Workshop Session 1:

Theoretical understanding of flow-based method, intuitiveness, hybrid-coupling

by Joel HOEKSEMA (APX), Adrien ATAYI (RTE) and Pieter SCHAVEMAKER (e-Bridge)

Workshop 1

Agenda

I. **Flow-based Method**
   I. Capacity Calculation principles
   II. Capacity Allocation principles

II. **Intuitiveness**
   I. Interaction with LT nominations and ID

III. **Hybrid Coupling**

Practical advise:

- This workshop is meant to be **interactive** and to give room for discussions
- Please feel free to **ask your questions** or to **comment** after each section
- Questions that go beyond the scope of this workshop will be collected and answered via the Q&A Forum afterwards

FB Capacity Calculation principle

- TSOs impose constraints to the market coupling algorithm in order to safeguard the grid
- FB constraints have two components:
  - **Remaining Available Margin (RAM):** number of MWs that can be used by the trades
  - **Power Transfer Distribution Factor (PTDF):** indicates how much MWs are used by the net positions resulting from the trades
- **The FB search space is the concatenation of the above mentioned constraints**

FB MATRIX

=

As many lines as there are **constraining critical branches** defined by TSOs

+

As many columns as there are **hubs (for each PTDF)**

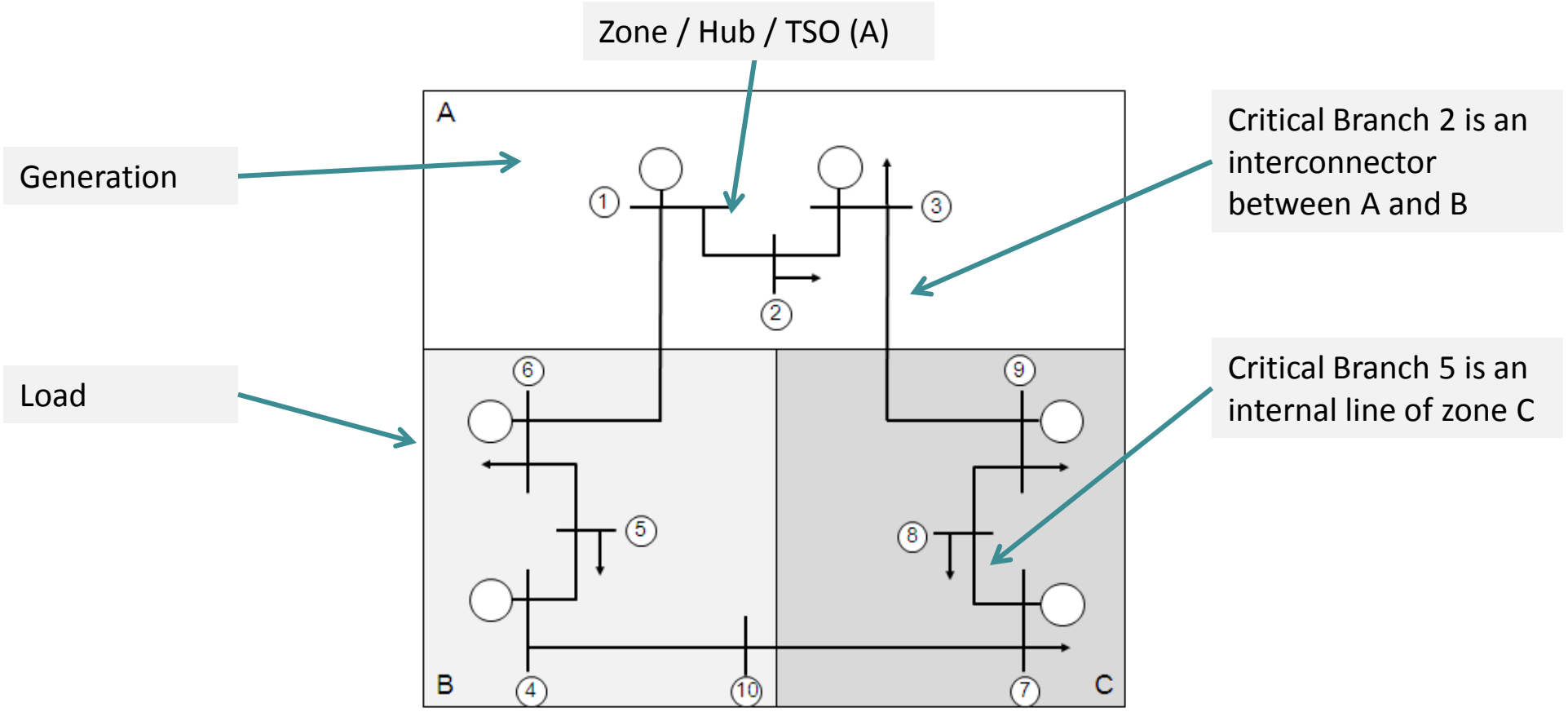
+

One column for the **RAM** (the **limiting value** in the inequation)

- In CWE, there are 4 hubs, but the overall DA balance imposes the sum of CWE Net Exchanges (Nex) to equal 0 (linear bound between the four hubs). Consequently, the CWE search-space is **3 dimensional**, each constraint being modeled by a plane in this space

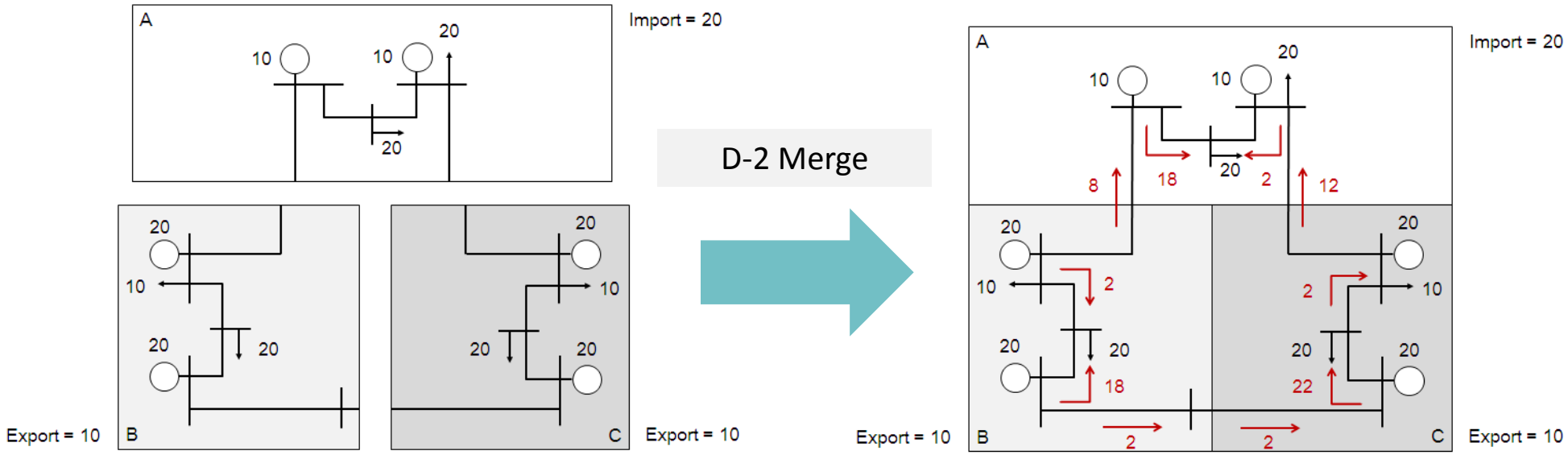
FB Parameters computation: An introduction

- For illustrating the principles of PTDF and RAM computation (how to compute the coordinates of each plane), we are going to use a **simplified network made of 10 nodes**, connected by 10 lines. Our example is constituted of **3 hubs/TSOs**



FB Parameters computation: the "basecase"

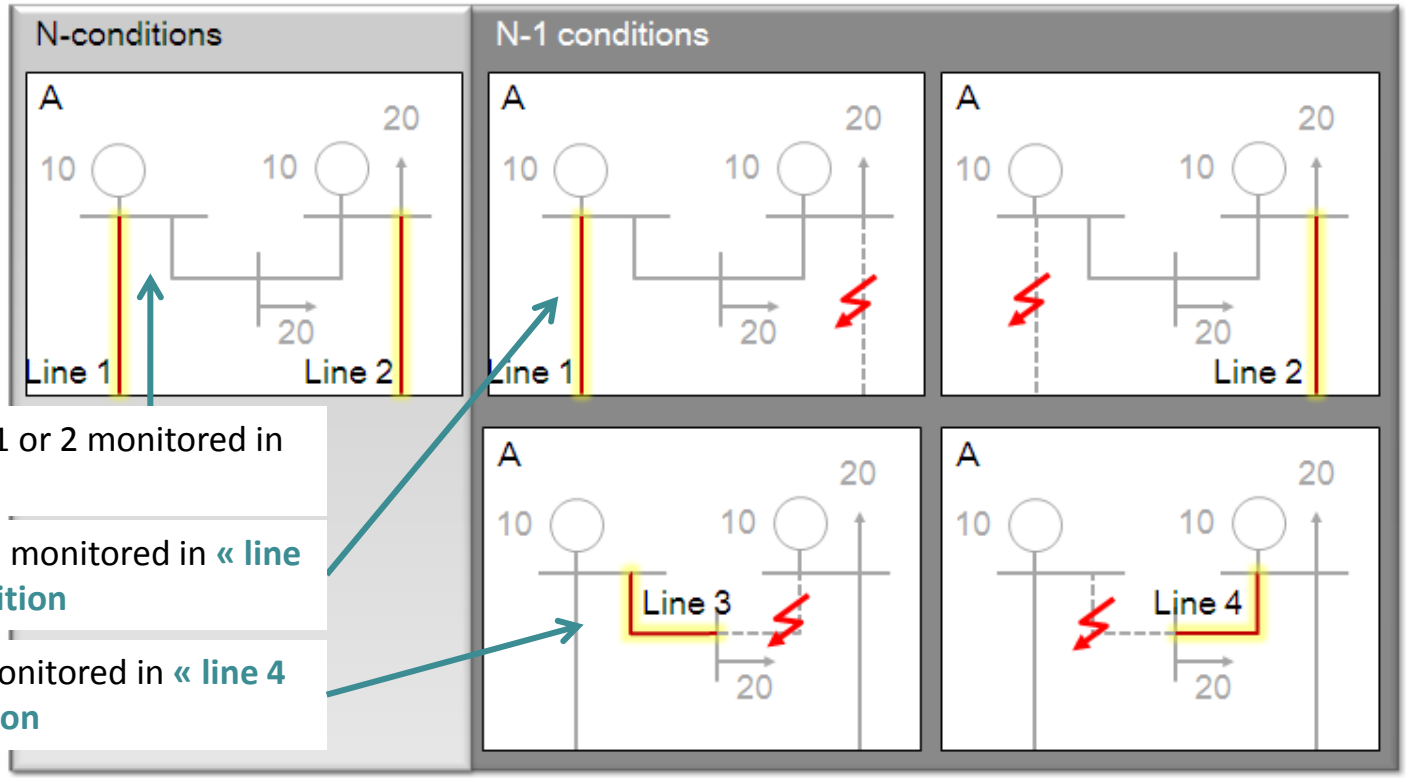
- **Two Day Ahead Congestion Forecast (D2CF)** process at each TSO
  - Provides the best estimation of the grid
  - Constitutes the working point for a predefined hour of day D
- **Centralized merging activity** to put together the D2CF building blocks of the Common Grid Model (CGM)
  - Representative load flow model of the grid for a predefined hour of day D
  - Basis for the coordinated capacity calculation process



FB Parameters computation: the "CBs"

- TSOs define the elements of the grid that they would like to monitor and that are significantly impacted by cross-border trades (CBs)
  - CBs can be **interconnectors** (lines 1 or 2) and **internal lines** (3 or 4)
  - CBs can be monitored in **"N situation"**, but also under outage scenarios, so called **"N-1 cases"**

Branches monitored by TSO A (Line 1 / 2 / 3 / 4, marked in yellow):



Interconnector 1 or 2 monitored in **« N » situation**

Interconnector 1 monitored in **« line 2 outage » condition**

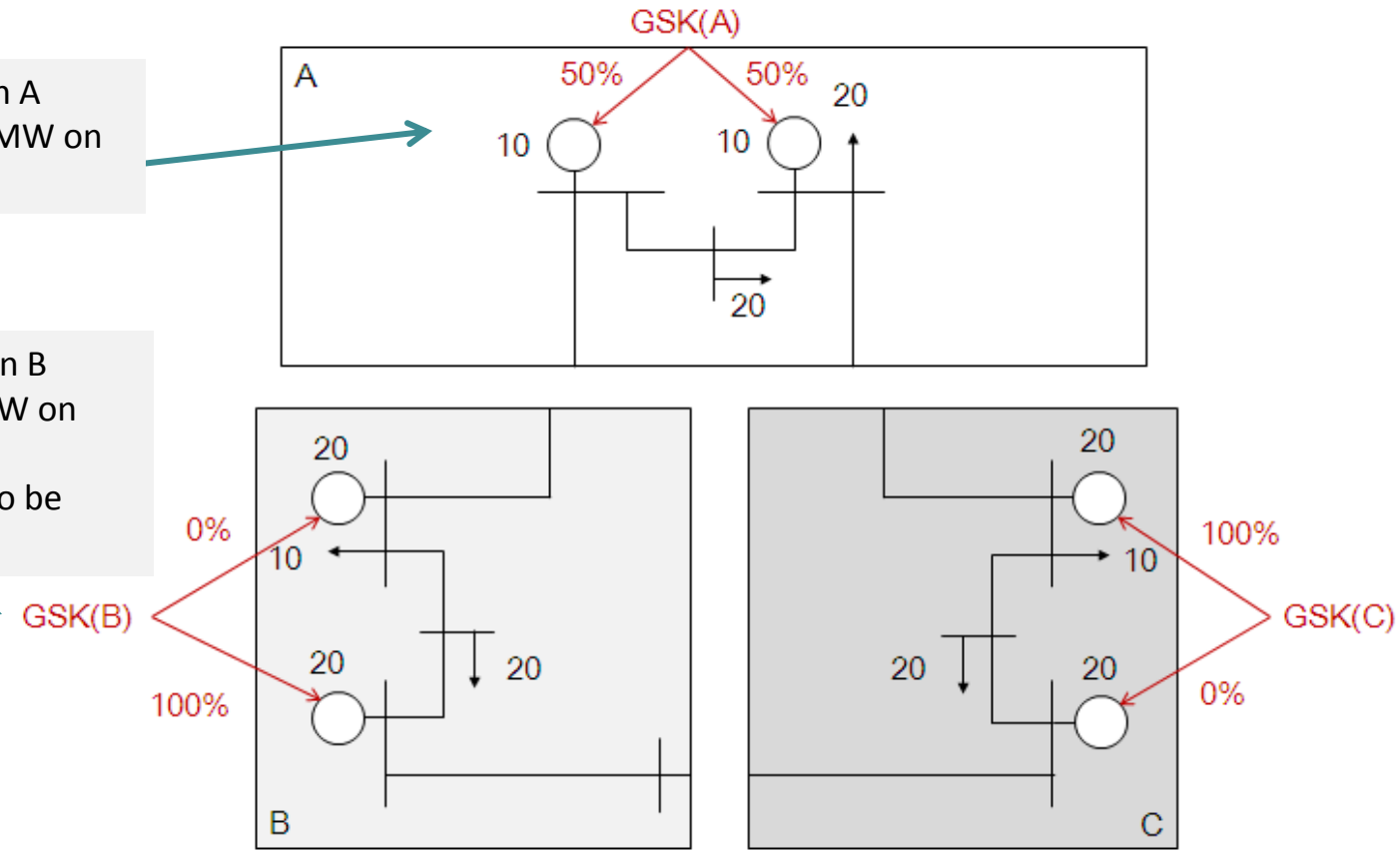
Internal line 3 monitored in **« line 4 outage » condition**

FB Parameters computation: the "GSK"

- The **Generation Shift Key (GSK)** indicates on which generation units a net position change of the hub will take place
- The GSK is a **linear relationship between Nex variation and generation pattern of each hub**

A variation of « N MW » of net position A will be derived into a variation of N/2 MW on each of the 2 units inside this hub

A variation of « N MW » of net position B will be derived into a variation of N MW on one unit
The other unit which is assumed not to be influenced by DA trades will not move

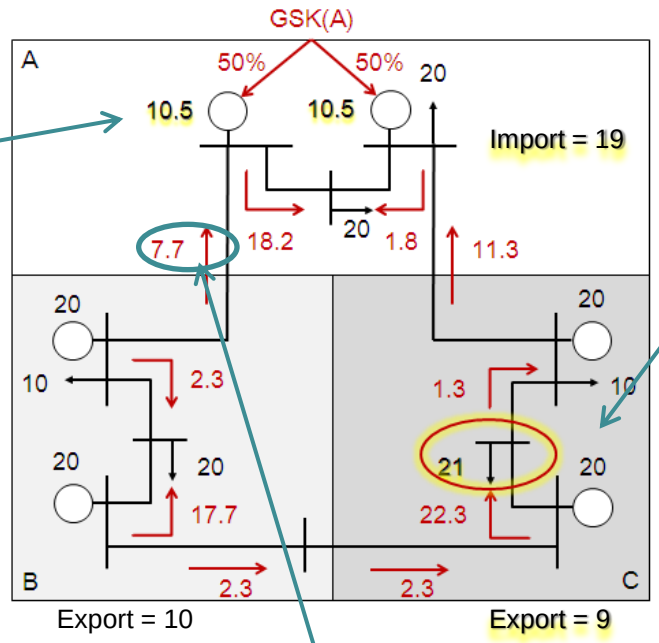


FB Parameters computation: the "PTDF"

1

We assume an **increase of 1 MW of Hub A net position**

According to GSK(A), this 1 MW is split in 0.5 MW in the 2 units of hub A



2

Overall balance is ensured by compensating this 1 MW by increasing the load of a **"reference node"**

3

The resulting flows on each CB are computed with a **DC load flow** and compared to flows from the basecase

- **The difference between resulting and initial flows is the basis for PTDF determination**
- For instance, flow on line 1 changed from 8 MW to 7.7 MW, after increasing A export of 1 MW
  Therefore, PTDF_line1 (Hub A) = - 30%

FB Parameters computation: the "PTDF" (2)

- The process described in the previous slide is repeated for each CB, for each Hub
- PTDFs are also computed in "N-1" conditions when deemed relevant by TSOs
  - The same "reference node" is used. Choice of this node has no impact
- Indeed, the **market coupling algorithm will optimize exchanges between hubs**
- An exchange of 1 MW from zone A to zone B (for instance) is equivalent to:

An exchange of 1 MW **from hub A to the reference node** **-** An exchange of 1 MW **from hub B to the reference node**

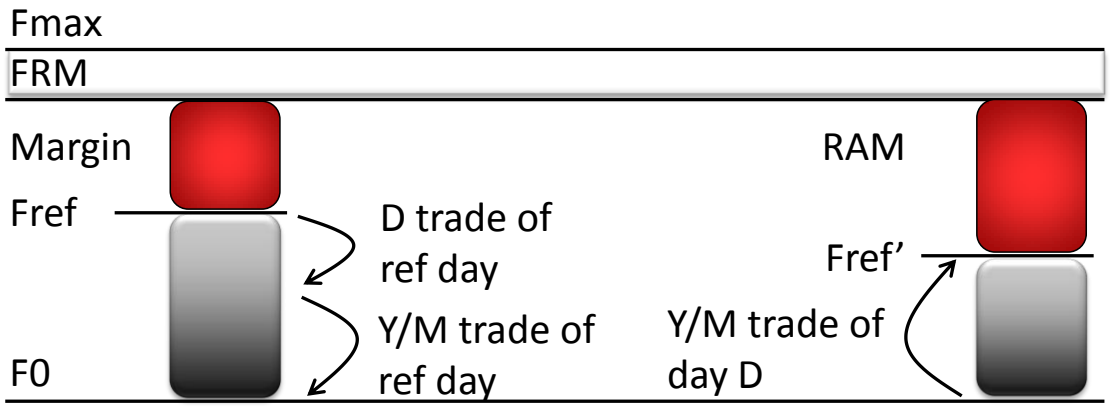
This property holds due to the linearity of the PTDF computation (DC load flow)

  - "hub-to-hub" PTDFs are therefore easily derived by substracting the "hub-to-reference" PTDFs computed before

- **Advantage of this approach**: A "concentration" of FB parameters in a small number of values (hub-to-reference PTDF). Computing and providing separately all combinations of hub-to-hub PTDF would be impractical, especially if the number of hubs increases

FB Parameters computation: RAM (1)

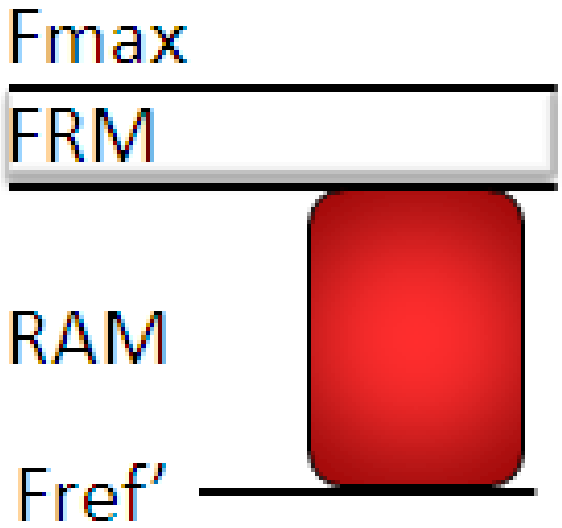
- After the illustration of PTDF computation, we will now address the **computation of RAM**
- In the flows observed in the D2CF basecase (the Fref) the impact of cross-border trade (of the reference day) is reflected. The flows are adjusted in accordance to the graph below, by using the PTDF computed before



- **Ex. For line 1:**
  - Fref = 8 (as computed on slide 32)
  - Net positions in the D2CF basecase: NP(A) = -20, NP(B) = 10, NP(C) = 10
  - F0 = Fref – (NP(A)*PTDF(A) + NP(B)*PTDF(B) + NP(C)*PTDF(C)) = 8 – (-20*-0.3 + 10*0.3 + 10*-0.1) = 8 – 8 = 0
  - Assume that the net positions due to the long-term nominations equal: NP(A) = -10, NP(B) = 5, NP(C) = 5
  - Fref' = F0 + (NP(A)*PTDF(A) + NP(B)*PTDF(B) + NP(C)*PTDF(C)) = 0 + (-10*-0.3 + 5*0.3 + 5*-0.1) = 0 + 4 = 4

FB Parameters computation: RAM (2)

- The maximum allowed flow on line 1 equals: **Fmax = 25**
- The Flow Reliability Margin (FRM) on line 1, the margin that the TSO needs to reserve in order to hedge against uncertainties has been assessed to be equal to: **FRM = 3**
- We computed the Fref' on line 1, the flow that is expected to flow on line 1 prior to the allocation of the Day-Ahead capacity to be: **Fref' = 4**
- The Remaining Available Margin (RAM) on line 1, the margin available for the market to be used under the FBMC amounts: **RAM = Fmax – FRM – Fref' = 25 – 3 – 4 = 18**



FB Parameters computation: summary

- Eventually, for each hour, the FB computation performed by TSOs leads to the **completed FB parameter matrix**, as in our example below for line 1:

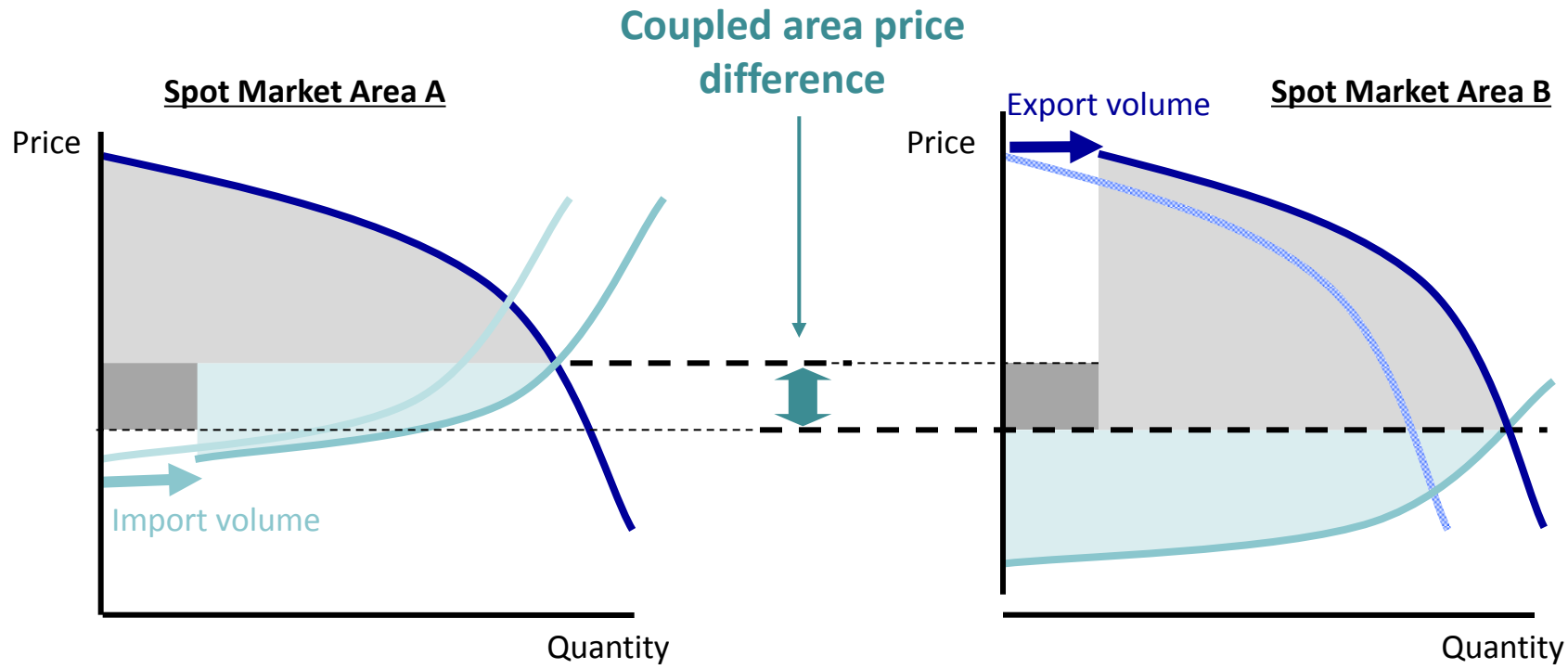
Monitored branch	Outage scenario	Zone A PTDF	Zone B PTDF	Zone C PTDF	RAM
Line 1	-	-0.3	0.3	-0.1	18

- **The concatenation of these constraints is the FB domain**
  - Each constraint is a hyperplane in a n-1-dimension search space, where n is the number of hubs
  - With 4 hubs in CWE, the FB search space is a kind of potato, made up of an average of 15 – 20 planes (corresponding to the most constraining CB)

- **This matrix is provided at 10:30 am in DA**, as in ATC today, as a set of constraints for the welfare optimization algorithm of the market coupling system

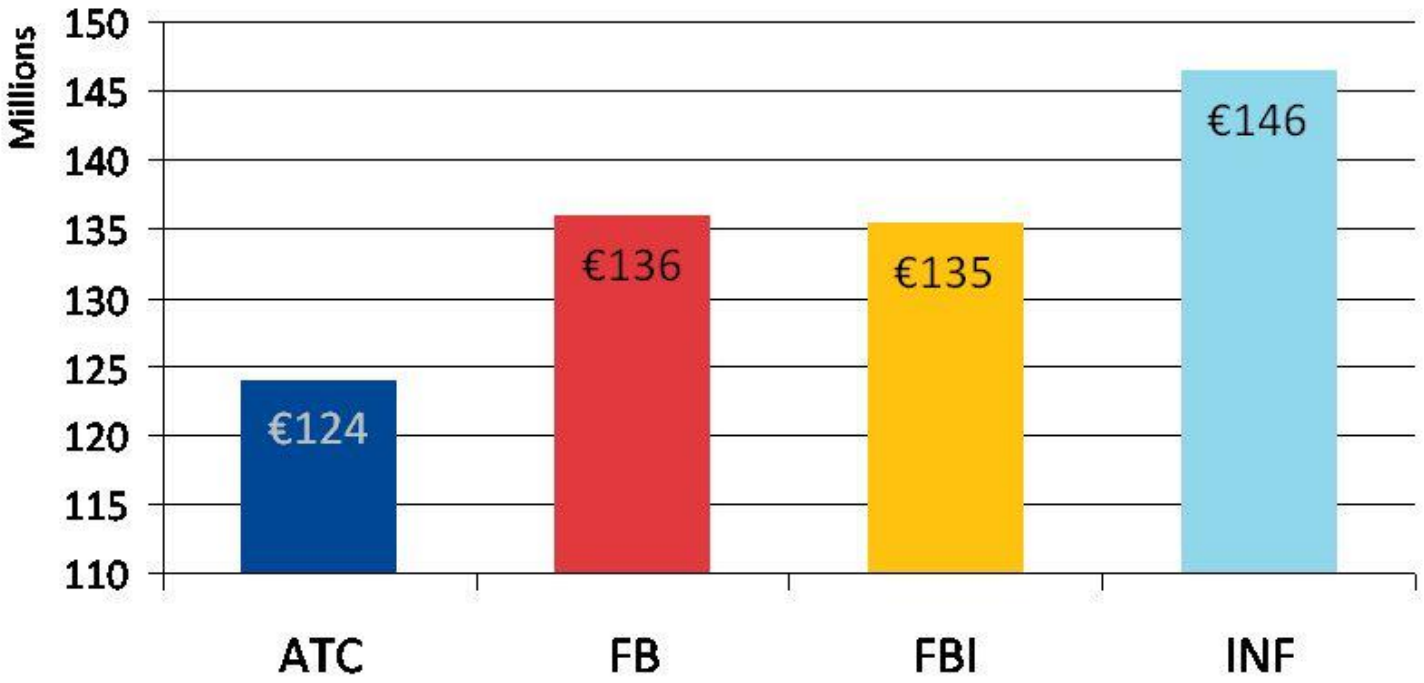
Capacity allocation: basic principle

WELFARE = *Seller surplus* + *Buyer Surplus* + *Congestion rent*



Outcome of FB Parameters computation: increased welfare

- Theory has been proved by parallel run results (welfare increase compared to uncoupled markets): **more capacity under FB leads to a higher welfare under FB** than under ATC



- ***Note***: Data from 1st of January to 28th of February 2013

Example (1/2)

Monitored branch	Zone A PTDF	Zone B PTDF	Zone C PTDF	RAM
Line 1	-0.3	0.3	-0.1	18

OBKs:

A: buy 1000MWh@50
B: sell 1000MWh@20
C: sell 1000MWh@30

Best price

1MW B->A exchange uses:
(0.3 – (-0.3)) = 0.6 MW
→ 18/0.6 = 30MWh can be exchanged

1MW C->A exchange uses:
(-0.1-(-0.3)) = 0.2 MW
→ 18/0.2 = 90MWh can be exchanged

Two choices:

1. A buys 30@20 from B
2. A buys 90@30 from C

Most welfare

Example (2/2)

Monitored branch	Zone A PTDF	Zone B PTDF	Zone C PTDF	RAM
Line 1	-0.3	0.3	-0.1	18

OBKs:

A: buy 1000MWh@50
B: sell 1000MWh@20
C: sell 1000MWh@30

Silly idea:
1MW C->B exchange uses:
-0.1-(0.3) = -0.4MW

notice sign

This exchange actually relieves the line by 0.4MW

Recall that 1MW C->A used 0.2MW on the line. I.e. each 1MW C->B exchange allows us to schedule 2MW C->A

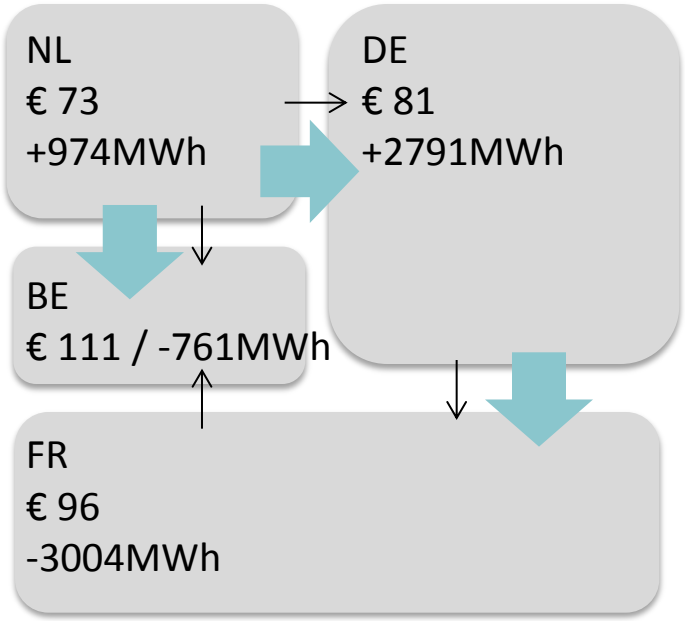
Since C->A exchanges generate welfare, we might even accept C->B exchanges that lose welfare (but less than what is gained on C->A). This would be an non-intuitive situation

Intuitive energy flows: introduction

Intuitive energy flows are exchanges from low price areas to high price areas

An intuitive situation

(December 2nd, 2010, hour 20, FB "standard" MC simulation)

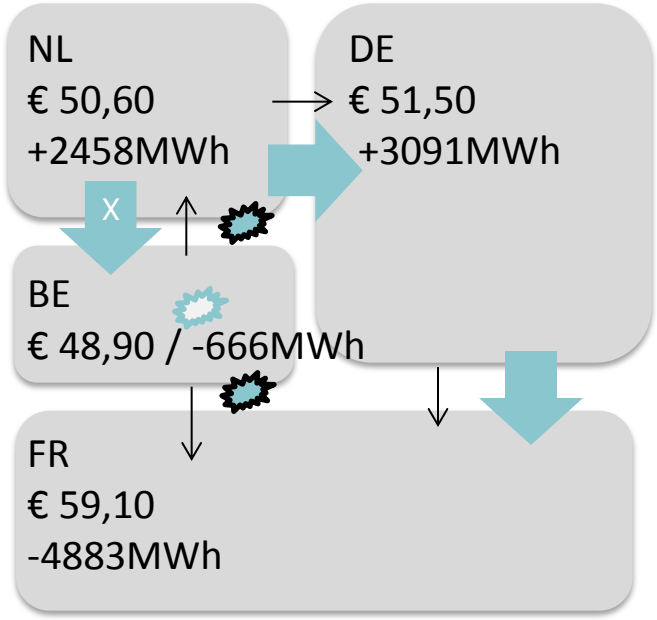


Bilateral commercial exchange

Possible intuitive exchange

A non-intuitive situation*

(December 1st , 2010, hour 07, FB "standard" MC simulation)



Area importing with the lowest price

Area unable to import intuitively

No decomposition exists such that all energy flows from low price to high price markets

However,

enforcing intuitiveness is an additional constraint at the cost of DA market welfare

**A second case can occur where an expensive market is forced to export, becoming even more expensive*

Intuitiveness within the CWE region

- Those non-intuitive flows from high price to low price areas were identified in FB MC simulations in 2008
- An algorithm was developed that can prevent such situations, which is called “intuitive patch”
- **Plain FB as well as FB intuitive will be simulated during the external parallel run** in order to facilitate the decision in favour of FB plain or FB intuitive in the CWE region

Intuitiveness within the CWE region

- So far, the choice of plain vs. intuitive FB is subject to the adapted point of view:
  - **From "within" the standard MC model**: FB "intuitive" MC only decreases the day-ahead market welfare while it does not bring any good property to the model → ***Choose FB "plain"***
  - **From "outside" the standard MC model**: Preference for ATC like properties which exist more often in "intuitive" FB. Areas involved in non-intuitive exchanges should not have to import (resp. export) with the lowest (resp. highest) price to "help" others. Smaller areas are more often involved in non-intuitive situations → ***Choose FB "intuitive"***
  - **With a "commodity market" point of view**: A product should not be sold in another country at a lower price than the price charged in its home market. The disappearance of partial convergence under FB "plain" prevents local reasoning that allowed forecasting easily the price range → ***Choose FB "intuitive"***

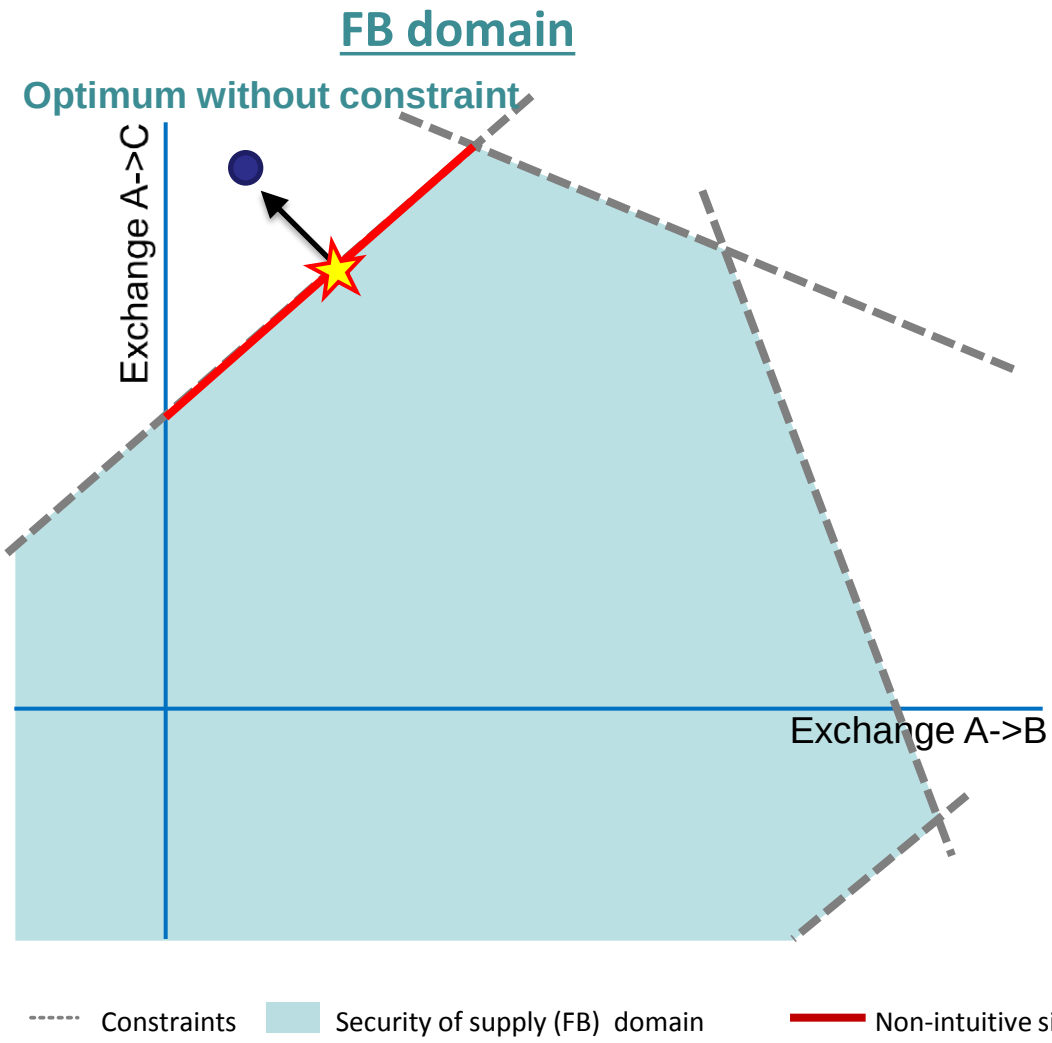
- *Please refer to the Intuitiveness Report, 2012.*

And in practice?

Observation of non-intuitivity

- During the external parallel run, **87 non-intuitive cases** have been found, out of the 1152 hours ➔ i.e. non-intuitive cases in less than 7.6% of the time
- 58 of those cases appeared on just five days
- Smaller countries are more impacted: predominantly Belgium and Netherlands were involved in the non-intuitive exchanges (e.g. the cheapest country and importing or most expensive and exporting)
- Less than 5% of the gain from the switch from ATC MC to FB “plain” MC is lost if FB “intuitive” MC is chosen
- 65% of the losses were on two days: January 28th (20%, 114k€) and February 25th (45%, 258 k€).

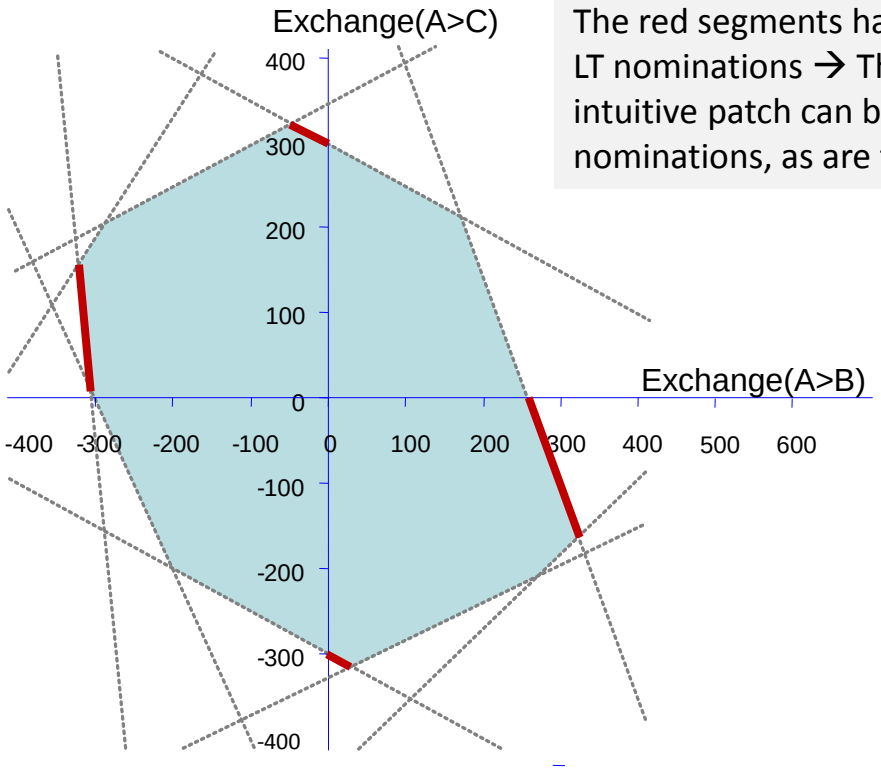
Graph: FB domain + non-intuitive situations



- Why would a market outcome on the red line correspond to a non-intuitive situation? Because:
- Increasing **A→B** frees capacity for **A→C** exchanges
- Consider the market outcome illustrated by the star
  - Here mcp(B) < mcp(A) < mcp(C)
  - More welfare can be obtained in the direction of the black arrow
  - No welfare gains can be expected in the feasible region: if one existed, that would have been the market outcome
  - I.e. apparently it is not favorable to exchange more on **A→B** : this flow therefore must be adverse

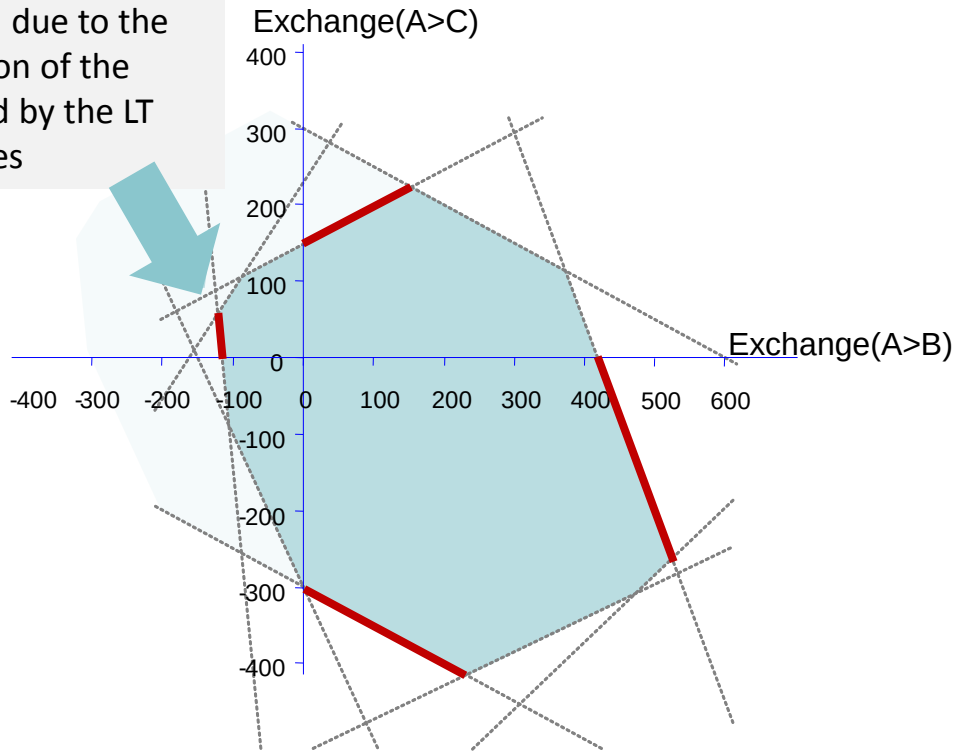
FB intuitive in interaction with LT and ID

FB domain before LT nominations



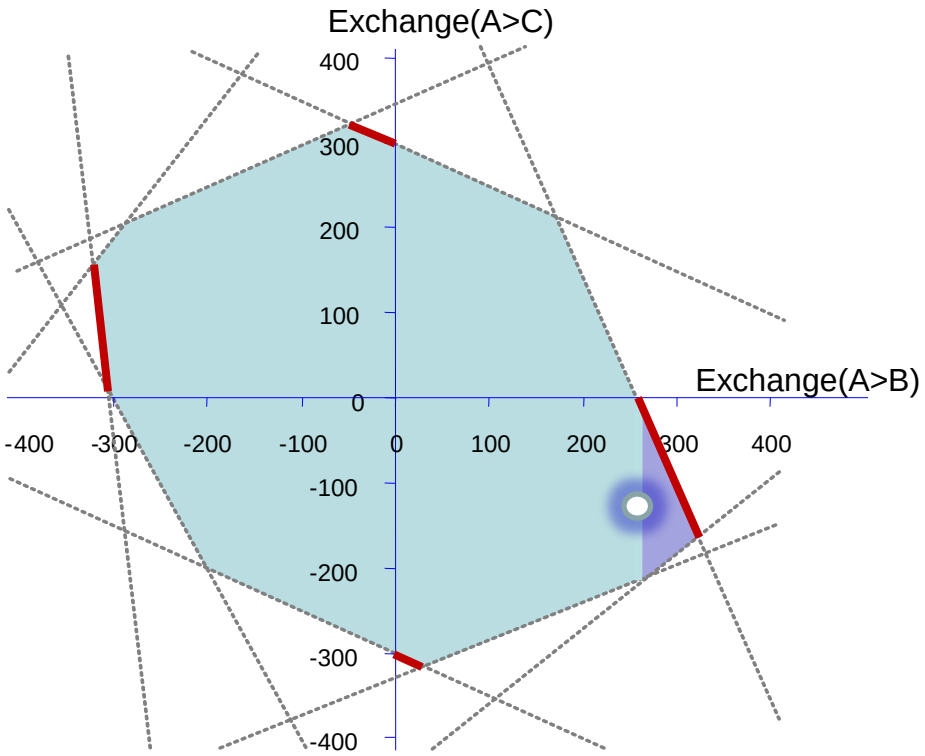
The red segments have changed due to the LT nominations → The application of the intuitive patch can be influenced by the LT nominations, as are the DA prices

FB domain after LT nominations



Constraints | Security of supply domain | Non-intuitive situations

Application of the intuitive patch and interaction with ID



- When enforcing intuitive market results, the FB domain is restricted and capacity is blocked
- The "blocked capacity" which is not used in the DA market could be fed into the ID market

→ **new (artificial) source of ID capacity increase**

Constraints
Non-intuitive situations
"blocked" capacity
Security of supply domain
Market clearing point

Hybrid Coupling: introduction

- CWE Project is not a standalone project and needs to **be fully integrated in the European market**
- Compatibility with neighboring regions using the ATC method has been ensured:

  CWE FB MC Go Live will start with a standard hybrid solution while keeping the opportunity to move to an advanced hybrid solution

- These two solutions are described in the following slides

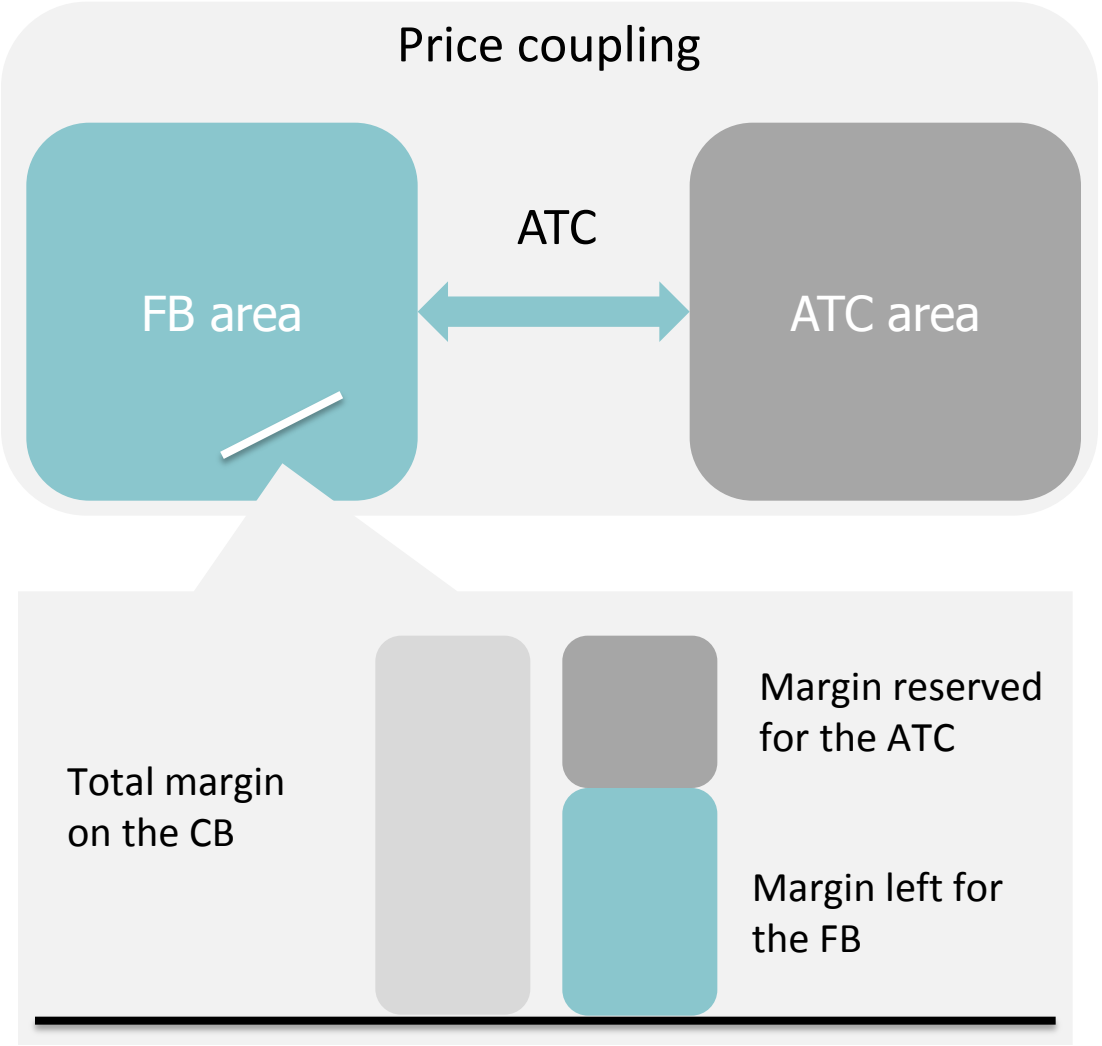
Hybrid Coupling

How deal with FB in CWE region and ATCs outside this area?

Hybrid coupling, two variants

1st variant: Standard

- Realized ATC transactions are not taken into account in the margin of the CBs
  ➔ TSOs need to reserve margins (worst-case) on their CBs for the possible usage by the ATC area
  - Just like today
  - No competition for the use of the scarce capacity in the allocation mechanism due to the ex-ante split
  - Not optimal: scarce capacity not always fully used



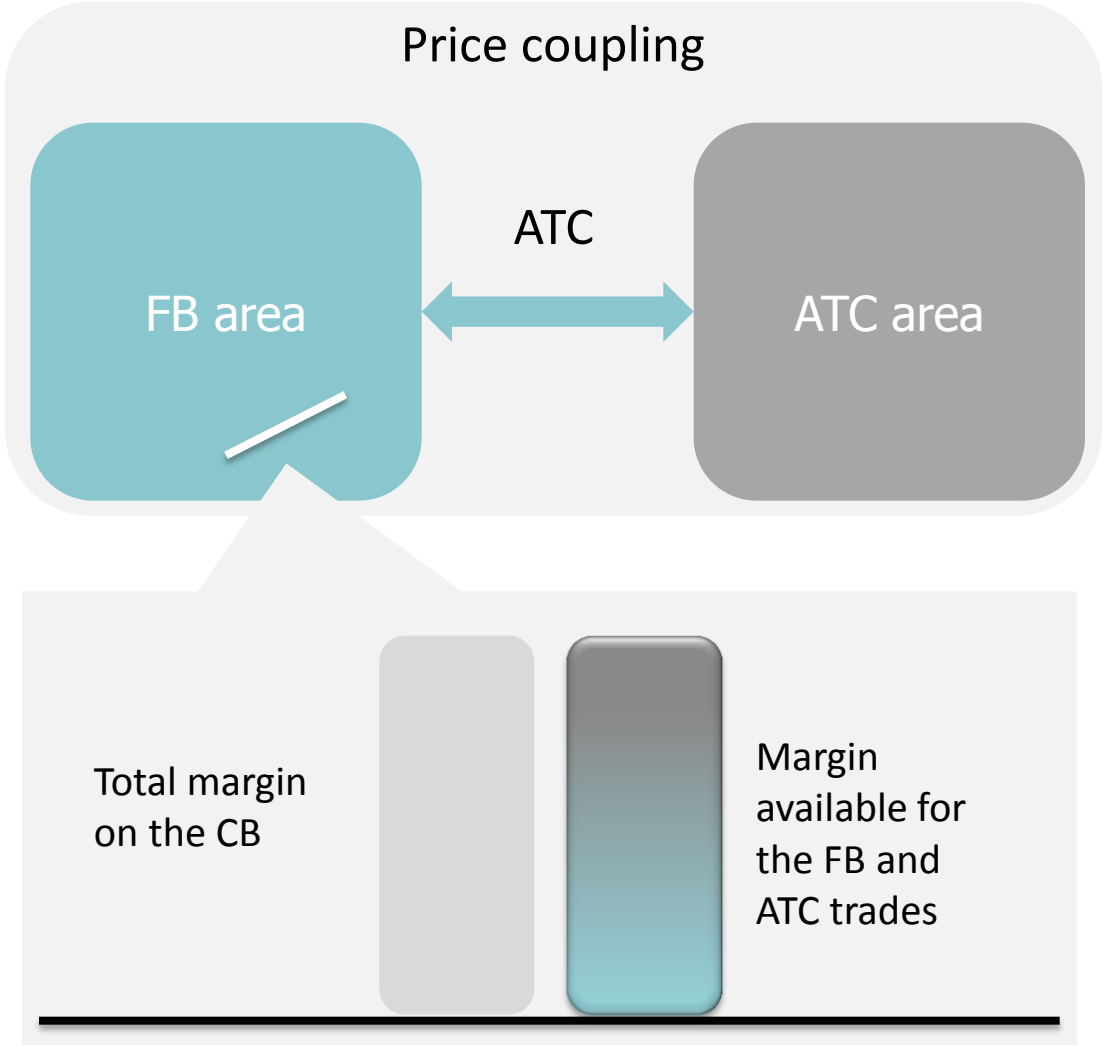
Hybrid Coupling

How deal with FB in CWE region and ATCs outside this area?

Hybrid coupling, two variants

2nd variant: Advanced

- Realized ATC transactions are taken into account in the margin of the CBs ➔ TSOs do not need to reserve margins on their CBs ➔ use of margin is market driven
  - Competition for the use of the scarce capacity in the allocation mechanism
  - Optimal use of scarce capacity
  - Maximum social welfare
  - The connection to the ATC area is subject to FB price properties



Q&A Session