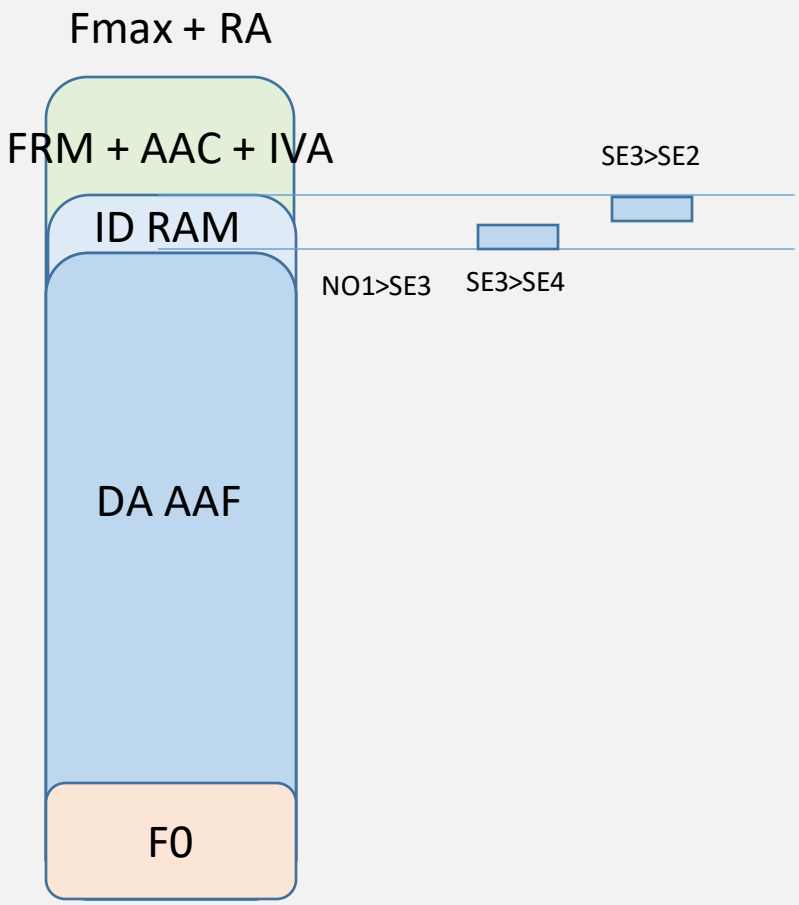
RAM relaxation and counter-intuitive flows



- Counter-intuitive flows occur when flows from high- to low-price areas allows for an increased use of the grid capacity to increase SEW (despite these counter-intuitive flows)
- When counter-intuitive flows occur, there will be some CNECs whose loading will be decreased by borders with counter-intuitive flows so that their loading can be increased beyond their capacity (RAM) by other borders
- The DA AAF for these CNECs is then equal to their RAM.
- No ID ATC can be given to borders that impact these CNECs.
- In the example on the left, NO1>SE3, SE3>SE4 and SE3>SE2 would all receive 0 ID ATC.
- With RAM relaxation, these borders may receive ID ATC, for example **SE3>SE4** and **SE3>SE2** on the left.

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Tuning of some parameters

Issue 3: small z2zPTDFs

Suppose $z2zPTDF_{SE2>SE3} = 0.01$ on a CNEC and that this CNEC is limiting for ATCE.

Limiting means that the extracted ATCs are such that all capacity available for ID is used:
sum(PTDF*ATC) = ID RAM

Then, the CNEC will limit the ATC SE2>SE3 despite this border having a very small loading effect (PTDF 1%) on the CNEC.

Solution: Set all z2zPTDFs smaller than 2% to zero.

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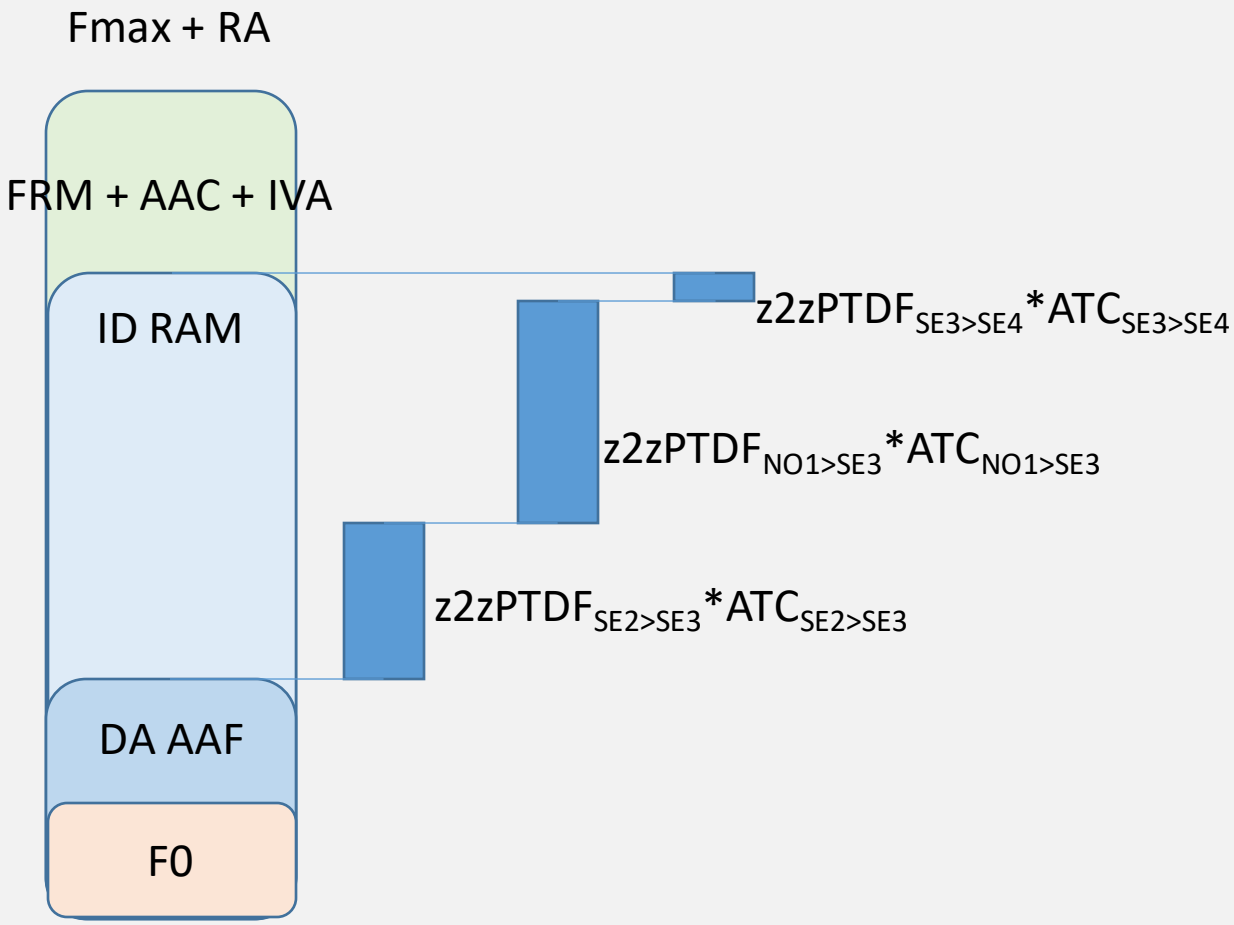
Issue 3: small z2zPTDFs



- Suppose that z2zPTDF$_{SE3>SE4}$ = 2%. The loading effect of SE3>SE4 on this CNEC is small but still, the capacity on this border can be constrained by this CNEC.
- In today's CC, we would not consider this CNEC when computing the ATC for SE3>SE4
- Where to set the limit, i.e. what PTDFs are low enough to be discarded is a trade-off between considering loading effects not very significant and creating possible overloads.
- Due to modelling errors, it may well be that some PTDFs are in reality higher.

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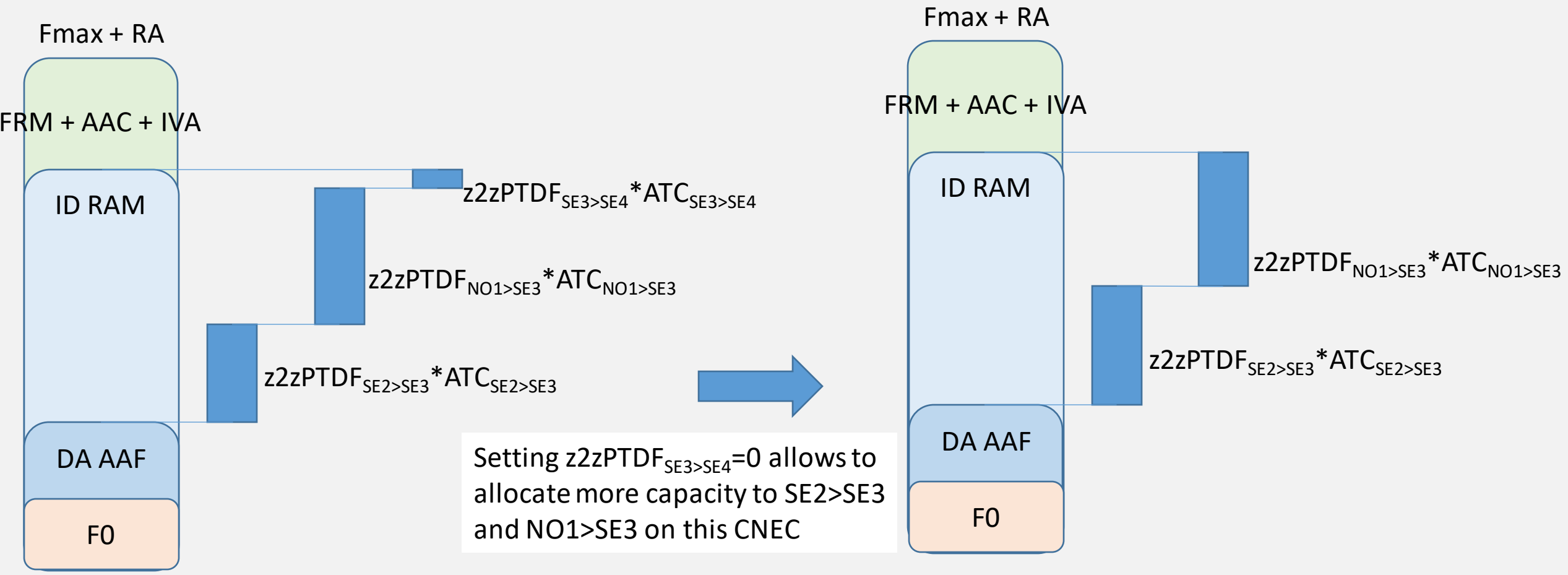
Issue 3: small z2zPTDFs



Setting z2zPTDF$_{SE3>SE4}$=0 allows to allocate more capacity to SE2>SE3 and NO1>SE3 on this CNEC

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Issue 3: small z2zPTDFs

Fmax + RA

FRM + AAC + IVA

ID RAM

DA AAF

F0

$z2zPTDF_{SE3>SE4} * ATC_{SE3>SE4}$

$z2zPTDF_{NO1>SE3} * ATC_{NO1>SE3}$

$z2zPTDF_{SE2>SE3} * ATC_{SE2>SE3}$

Setting $z2zPTDF_{SE3>SE4}=0$ allows to allocate more capacity to SE2>SE3 and NO1>SE3 on this CNEC.
But it creates a risk for overloads, since the loading effect of SE3>SE4 may really materialize in reality (if there are ID trades from SE3 to SE4)

Fmax + RA

FRM + AAC + IVA

ID RAM

DA AAF

F0

Possible overload

Resulting flow from ID trades

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ATCE - overview

- Pre-processing:
  - Set negative z2zPTDFs to zero.
  - Relax ID RAM on CNECs with 10 MW.
  - Set z2zPTDFs under 2% to zero

- Optimization

Maximize trading space

Such that

Relaxed induced flows on CNECs <= ID RAM + relaxation

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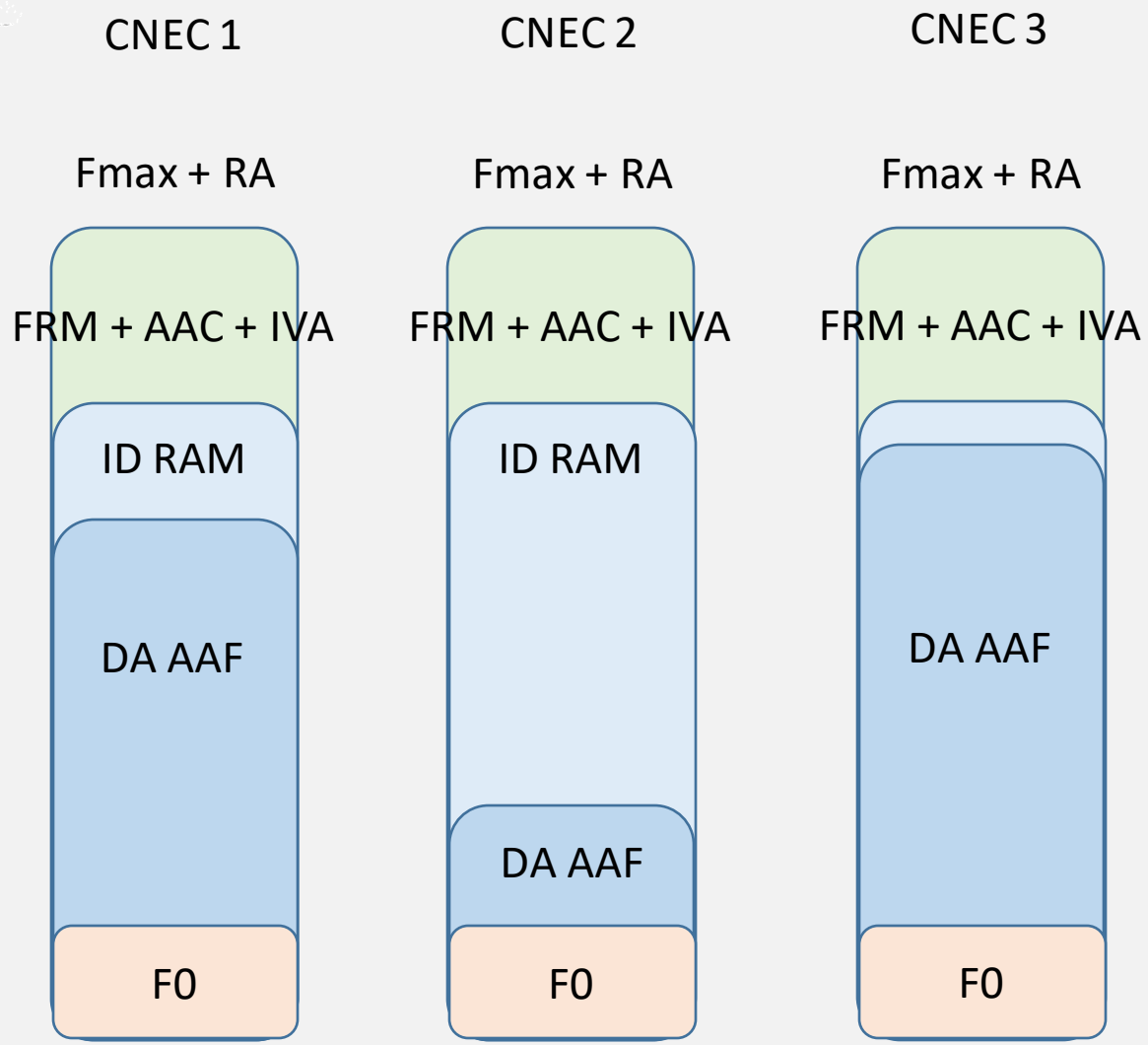
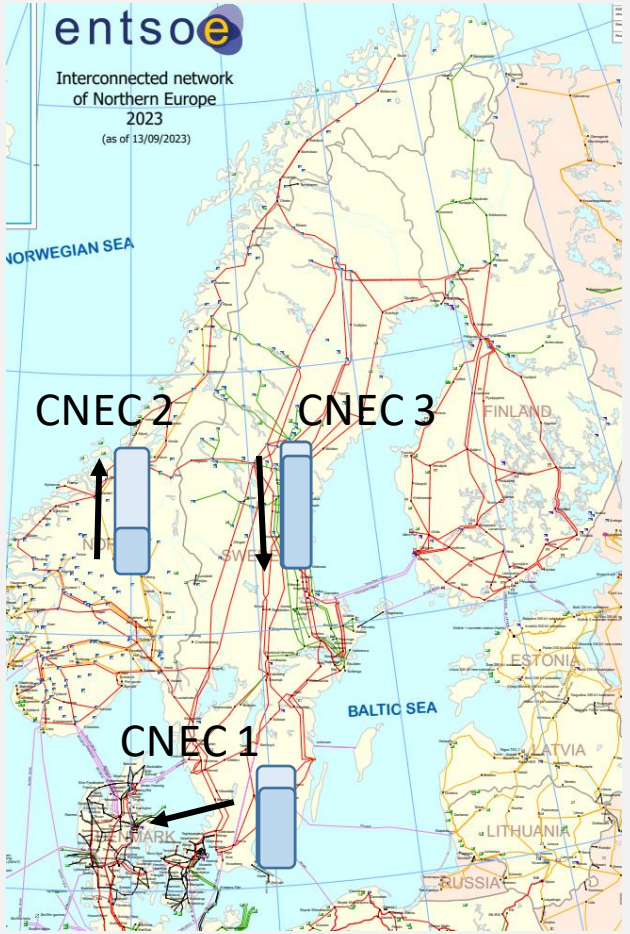
ATC example





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ATCE example

CNEC 1

Fmax + RA

FRM + AAC + IVA

ID RAM

DA AAF

F0

SE4>DK2

CNEC 2

Fmax + RA

FRM + AAC + IVA

ID RAM

DA AAF

F0

SE3>SE2

NO1>NO3

CNEC 3

Fmax + RA

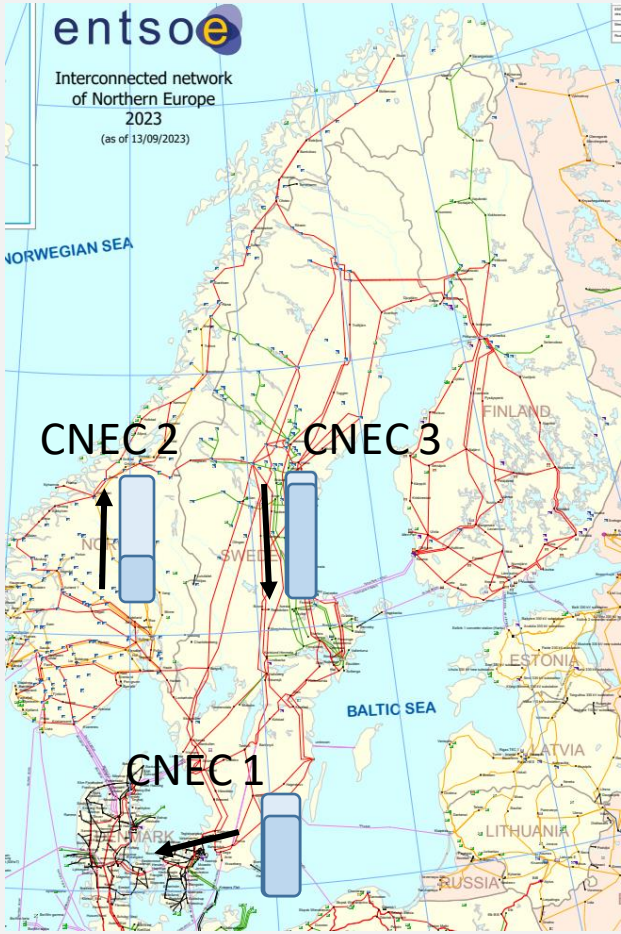
FRM + AAC + IVA

DA AAF

F0

NO3>NO1

SE2>SE3



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Agenda

- Introduction: Difference between NTC and ATCE
- Background: Flowbased capacity calculation
- Methodology: Review of the ATCE
- **Arbitrage analysis**

Background

- For the intraday market, FB parameters are converted to ATC values (or, more specifically, the combination of NTC and AAC values) using an ATC extraction (ATCE) method.
  - A detailed description of the ATCE method is available at: https://nordic-rcc.net/flow-based/methodology/
- The method, as it is currently applied, implies that some additional capacity will be released to the intraday market that was not available for the day-ahead market. This introduces some possibilities for arbitrage between intraday and day-ahead.

Arbitrage and non-intuitive flows

- During the EPR, questions/concerns related to arbitrage possibilities have often been discussed in conjunction with non-intuitive flows.
- However, as will be shown on subsequent slides, arbitrage possibilities arise also with intuitive flows.
- The connection between arbitrage and non-intuitiveness is therefore empirical: In many cases they coincide, but they do not necessarily have to (and there are plenty of cases where they do not).

Illustrative example of arbitrage

- If – for whatever reason – intraday capacity is released from a low-priced to a high-priced bidding zone, and if this situation can be foreseen by market participants, an arbitrage opportunity arises.
- Fictitious example:
  - DA price SE1 = 30 EUR/MWh, DA price SE2 = 20 EUR/MWh
  - Large amount (say >> 100 MW) of initial ID capacity from SE2 to SE1
- Example of arbitrage strategy for a BRP in this case:
  - Enter into two positions in DA:
    - Buy 100 MWh in SE2 and sell 100 MWh in SE1. Collect 100*(30-20)=1000 EUR from DA market
  - When ID market opens, immediately sell 100 MWh in SE2 and buy 100 MWh in SE1. If enough ID capacity is available, the BRP can buy and sell at the same (or, at least, very similar) prices. No (or very small) financial consequence for the BRP from trades in the ID market.
  - In the end, the BRP has no position in any bidding zone but has earned approximately 1000 EUR. In addition, the BRP doesn't have to produce 100 MWh that were sold to DA, which may result in additional profits on top of 1000 EUR.

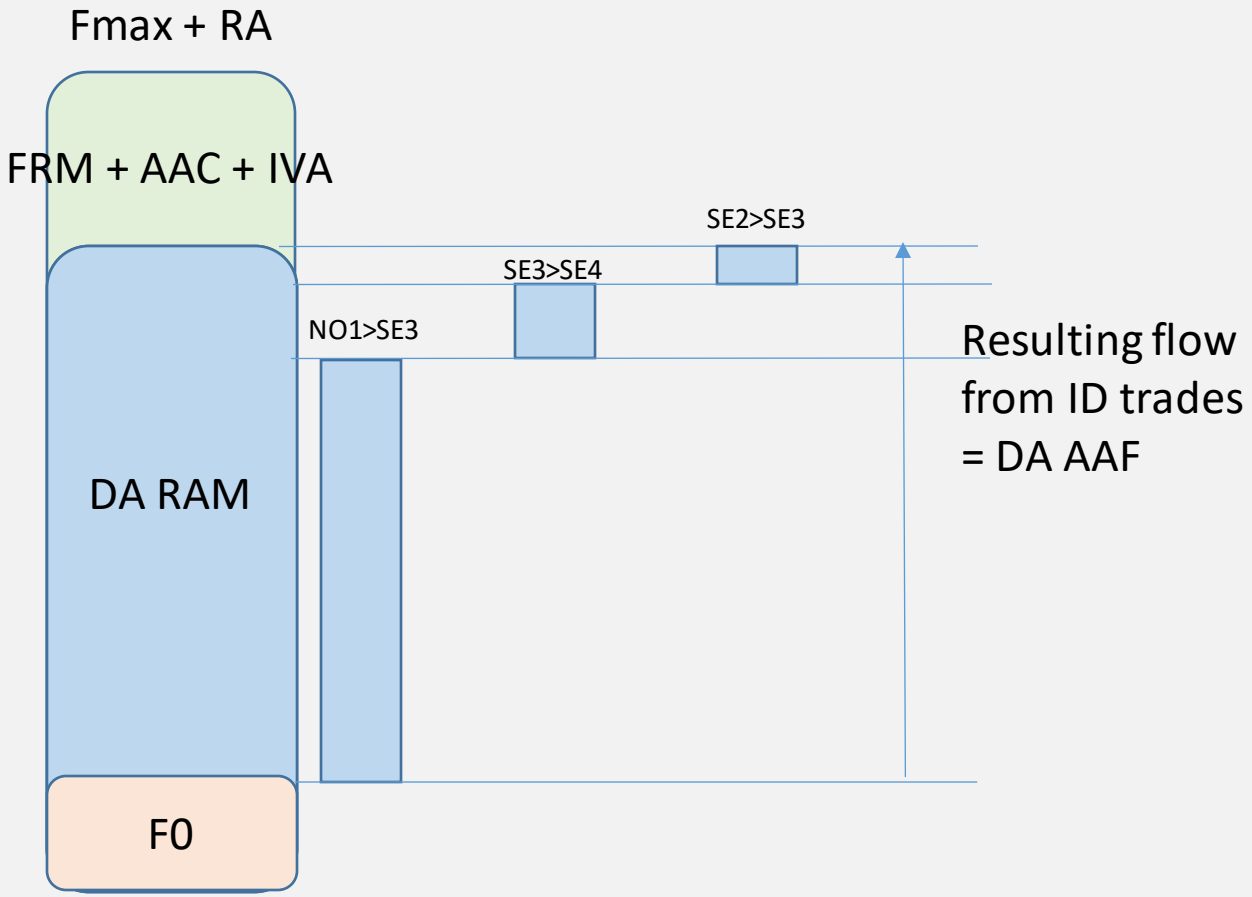
Predictability

- Market participant's ability to respond to arbitrage possibilities depend on their ability to predict the arbitrage situation.
- Easy-to-predict arbitrage situations
  - Market participants have incentives to change their behavior already in the day-ahead market.
  - Can be exploited by market participants irrespectively of their intent to trade for underlying consumption or production.
- Hard-to-predict arbitrage situations
  - Less likely to have an impact on the day-ahead market.
  - More difficult to exploit for market participants who do not have actual (and flexible) resources in the bidding zones.

Arbitrage possibilities in EPR

- With a strict implementation of the ATCE method, meaning that no relaxation is performed of any kind, the extracted ID NTC domain will be fully contained within the DA FB domain.
  - In this case, the ATCE method would not introduce arbitrage opportunities since no ID capacity would be released when there is a positive DA price difference.
  - This is not because there is some explicit step in the ATCE method that prevents arbitrage opportunities, but it follows from that the NTC domain must remain within the FB domain.
- However, with the relaxations applied (PTDF relaxation and/or RAM relaxation), the NTC domain is allowed to expand beyond the FB domain. When this is the case, arbitrage opportunities may arise.
- The relaxation parameters applied during EPR has been revised from 5% PTDF-relaxation, to a combination of 2% PTDF-relaxation and 10 MW RAM relaxation. This has reduced the arbitrage possibilities.

Arbitrage illustration



- Suppose a CNEC is fully loaded after DA market clearing.
- Without relaxation, there is no capacity left on the CNEC for ID, meaning ID ATC = 0 for NO1>SE3, SE3>SE4 and SE2>SE3.

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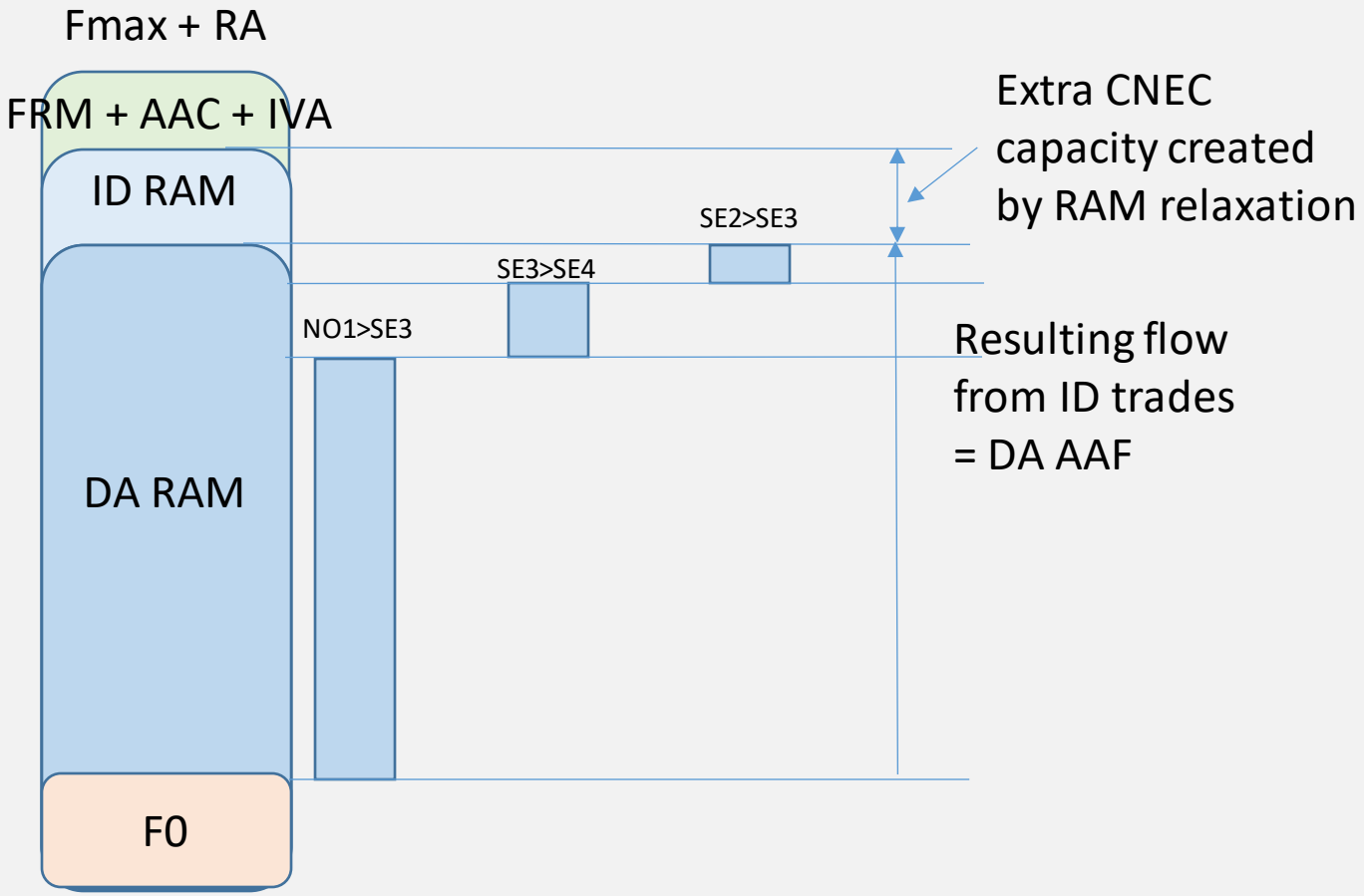
Arbitrage illustration



- Suppose a CNEC is fully loaded after DA market clearing, with for example, price SE3 > price SE2.
- With 10 MW RAM relaxation, capacity may become available for trading on SE2>SE3, resulting in an arbitrage possibility.
- A BRP could sell in SE3 and buy in SE2 on DA, and trade in the other direction in ID.

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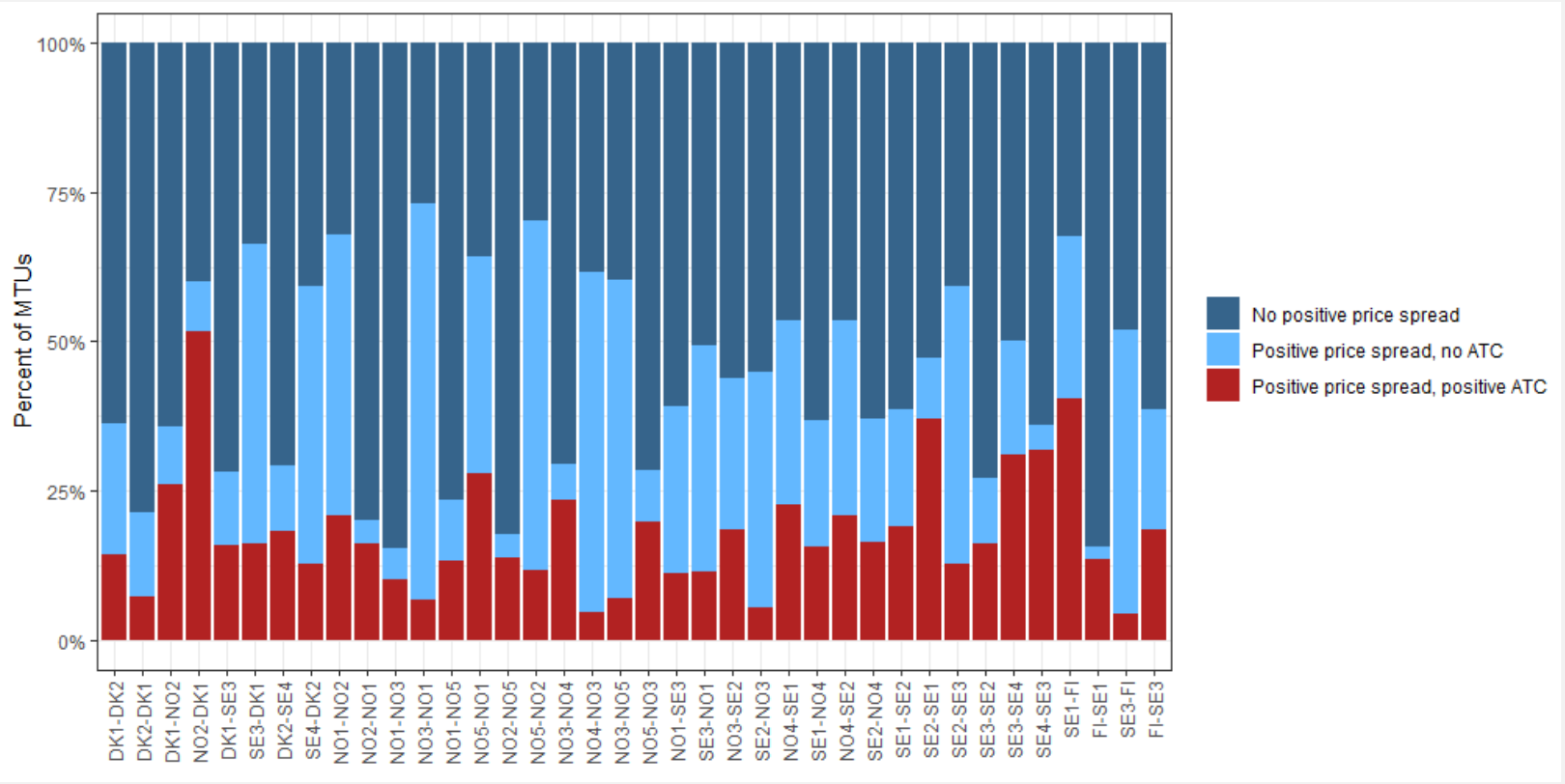
Analysis of re-run data

- The following slides visualize the magnitude of the arbitrage opportunities observed in EPR, using the updated parameter settings.
- The analysis is based on the data from the “re-run”, covering June 26, 2023 through March 24, 2024.
- The visualizations show data for internal Nordic borders.

Percent of MTUs with arbitrage possibilities



Conditions for arbitrage possibility to occur between A and B:

1. DA Price A > DA Price B
   (BRP can sell in A at higher price than buying in B)
2. ID ATC(B->A) > 0
   (BRP can adjust its portfolio by selling in B and buying in A, at close to no cost)

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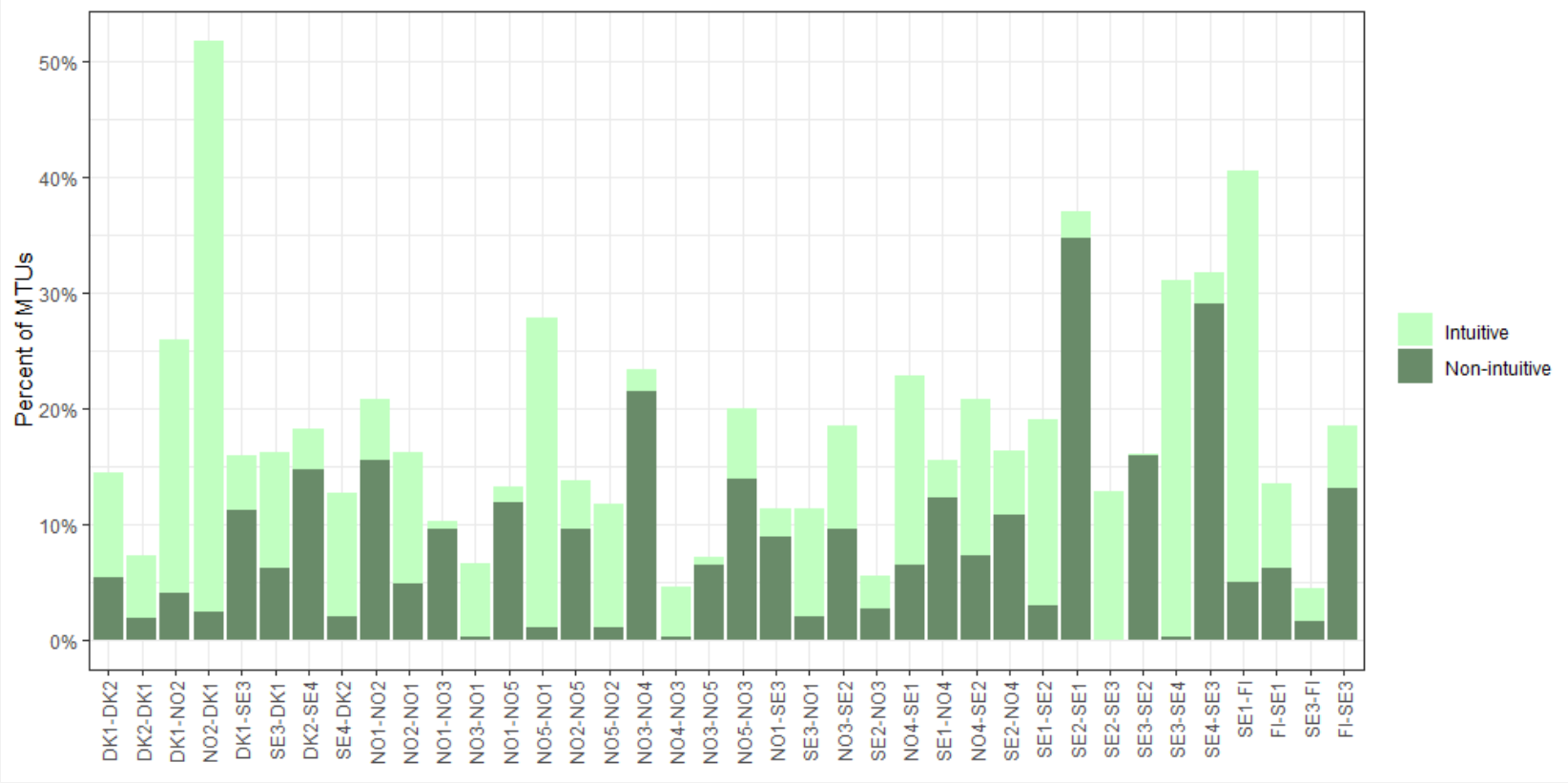
Percent of MTUs with arbitrage possibilities, by intuitiveness of flow



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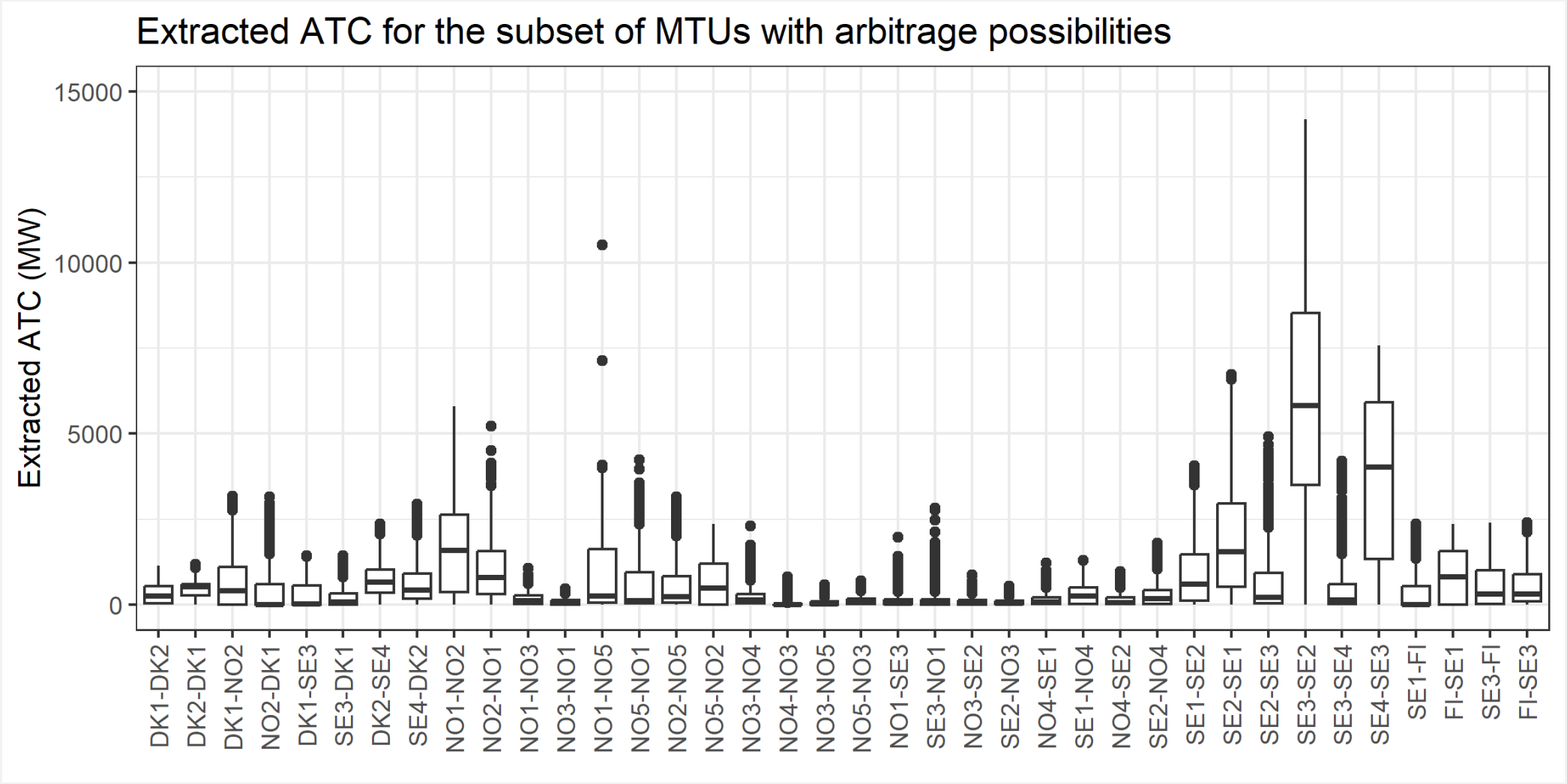
ATC and price spread



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Arbitrage - conclusion

- Arbitrage possibilities occur when
  1. DA Price A > DA Price B
     (BRP can sell in A at higher price than buying in B)
  2. ID ATC(B->A) > 0
     (BRP can adjust its portfolio by selling in B and buying in A, at close to no cost)
- Given condition 1, the second condition can only occur when relaxation is applied in the ATCE methodology. Otherwise, DA MC would have allocated more capacity from B to A to further increase the SEW.
- Potential consequences, not quantified as of yet:
  1. Part of ID ATC may be used by market participants when arbitrage possibilities occur for financial optimisation, which may reduce ID ATC available for physical needs.
  2. In case arbitrage possibilites are predictable, market participants may change their DA bidding strategies, which will impact the price formation on DA.