



Workshop - Core DA FB CC Concept

Core Consultative Group meeting
6th of July 2017 – Munich





I. CAPACITY CALCULATION METHODOLOGY

1. Inputs
2. Capacity calculation approach

II. CAPACITY CALCULATION PROCESS

1. Creation of a common grid model
2. Regional calculation of cross-zonal capacity
3. Back-up & Fallback processes



I. CAPACITY CALCULATION METHODOLOGY

1. Inputs

- Operational security limits, contingencies and allocation constraints
- Flow Reliability Margin (FRM)
- Generation Shift Key (GSK)
- Remedial Action (RA)

2. Capacity calculation approach

- Mathematical description
- CNEC selection
- Min Net Transmission Capacity (NTC) inclusion
- Rules on the adjustment of power flows on CNEs due to RA
- Capacity calculation on non Core borders

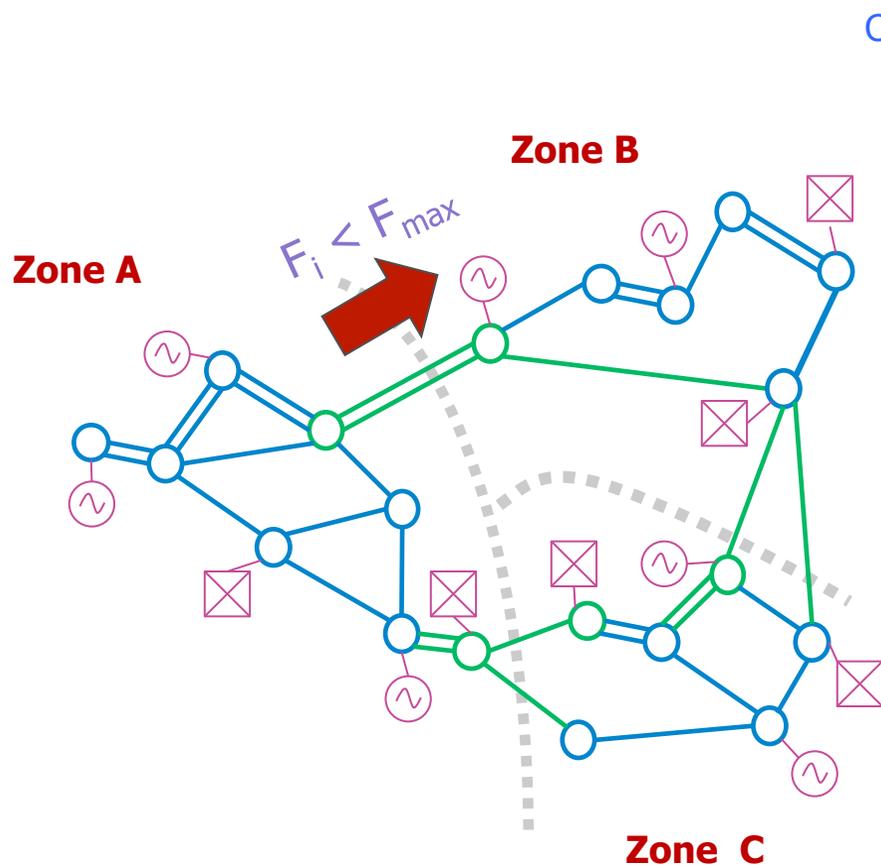




1. Inputs

Operational security limits and contingencies

(1-3)



Critical Network Element

- The TSOs select some grid elements they want to be monitored during the calculation (= the ones which could limit the capacity);
- Cross-border lines and internal lines that are significantly impacted by cross-border exchange;
- The available capacity for each CNE is determined based on the physical limit of the line.

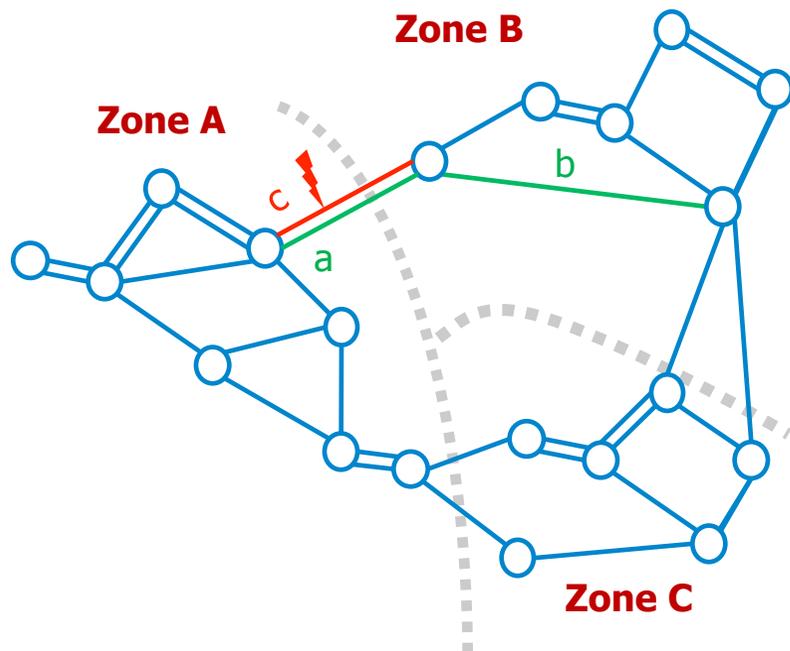
Legend

- **F_i** – Actual flow on the branch
- **F_{max}** – Maximum allowable flow on a given critical branch



1. Inputs

Operational security limits and contingencies (2-3)



Critical Network Element

- The TSOs select some grid elements they want to be monitored during the calculation (= the ones which could limit the capacity)

Contingency

- A CNE can be monitored in « N-1 » state (with contingency simulation). Then CNEC is used generally to describe : a monitored line in a specific topology scenario, due to a specific contingency simulation

How to chose CNECs?

- They are significantly impacted by exchanges among zones
- They can be interconnectors or internal lines



1. Inputs

Operational security limits and contingencies (3-3)

I_{max}

- The maximum admissible current (I_{max}) is the physical limit of a CNE determined by each TSO in line with its operational security policy. I_{max} is defined as a permanent or temporary physical (thermal) current limit of the CNE. A temporary current limit means that an overload is only allowed for a certain finite duration (e.g. 115% of permanent physical limit can be accepted during 15 minutes).

F_{max}

- The value F_{max} describes the maximum admissible power flow on a CNEC in MW.
- F_{max} is calculated from I_{max} by the given formula:

$$F_{max} = \sqrt{3} \cdot I_{max} \cdot U \cdot \cos(\varphi)$$

FAV

- With the Final Adjustment Value (FAV), operational skills and experience, that cannot be taken into account in the flow-based parameters otherwise, can find a way into the flow-based methodology by increasing or decreasing the remaining available margin (RAM) on a particular CNE.
- Positive values of FAV (given in MW) reduce the available margin on a CNE while negative values increase it. The FAV can be set by the responsible TSO during the validation phase.



1. Inputs

Flow Reliability Margin (FRM)

(1-4)

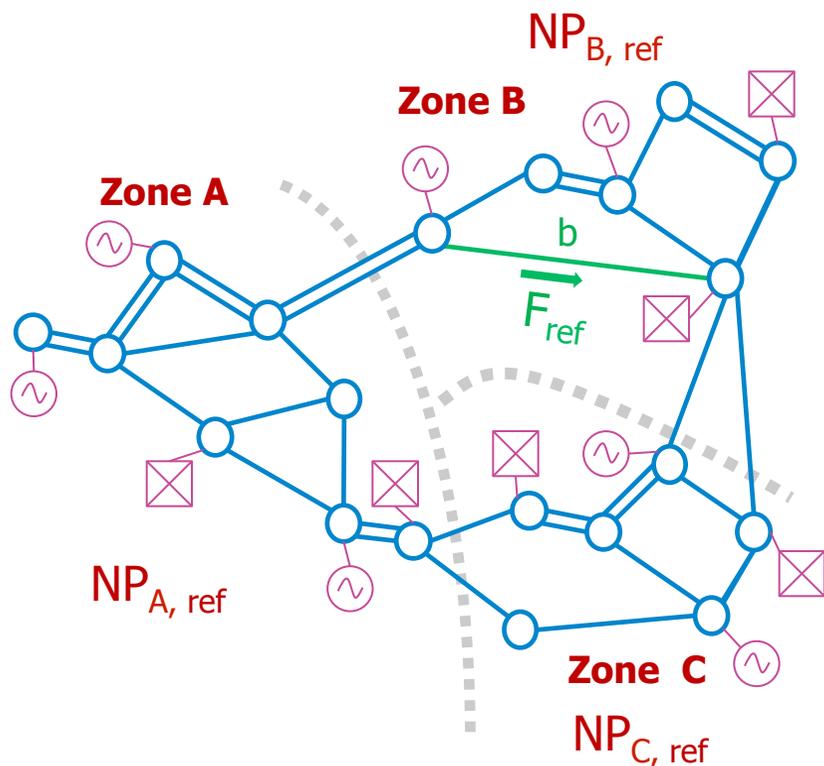
- FRMs are security margins taken on CNEC in order to cope with uncertainties on the flows expected on CNEC. These uncertainties result from all unexpected events occurring between the determination of the FB parameters and the real time (change of generation and consumption patterns, change of exchanges on the other borders, etc.) and also from uncertainties linked to the absence of exact locational information on the origin and destination of trades available at clearing time.
- Reliability margins are key for ensuring security of the grid, nonetheless they do not have to be oversized: they reduce the capacities available to the market and the welfare of the MC.
- FRMs are determined and justified by the Transmission System Operators (TSOs) on the basis of statistical analysis applied on observed data.



1. Inputs

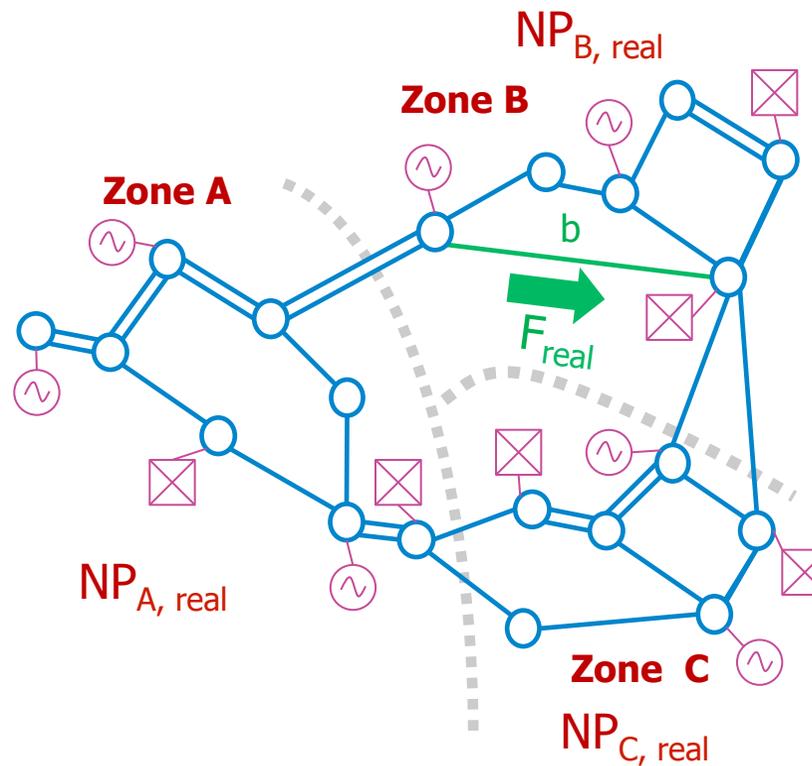
Flow Reliability Margin (FRM)

CGM_{D-2} with reference net positions



(2-4)

CGM_{real time}



Legend

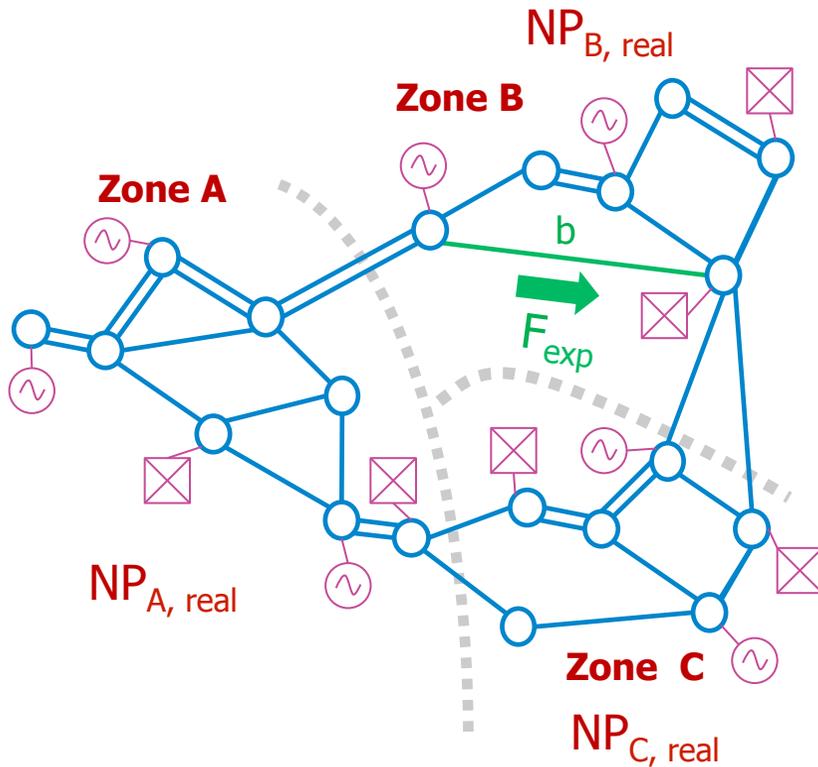
- **CGM** – Common Grid Model
- **NP** – Net Position = Export - Import = the volume of power to be exported or imported
- **F_{ref}** – Reference flow, reflects the loading of the CBs given the exchange programs of the chosen reference day



1. Inputs

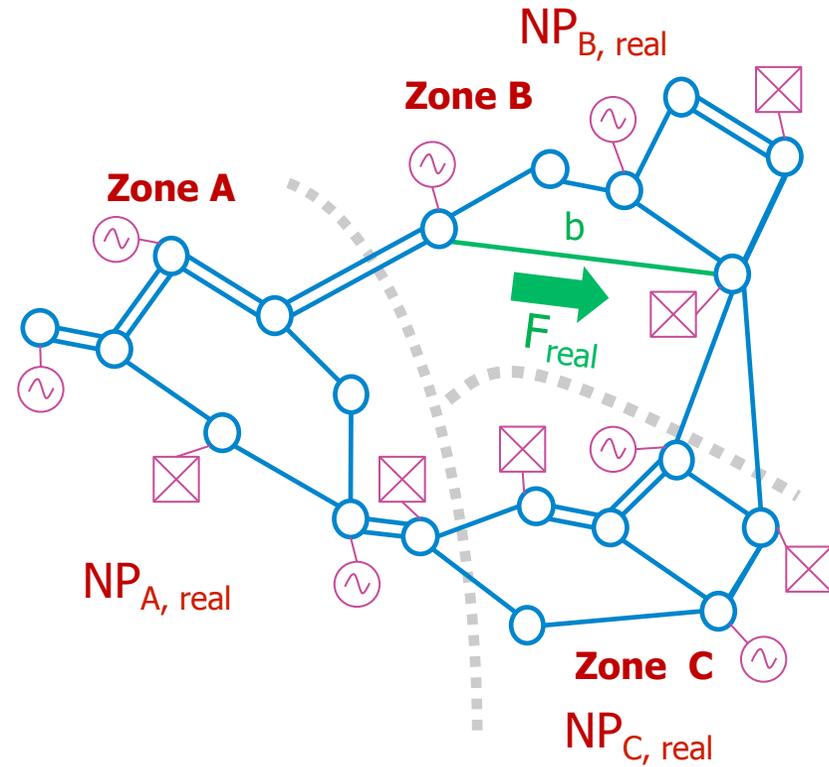
Flow Reliability Margin (FRM)

CGM_{D-2} with real time net positions



(3-4)

CGM_{real time}



Legend

- **CGM** – Common Grid Model
- **NP** – Net Position = Export - Import = the volume of power to be exported or imported
- **F_{exp}** – Expected flow

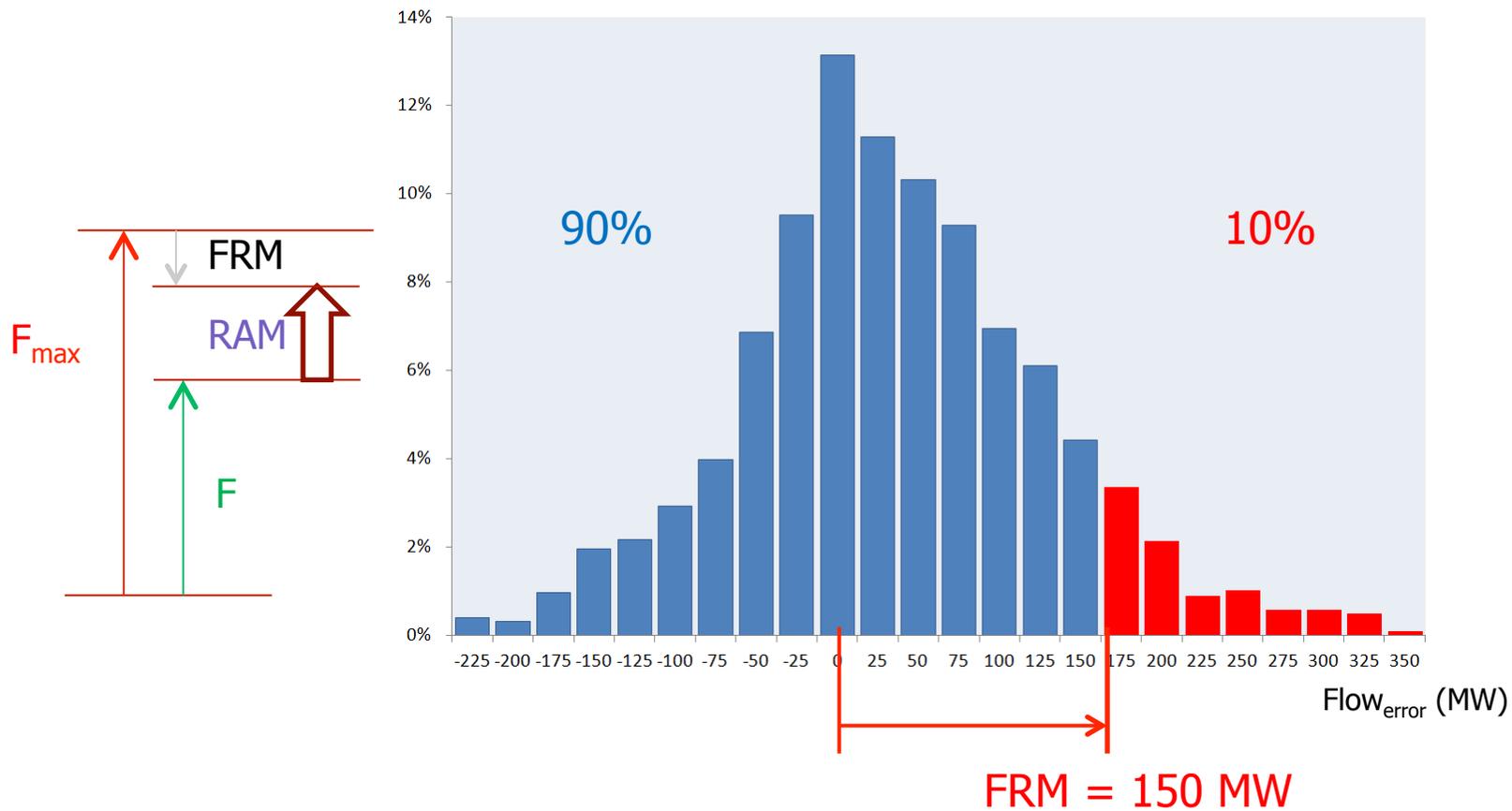


1. Inputs

Flow Reliability Margin (FRM)

(4-4)

$$\text{Flow error} = F_{\text{real}} - F_{\text{exp}}$$

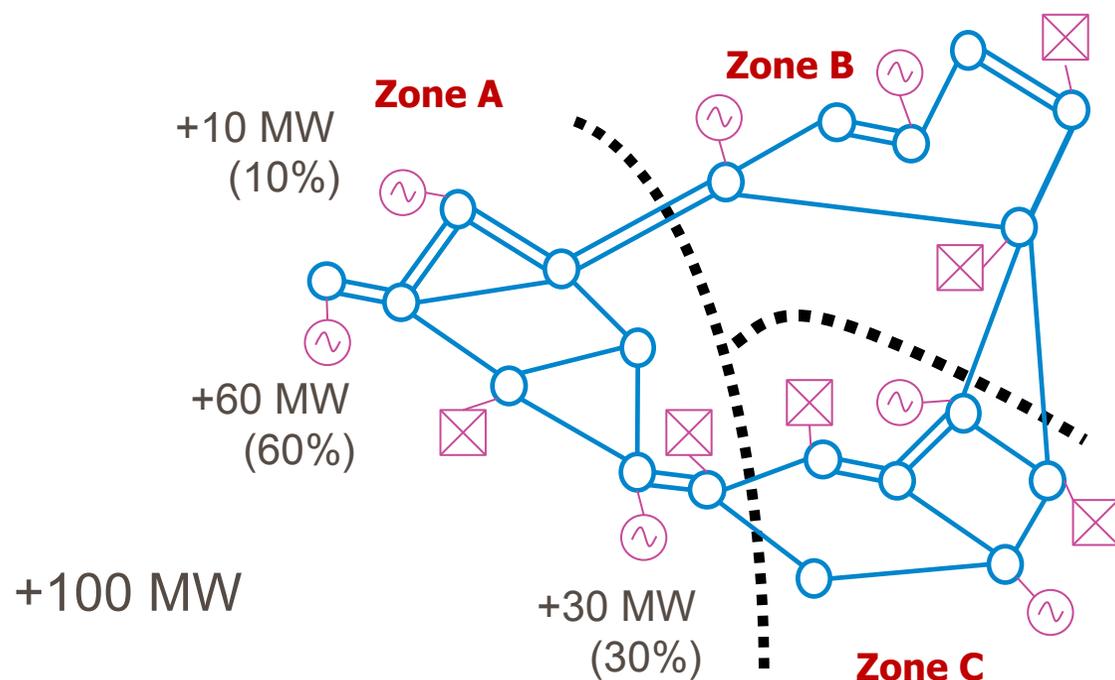




1. Inputs

Generation Shift Key (GSK)

- GSK defines how (in %) a change in net position is mapped to generating units of a bidding zone; used to translate the change in balance of one MW into a change on the equivalent generation of specific nodes of that area.
- The GSK values can vary for every hour and are given in dimensionless units. (A value of 0.05 for one unit means that 5% of the change of the net position of the hub will be realized by this unit).
- GSK is a necessary approximation of the real dispatch behavior. The approximation impact is mitigated by using best available forecasted net positions for CGM creation, such that GSK only covers the difference of the net position between forecast and market coupling result.





1. Inputs

External Constraints (EC)

Besides active power flow limits on Critical Network Elements, other specific limitations may be necessary to maintain the transmission system within operational security limits.

Such specific limitations cannot be efficiently transformed into maximum flows on individual Critical Network Elements

Therefore, they are expressed as import/export limits, i.e. maximum import and/or export of bidding zones.

These so-called **External Constraints** are determined by the TSOs and taken into account during the day-ahead market coupling in addition to the power flow limits on Critical Network Elements.

The usage of External Constraints is justified by several reasons, among which:

- Avoid market results which lead to stability problems in the network, detected by system dynamics studies;
- Avoid market results which are too far away from the reference flows going through the network in the D-2 CGM, and which in exceptional cases would induce extreme additional flows on grid elements, leading to a situation which could not be validated as safe by the concerned TSO during the validation step;
- Needs of a minimum level of operational reserve for balancing.

The External Constraints are regularly reviewed and potentially updated at least once a year.



1. Inputs

Remedial Actions (RA)

(1-4)

General Description

- During Flow Based parameters calculation Core TSOs will take into account Remedial Actions (RAs) in D-2 to optimize cross-zonal capacities while ensuring a secure power system operation
- Power flows can generally only be re-routed and hence a flow reduction on one CNEC automatically leads to an increase of flow on one or more CNECs
- The Remedial Action Optimization (RAO) performed in Core CCR aims at managing this trade-off, while modifying the shape of the flow-based domain in order to accommodate the expected market preferences

Remedial Actions

- Each Core TSO can define explicit RAs for DA FB CC, e.g.
 - Changing the tap position of a phase shifting transformer (PST). Affects the RAM of CNECs
 - Topological measure: opening or closing of one or more line(s), cable(s), transformer(s), bus bar coupler(s), or switching of one or more network element(s) from one bus bar to another. Affects the RAM and PTDF of CNECs
- In principle, all measures can be preventive (applied before an outage occurs and hence effective for all CNECs) or curative, i.e. for defined contingencies only.



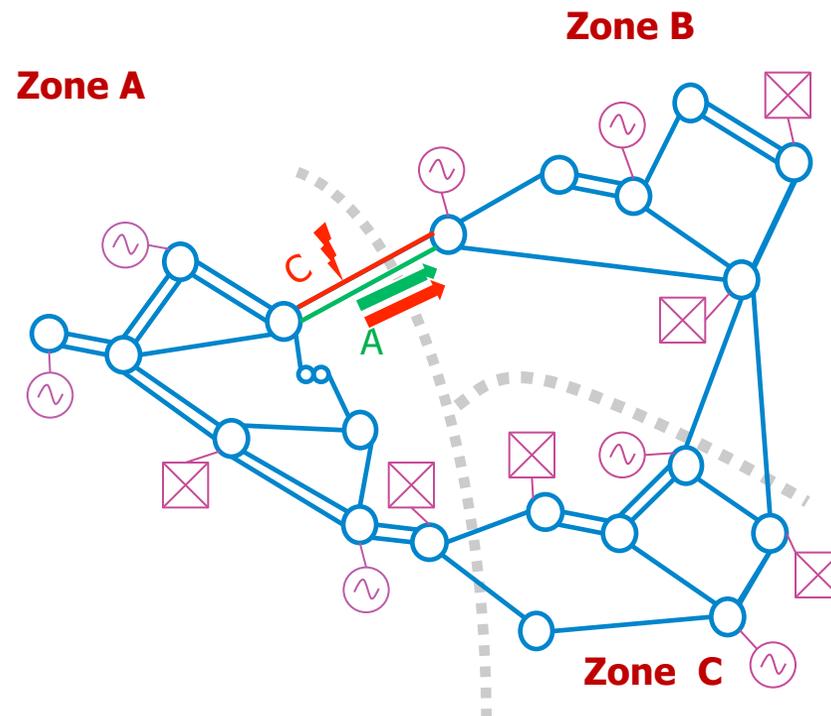
1. Inputs

Remedial Actions (RA)

(2-4)

Topological Measures

- Consider CNE A with contingency C
- Load on A would significantly increase, since the flow of C would be mainly distributed to A in case of outage of C





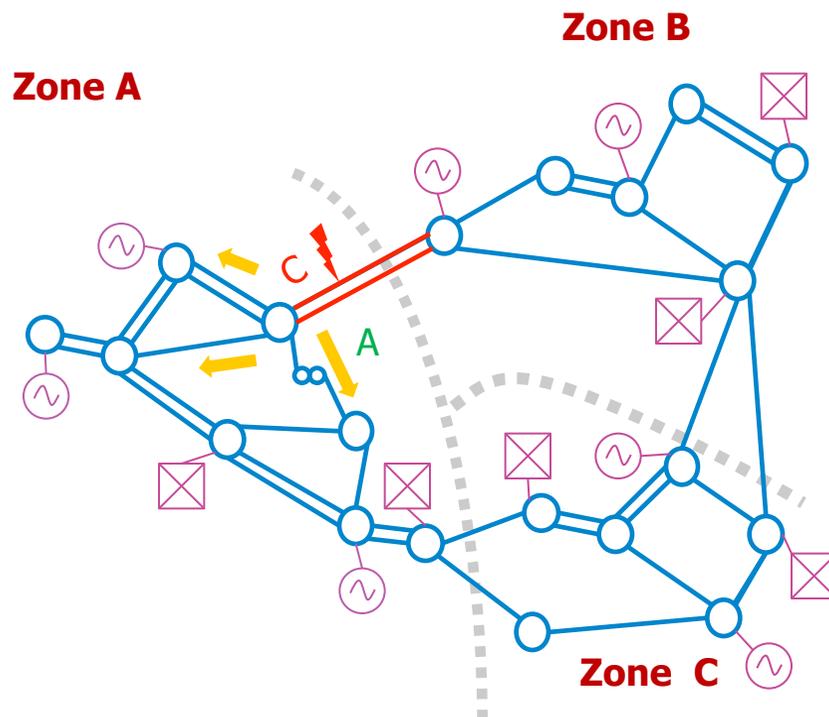
1. Inputs

Remedial Actions (RA)

(3-4)

Topological Measures

- Consider CNE A with contingency C
- Load on A would significantly increase, since the flow of C would be mainly distributed to A in case of outage of C
- Possible remedy: also switching off A, in order to avoid overloading. Flow is then distributed to other branches. It has to be ensured, that no overload on other CNEs is created.
- Switching of A in contingency situation C is called a curative topological measure





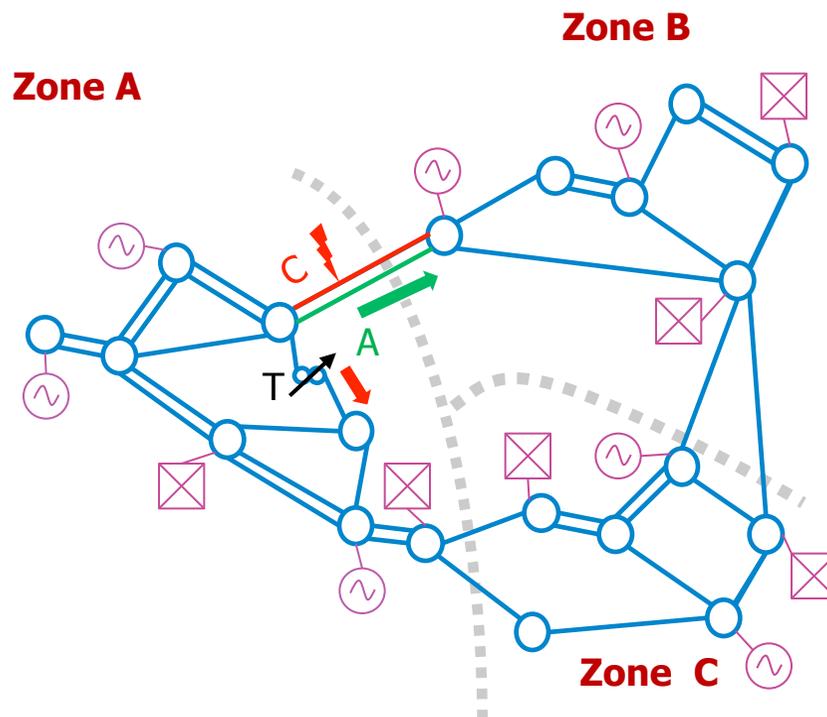
1. Inputs

Remedial Actions (RA)

(4-4)

Phase Shifting Transformers (PST)

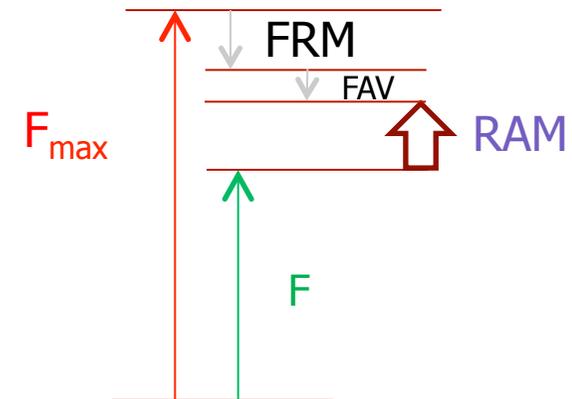
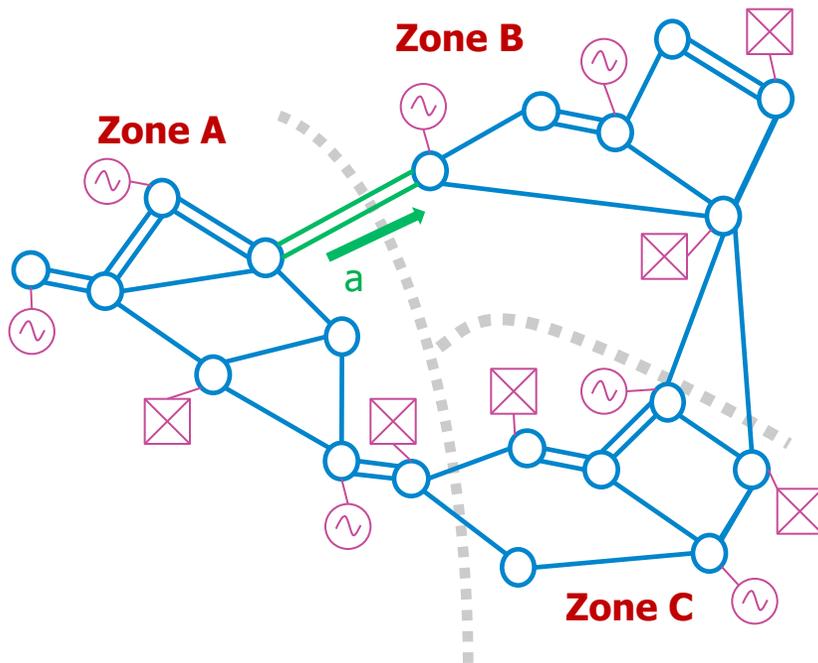
- Consider same situation: CNE A with contingency C
- The PST T nearby the CNEACC could be used to decrease the flow on CNEACC, while increasing the flow on the PST and all following branches. It has to be ensured, that no overload on other CNE(C)s is created
- This measure could be applied preventive (thus all CNE would be affected) or curative, after the contingency C realizes





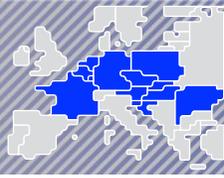
Mathematical description: RAM

(1-3)



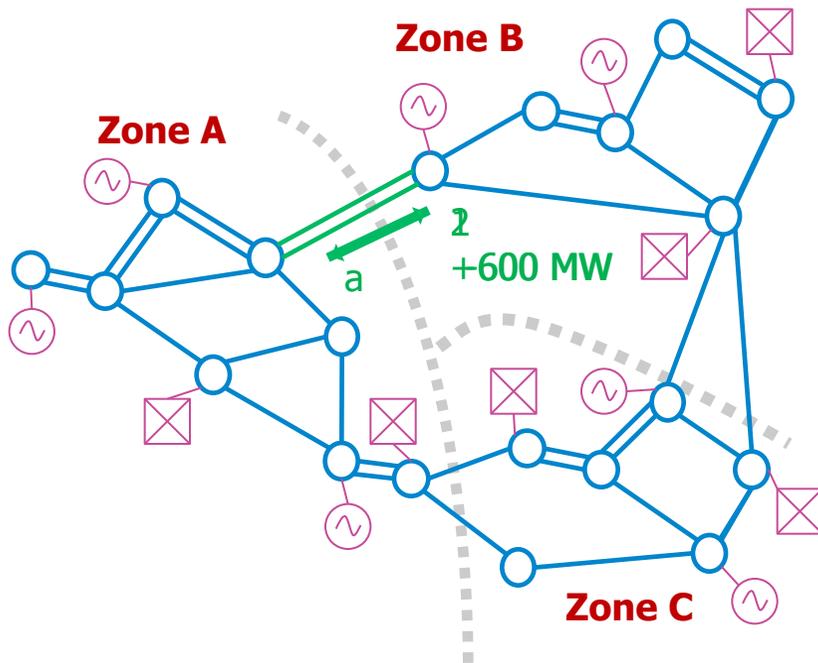
Legend

- ☒ Consumption node
- ⊖ Generation node
- ▬ Two parallel lines
- ▬ One line
- ▬ Monitored line
- - - Bidding zone border
- Electricity flow

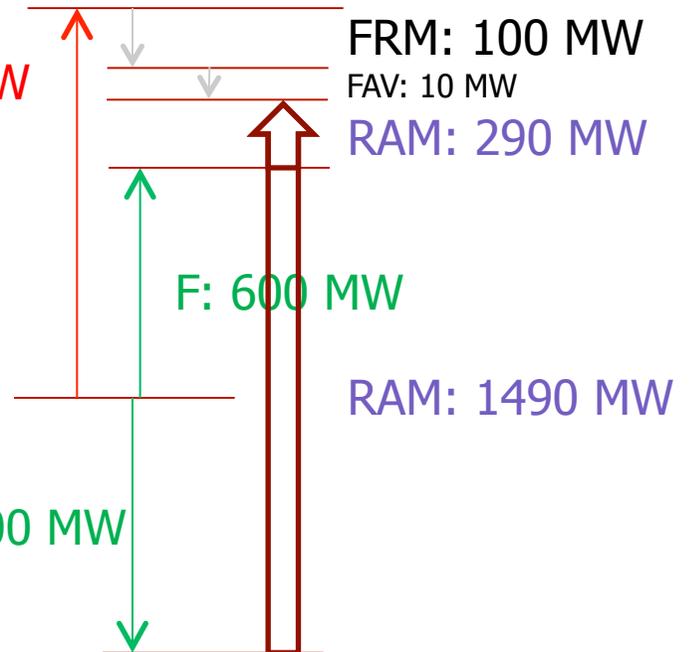


Mathematical description: RAM

(2-3)



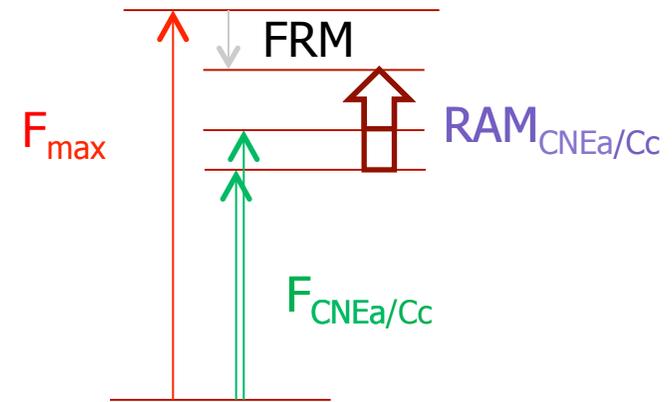
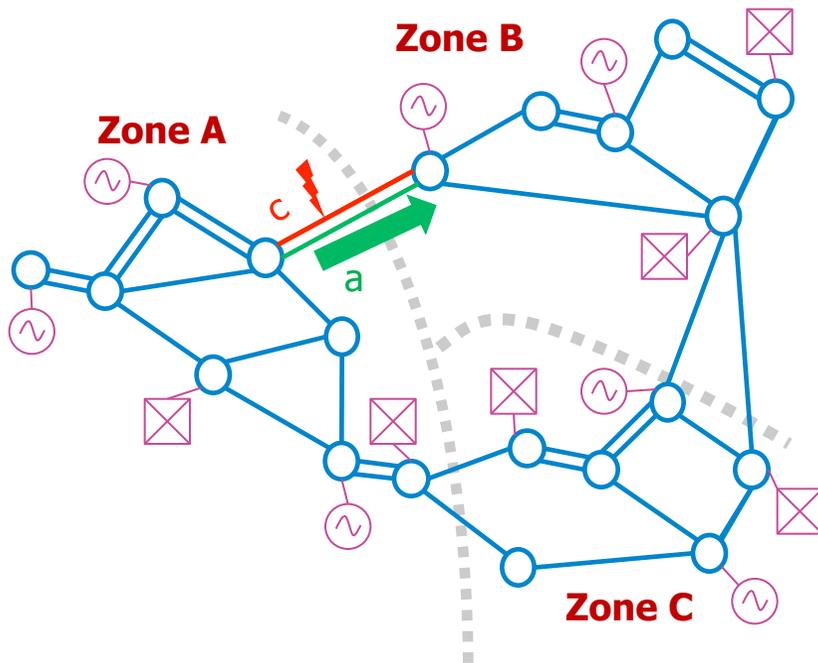
F_{max} : 1000 MW





Mathematical description: RAM

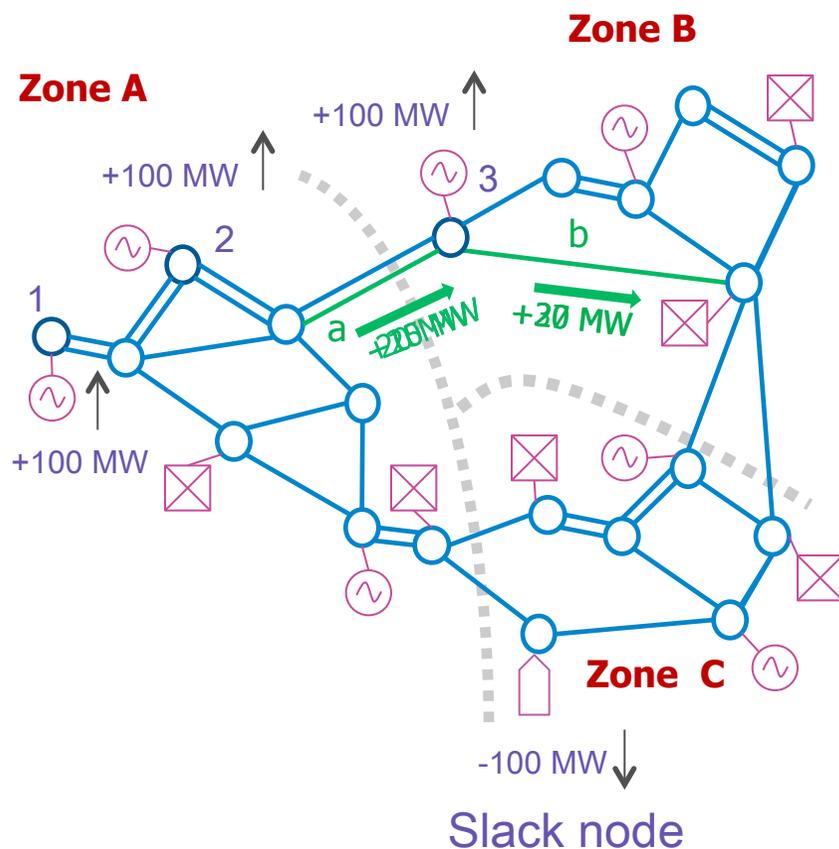
(3-3)





Mathematical description: nodal PTDF

(1-2)



$PTDF_{i,l}$	CB_a	CB_b
Node 1	15%	20%
Node 2	20%	27%
Node 3	-20%	30%

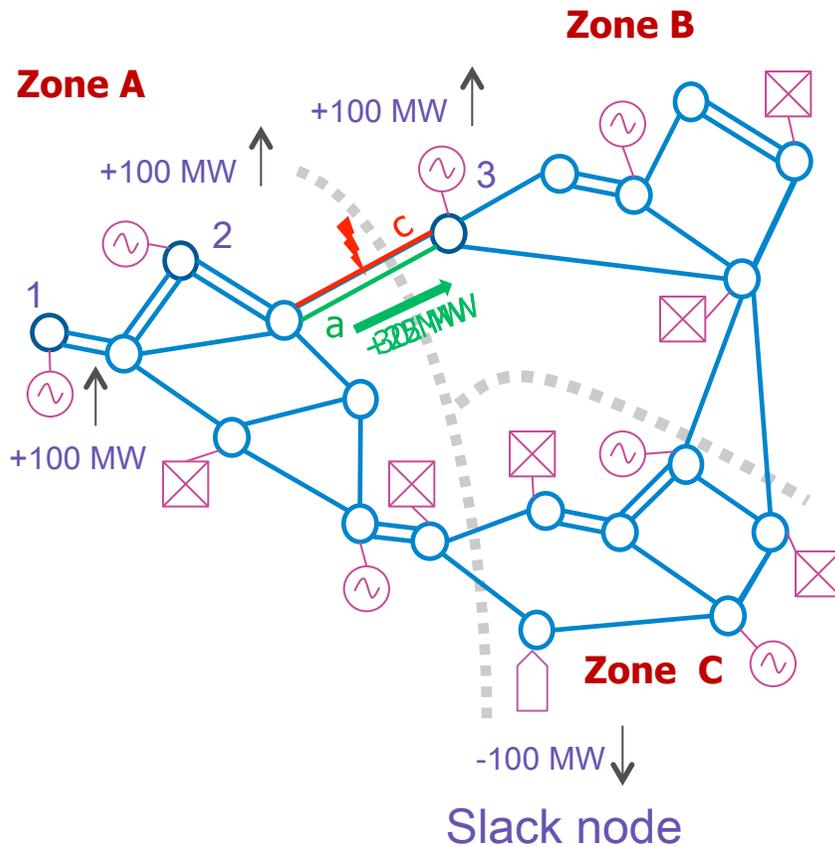
Legend

- **Slack node** – special virtual node that serves to balance active/reactive power



Mathematical description: nodal PTDF

(2-2)

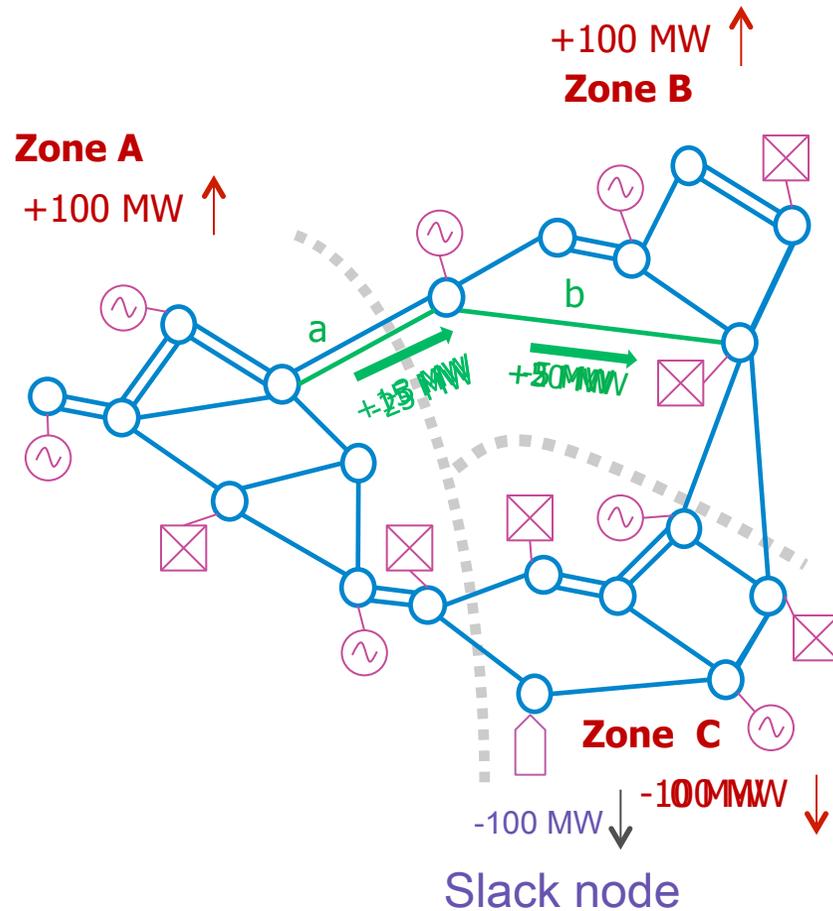


$PTDF_{i,l}$	CB_a	CB_b	CB_a/CO_c
Node 1	15%	20%	22%
Node 2	20%	27%	25%
Node 3	-20%	30%	-30%

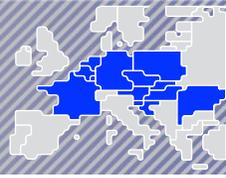


2. Capacity calculation approach

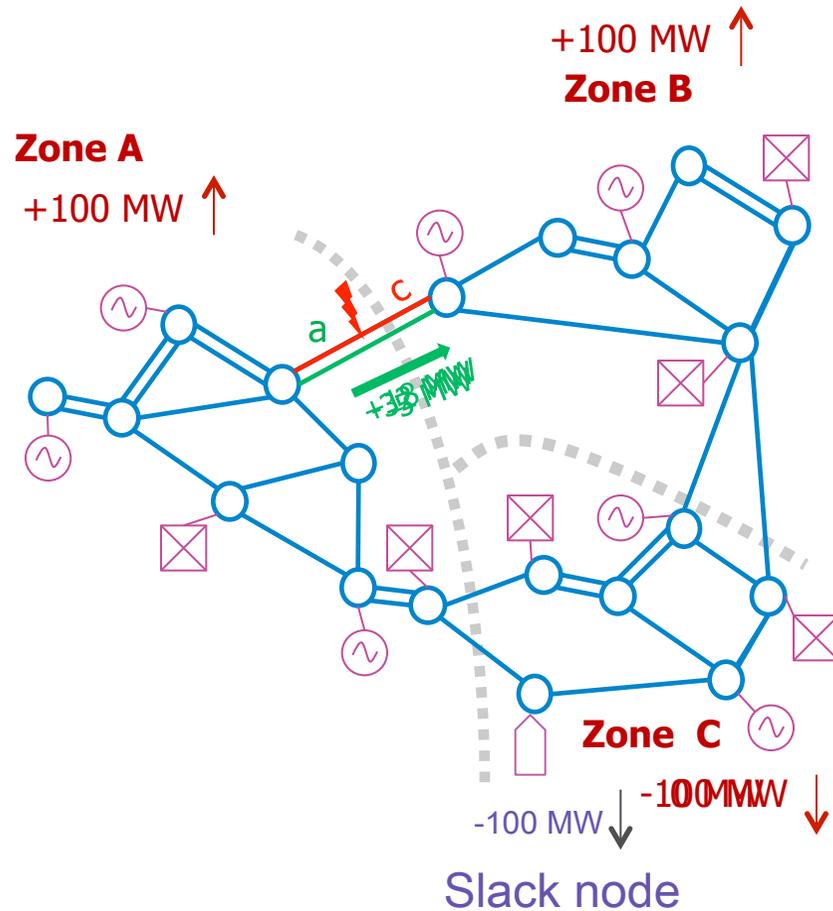
Mathematical description: zone-to-slack PTFDF (1-2)



$PTDF_{z,l}$	CB_a	CB_b	CB_a/CO_c
Zone A	15%	20%	
Zone B	-25%	5%	
Zone C	-3%	-5%	



Mathematical description: zone-to-slack PTFDF (2-2)

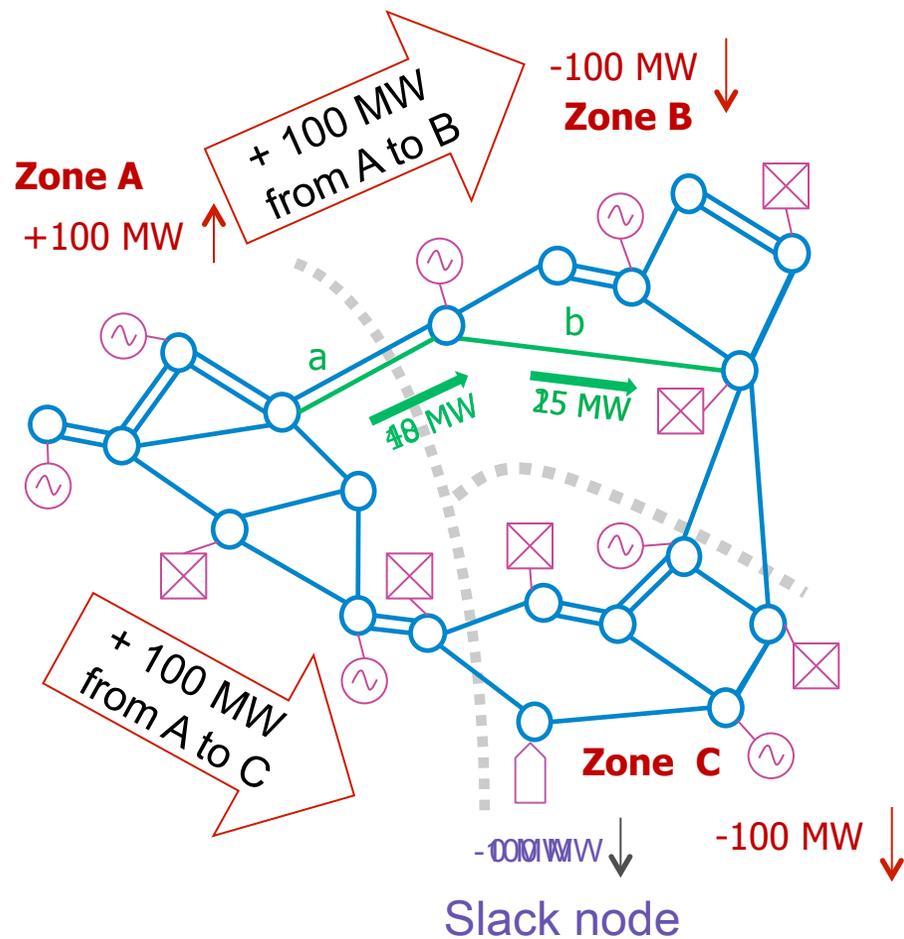


$PTDF_{z,l}$	CB_a	CB_b	CB_a/CO_c
Zone A	15%	20%	18%
Zone B	-25%	5%	-32%
Zone C	-3%	-5%	-5%

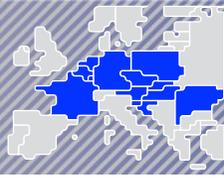


2. Capacity calculation approach

Mathematical description: zone-to-zone PTDF (1-3)

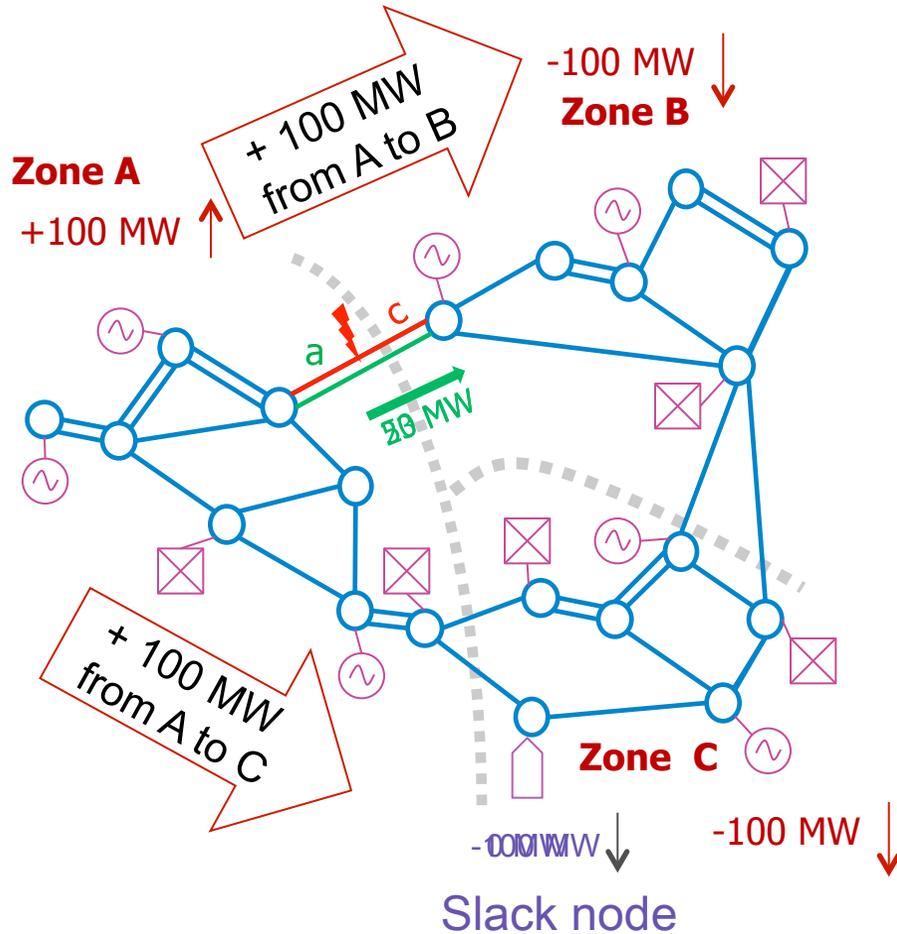


$PTDF_{z1 \rightarrow z2, l}$	CB_a	CB_b	CB_a/CO_c
Exchange A \rightarrow B	40%	15%	
Exchange A \rightarrow C	18%	25%	

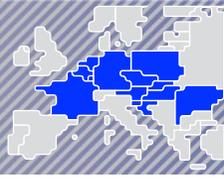


2. Capacity calculation approach

Mathematical description: zone-to-zone PTFDF (2-3)

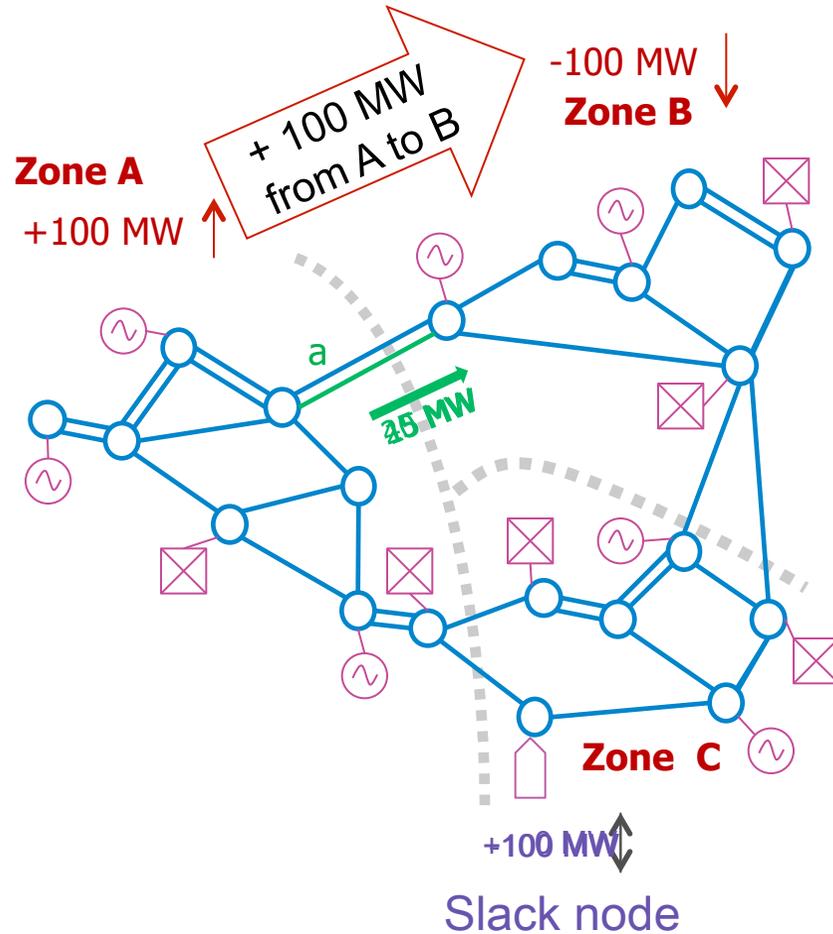


$PTDF_{z1 \rightarrow z2, l}$	CB_a	CB_b	CB_a/CO_c
Exchange A \rightarrow B	40%	15%	50%
Exchange A \rightarrow C	18%	25%	23%



2. Capacity calculation approach

Mathematical description: zone-to-zone PTDF (3-3)



$$\begin{aligned} \text{PTDF}_{A \rightarrow B, a} &= \text{PTDF}_{A, a} - \text{PTDF}_{B, a} \\ &= 15\% - (-25\%) \\ &= 40\% \end{aligned}$$



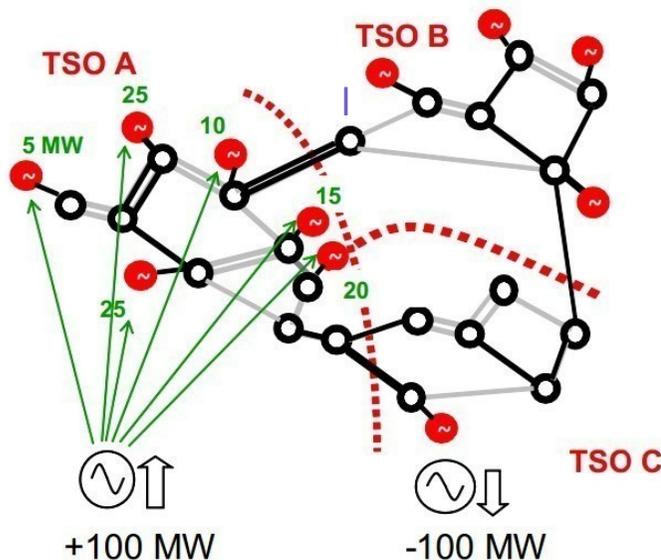
2. Capacity calculation approach

Mathematical description: GSK

- GSKs coefficients translate the nodal PTDFs into zonal PTDFs by distributing zonal variations on the generating nodes:

$$\begin{array}{c} \boxed{\text{Zonal PTDF}} \\ \begin{bmatrix} A_{1 \rightarrow 2}^A & \dots & A_{1 \rightarrow 2}^Z \\ \vdots & & \vdots \\ A_{l \rightarrow m}^A & \dots & A_{l \rightarrow m}^Z \end{bmatrix} \end{array} = \begin{array}{c} \boxed{\text{Nodal PTDF}} \\ \begin{bmatrix} \alpha_{\text{line } 1 \rightarrow 2}^{\text{node } 1} & \dots & \alpha_{\text{line } 1 \rightarrow 2}^{\text{node } q} \\ \vdots & & \vdots \\ \alpha_{\text{line } l \rightarrow m}^{\text{node } 1} & \dots & \alpha_{\text{line } l \rightarrow m}^{\text{node } q} \end{bmatrix} \end{array} \cdot \begin{array}{c} \boxed{\text{GSK}} \\ \begin{bmatrix} gsk_{\text{node } 1}^{\text{zone } A} & \dots & gsk_{\text{node } 1}^{\text{zone } Z} \\ \vdots & & \vdots \\ gsk_{\text{node } q}^{\text{zone } A} & \dots & gsk_{\text{node } q}^{\text{zone } Z} \end{bmatrix} \end{array}$$

Example:





2. Capacity calculation approach

Mathematical description: FB matrix

(1-11)

$$\text{Flow}_{\text{commercial allocation}} = \text{NP}_{\text{Belgium}} \times \text{PTDF}_{\text{Belgium}} + \text{NP}_{\text{Germany}} \times \text{PTDF}_{\text{Germany}} + \text{NP}_{\text{France}} \times \text{PTDF}_{\text{France}} + \text{NP}_{\text{Netherlands}} \times \text{PTDF}_{\text{Netherlands}}$$

$$\text{Flow}_{\text{commercial allocation}} < \text{RAM}$$

Example:

CNEC	RAM	BE	DE	FR	NL
101	1208	6,7%	-11,8%	-6,6%	-13,8%
102	1024	7,7%	-11,5%	-15,8%	-7,5%
103	1175	-3,2%	-19,3%	-32,5%	-11,5%
104	724	-5,6%	14,9%	6,1%	18,8%
105	887	15,8%	0,9%	-7,1%	7,0%
106	836	-11,6%	-16,0%	-25,6%	-9,7%
107	452	4,3%	-4,8%	-5,7%	-2,2%
108	1522	5,8%	-15,4%	-6,3%	-19,4%
109	1093	1,9%	12,9%	6,6%	32,5%



2. Capacity calculation approach

Mathematical description: FB matrix

(2-11)

$$NP_{\text{Germany}} = NP_{\text{France}} = 0$$

$$NP_{\text{Belgium}} = \frac{\text{RAM}}{\text{ptdf}_{\text{Belgium}}} - \frac{\text{ptdf}_{\text{Netherlands}}}{\text{ptdf}_{\text{Belgium}}} \times NP_{\text{Netherlands}}$$

Example:

CNEC	RAM	BE	DE	FR	NL
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109	1093	1,9%	12,9%	6,6%	32,5%

$$NP_{\text{Belgium}} = \frac{1208}{0.067} - \frac{-0.138}{0.067} \times NP_{\text{Netherlands}}$$

$$NP_{\text{Blg}} = \frac{1208}{0.067} - \frac{-0.138}{0.067} \times NP_{\text{nth}}$$



2. Capacity calculation approach

Mathematical description: FB matrix

(3-11)

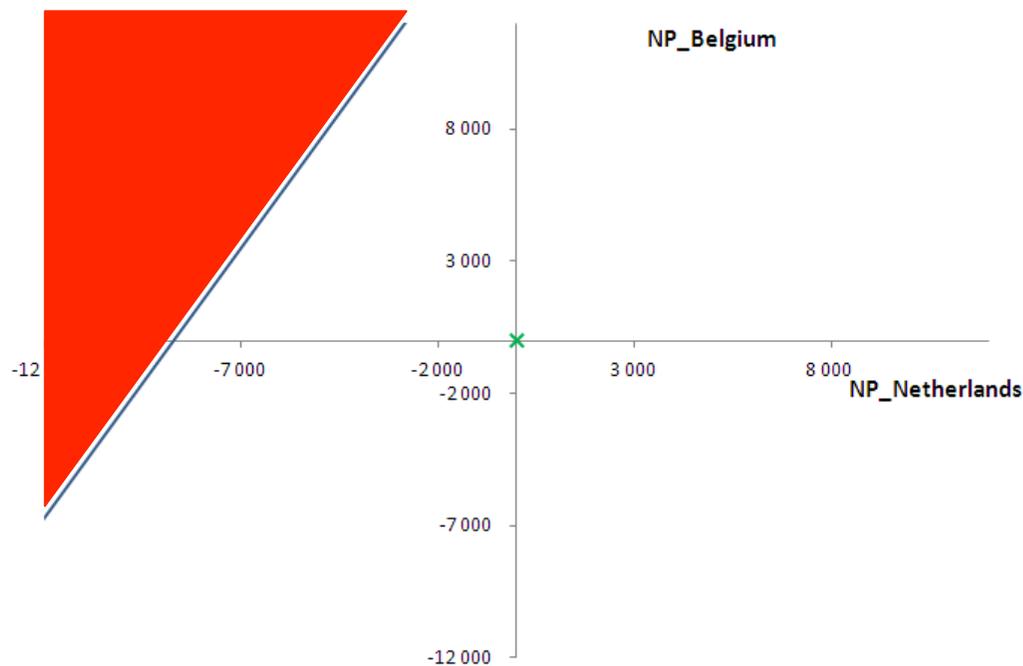
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Non-secure domain





2. Capacity calculation approach

Mathematical description: FB matrix

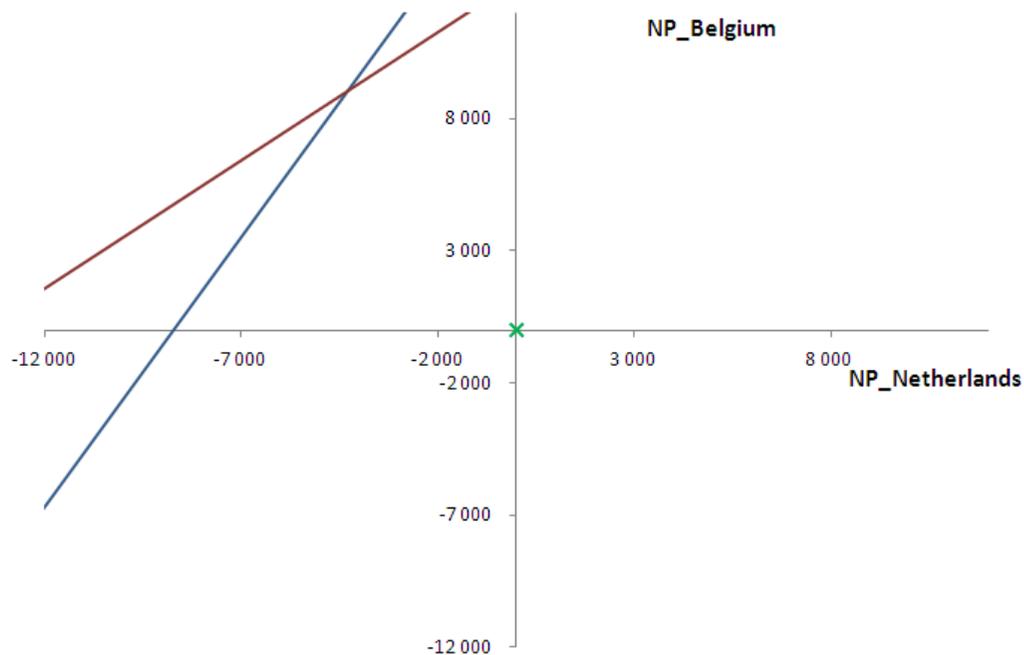
(4-11)

$$NP_{\text{Germany}} = NP_{\text{France}} = 0$$

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2. Capacity calculation approach

Mathematical description: FB matrix

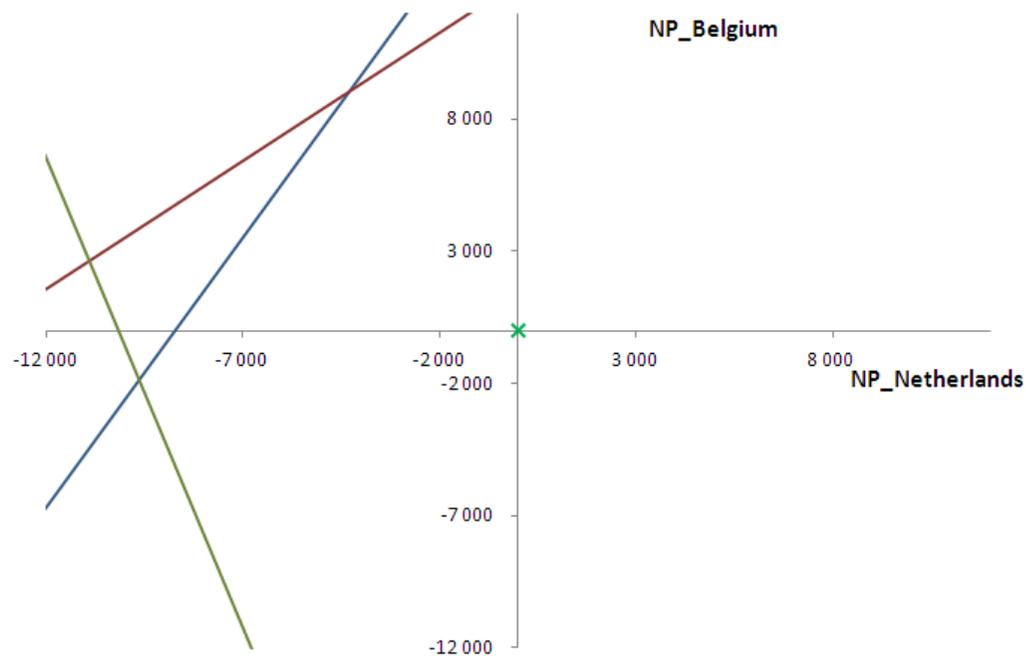
(5-11)

$$NP_{\text{Germany}} = NP_{\text{France}} = 0$$

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2. Capacity calculation approach

Mathematical description: FB matrix

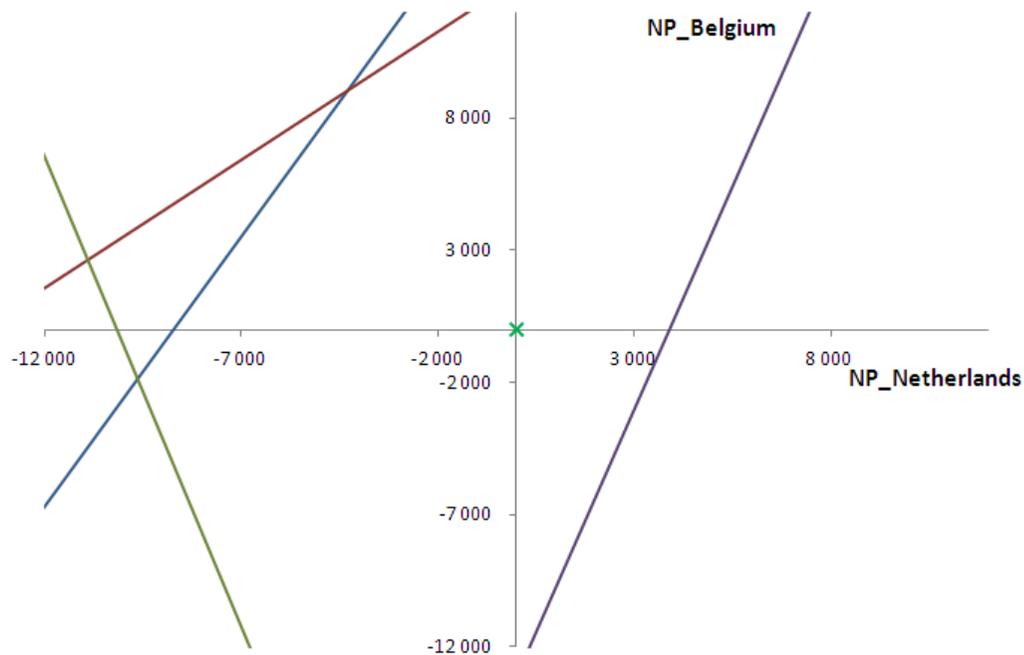
(6-11)

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2. Capacity calculation approach

Mathematical description: FB matrix

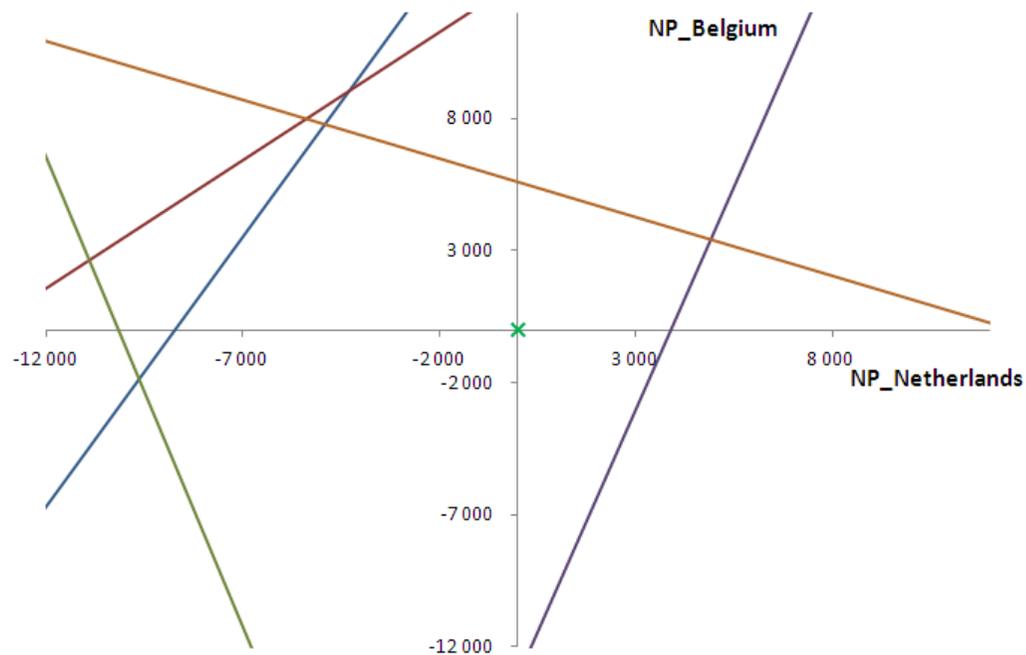
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Mathematical description: FB matrix

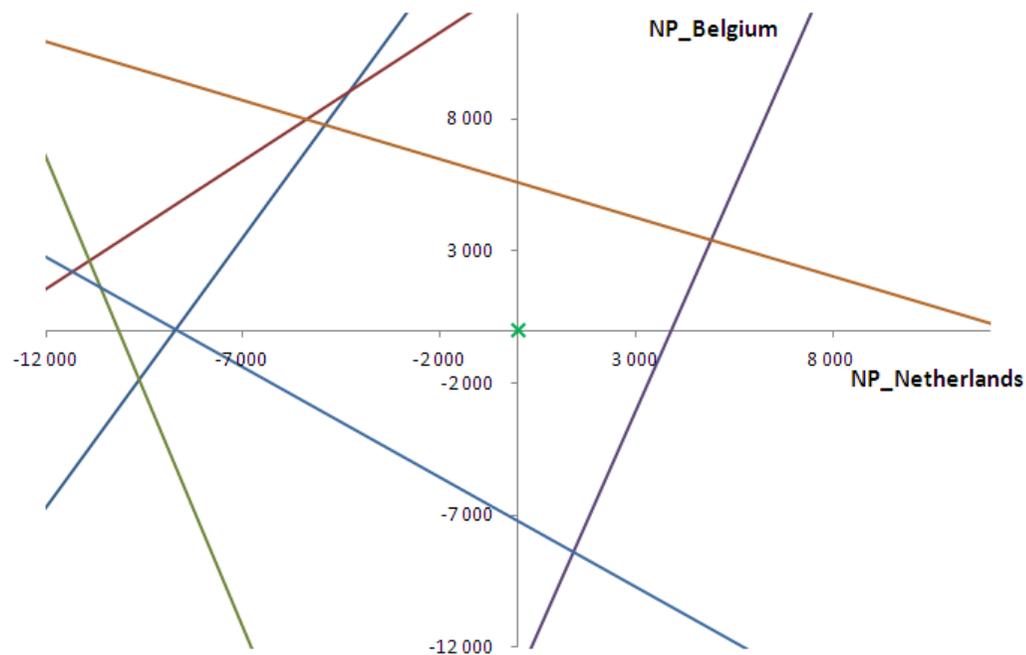
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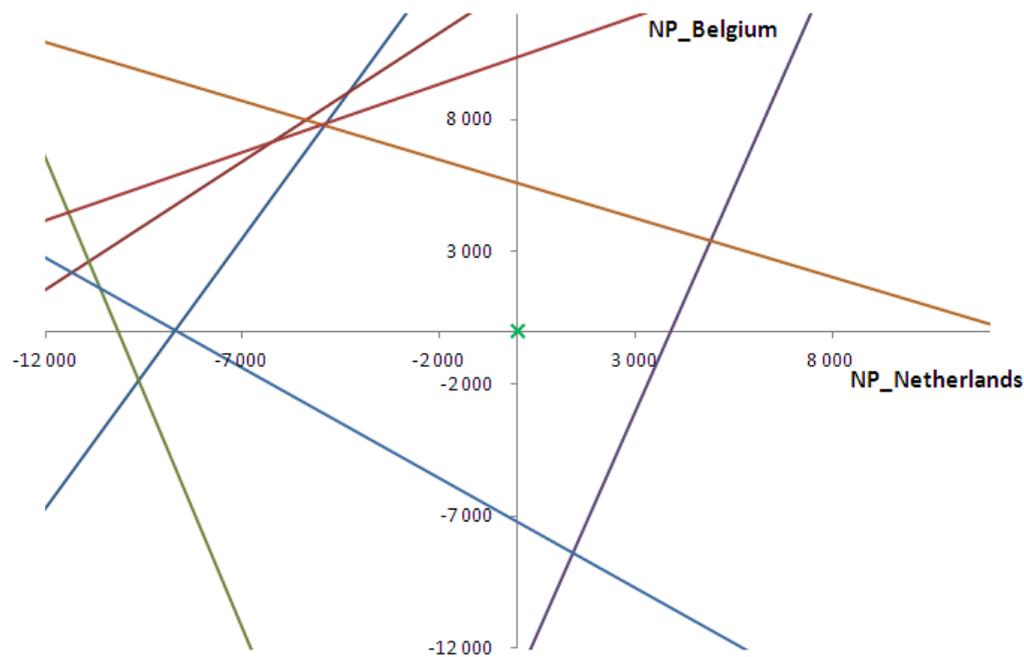
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Mathematical description: FB matrix

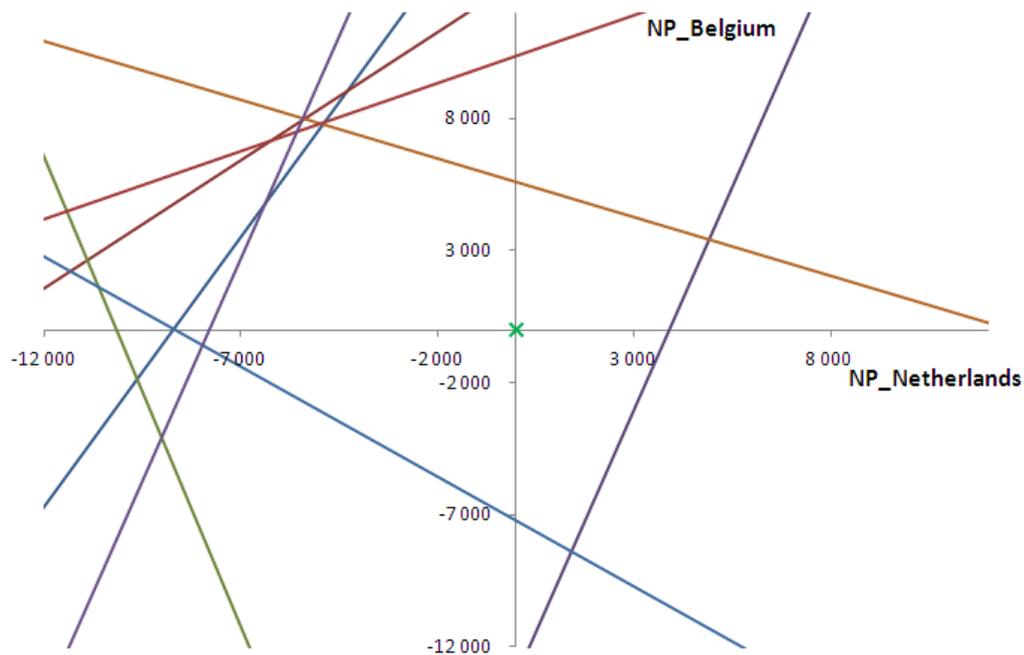
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2. Capacity calculation approach

Mathematical description: FB matrix

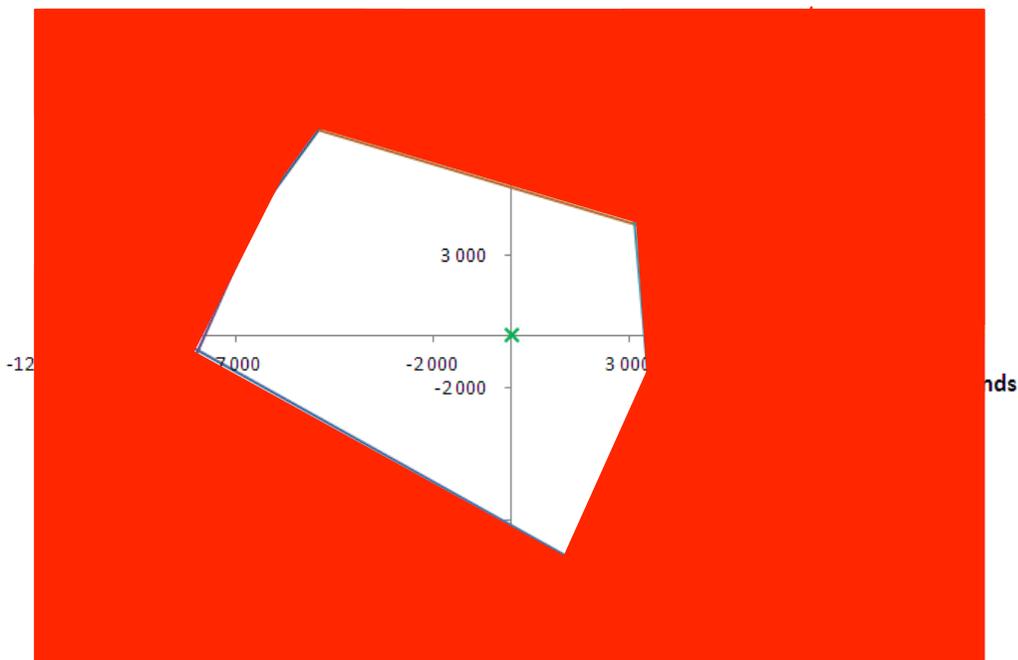
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2. Capacity calculation approach

(1-5)

STEP 1: Creation of CNE and Contingency combinations

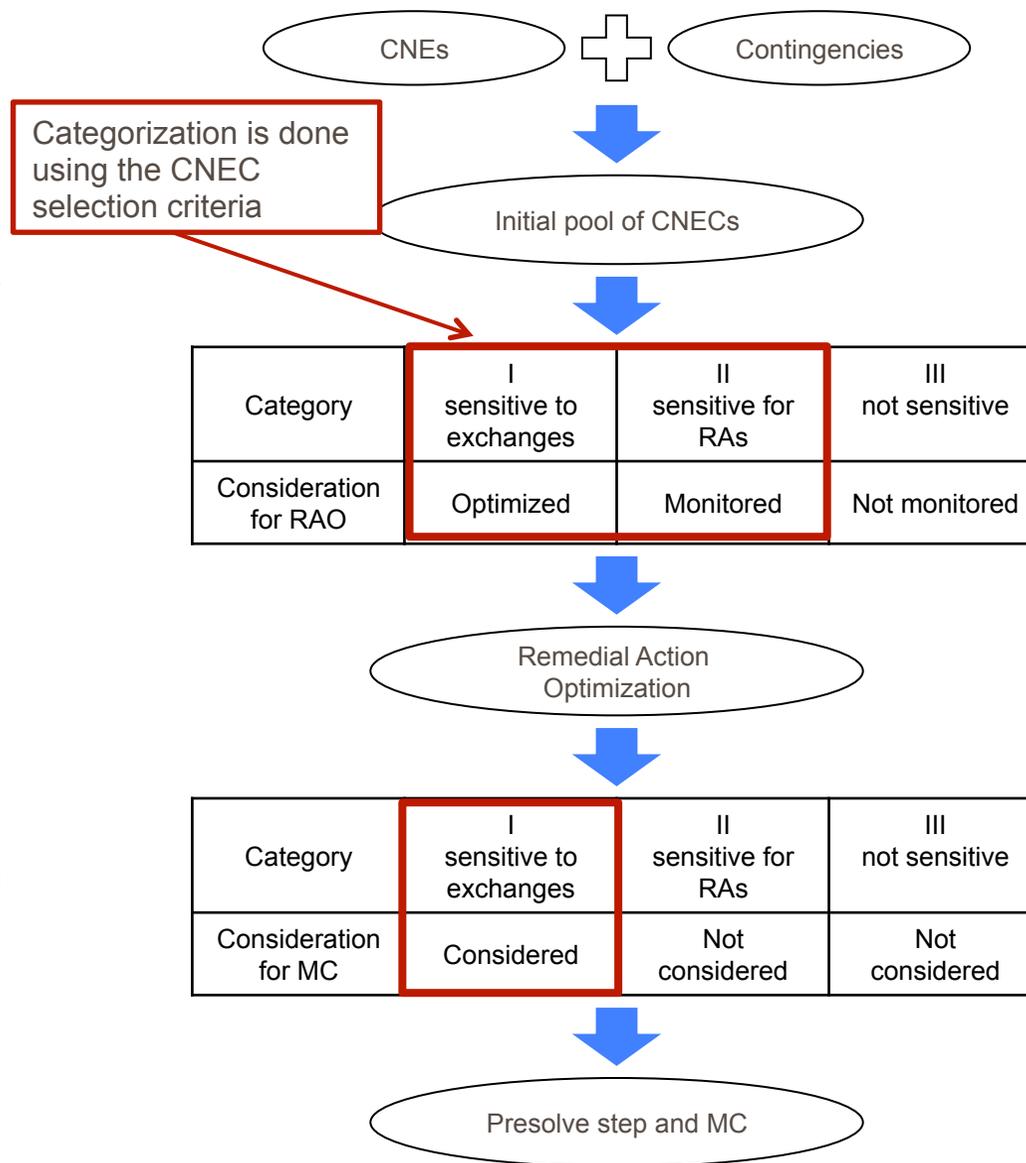
- Each TSO creates a list of CNEs and Contingencies (not CNECs yet) to be monitored during the RAO process or DA MC

STEP 2: Selection of CNECs for RA optimization

- Contingencies within a TSOs grid or observability area will be associated to a TSO's CNEs (criteria to be aligned with future SO GL)
- Initial pool of CNECs divided in three categories:
 - I: CNECs which are sensitive to cross border exchanges (threshold still to be determined).
 - II: CNECs which are not highly sensitive to cross border exchanges, but are significantly impacted by certain RAs.
 - III: CNECs which are neither highly sensitive to cross border exchanges nor impacted by certain RAs.
- CNECs from cat I and II are considered for RAO

STEP 3: Selection of the final constraints for regional market coupling

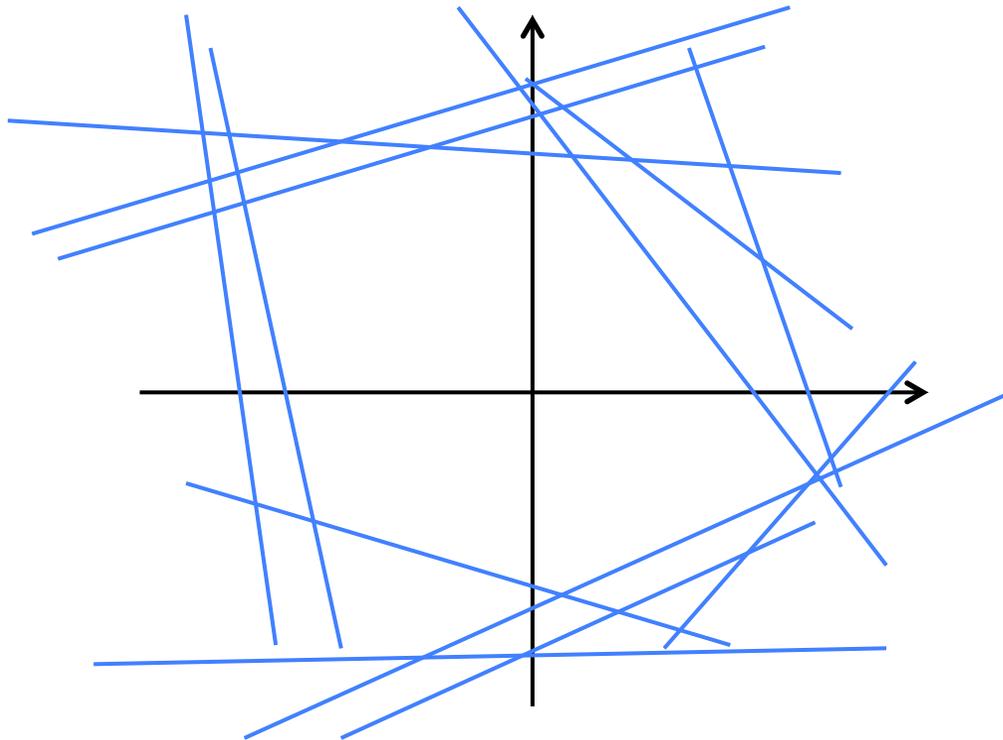
- After the RAO, the RAs will be applied on all CNECs and the CNECs will be again divided up into the 3 categories mentioned above.
- Only CNECs passing the CNEC selection criteria will be withheld for MC



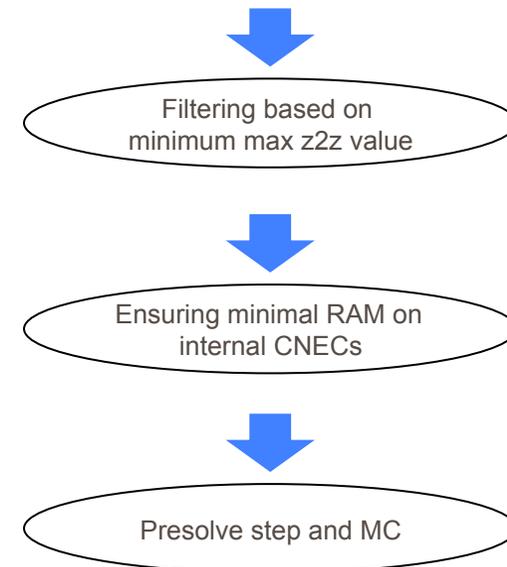


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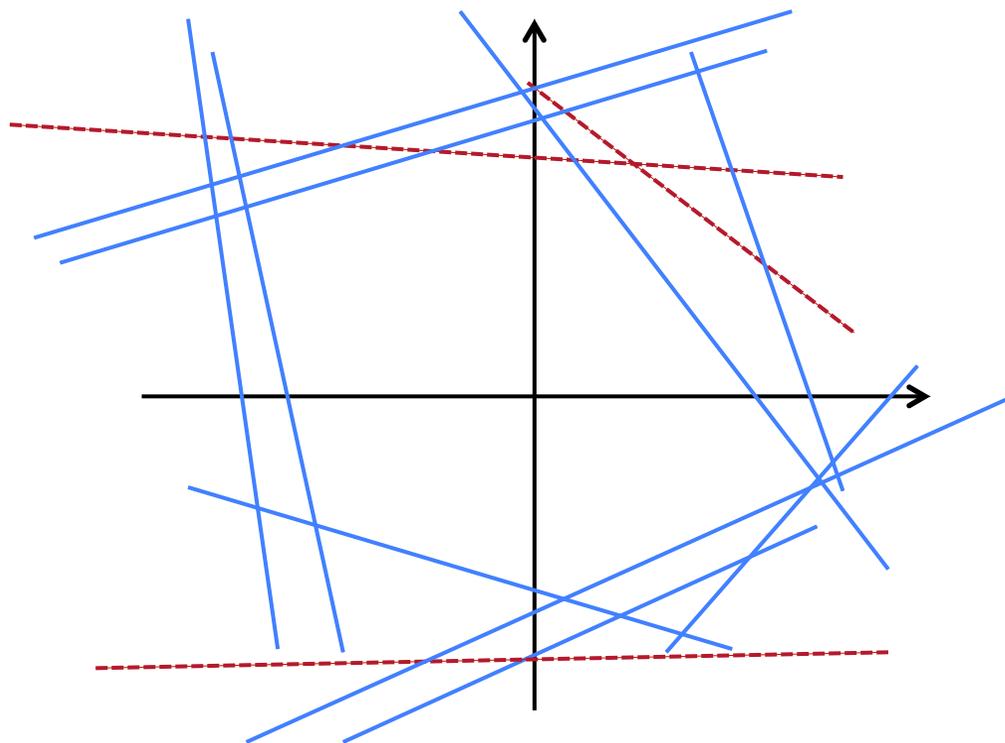
Category	I sensitive to exchanges	II sensitive for RAs	III not sensitive
Consideration for MC	Considered	Not considered	Not considered





STEP 3: Selection of the final constraints for regional market coupling

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Category	I sensitive to exchanges	II sensitive for RAs	III not sensitive
Consideration for MC	Considered	Not considered	Not considered



Step 1	Zone-to-zone PTDF		
	A→B	C→D	E→F
CNEC ₁	2 %	8 %	6 %
CNEC ₂	1 %	3 %	2 %
CNEC ₃	12 %	10 %	4 %

Example: threshold x=5 %

CNEC₂ not considered for MC

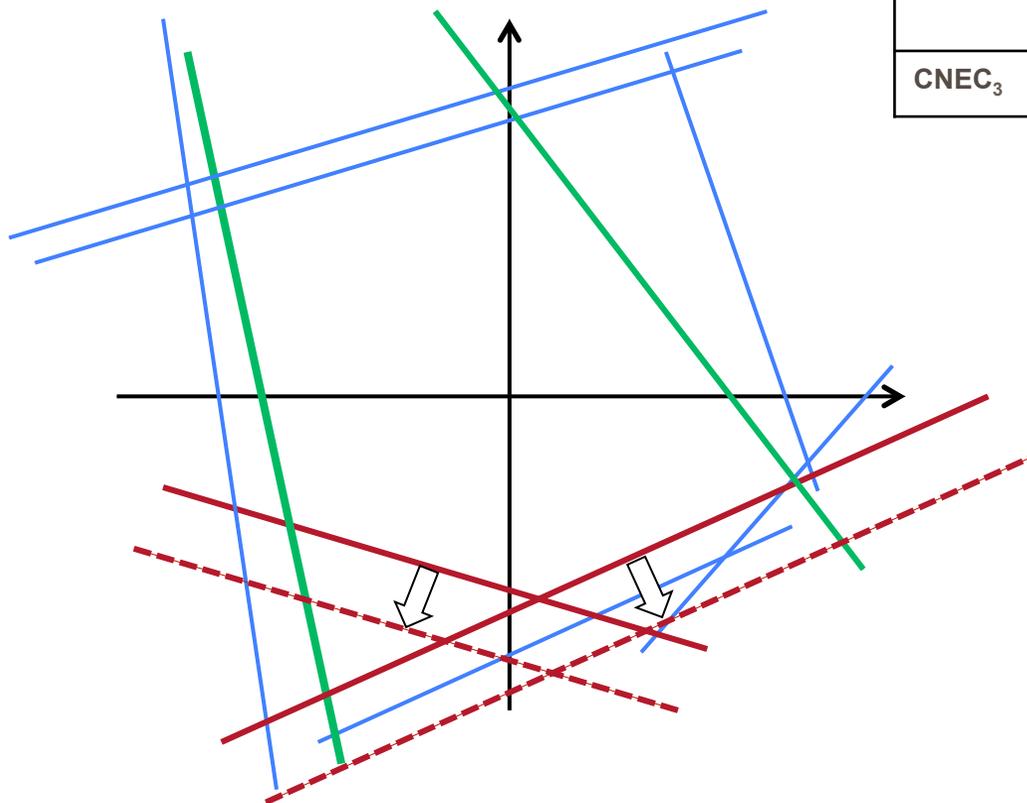


STEP 3: Selection of the final constraints for regional market coupling

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Step 2	Zone-to-zone PTDF			RAM in % of F_{max}	
	A→B	C→D	E→F	initial	final
CNEC ₁	2 %	8 %	6 %	8 %	10 %
CNEC ₃	12 %	10 %	4 %	15 %	15 %

RAM increased (example: threshold $y=10\%$)



Ensuring minimal RAM on internal CNECs

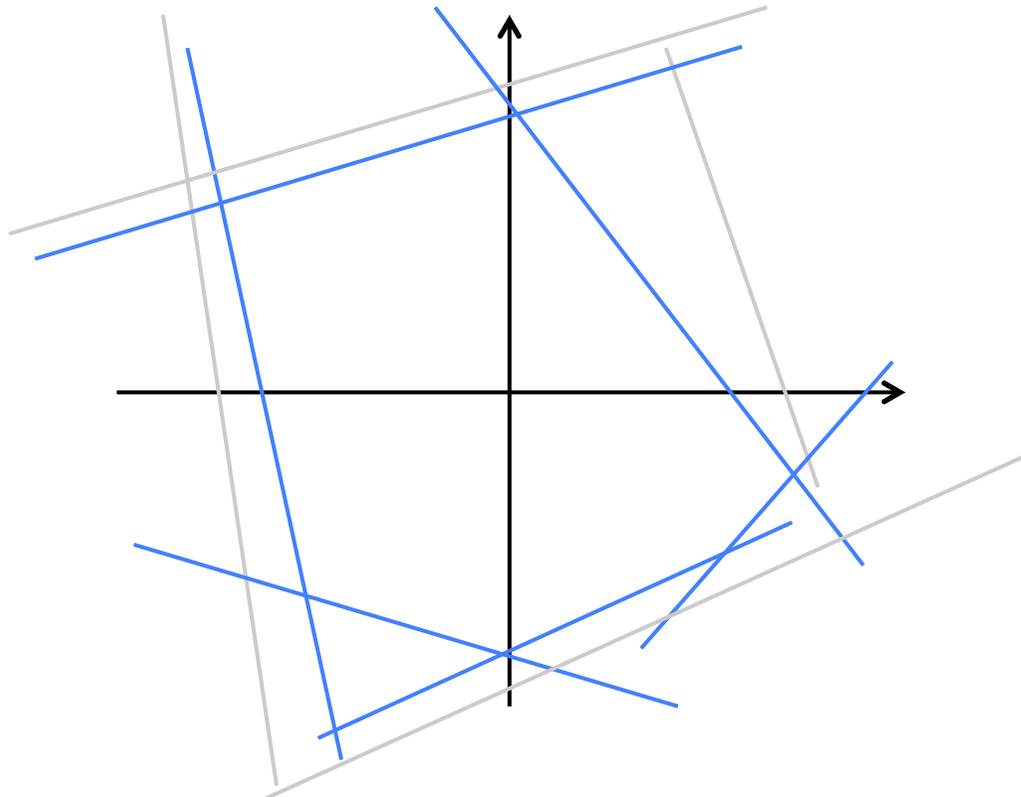
No change for cross border lines even if the RAM is below $Y\%$

RAM increase to $Y\%$ for internal lines

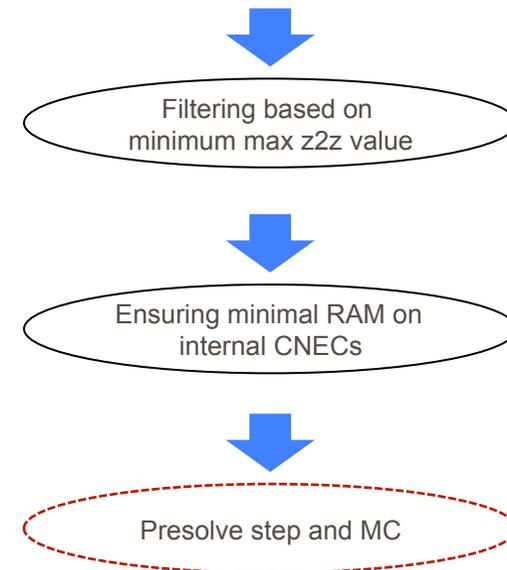


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Category	I sensitive to exchanges	II sensitive for RAs	III not sensitive
Consideration for MC	Considered	Not considered	Not considered





2. Capacity calculation approach

During upcoming Core Experimentation (until Sep 2017), the CNEC selection study shall prepare the decision on CNEC Selection rules and criteria to be adopted in the Core DA FB Approval Package.

In this study, Core TSOs will investigate the feasibility of a 2-step CNEC selection approach:

CWE
stats quo

Step 1: Filtering, i.e. deciding which CNECs are taken into consideration

- Cross-zonal CNECs: always considered
- Internal CNECs: max. zone-to-zone PTDF < x %
→ CNEC is not considered for MC (i.e. any overloading due to MC is accepted)

New

Step 2: Ensuring minimum margin for MC

- Cross-zonal CNECs: no adjustment
- Internal CNECs: If computed RAM < y % of Fmax, it is increased to y % of Fmax
→ limited extent of overloading is accepted

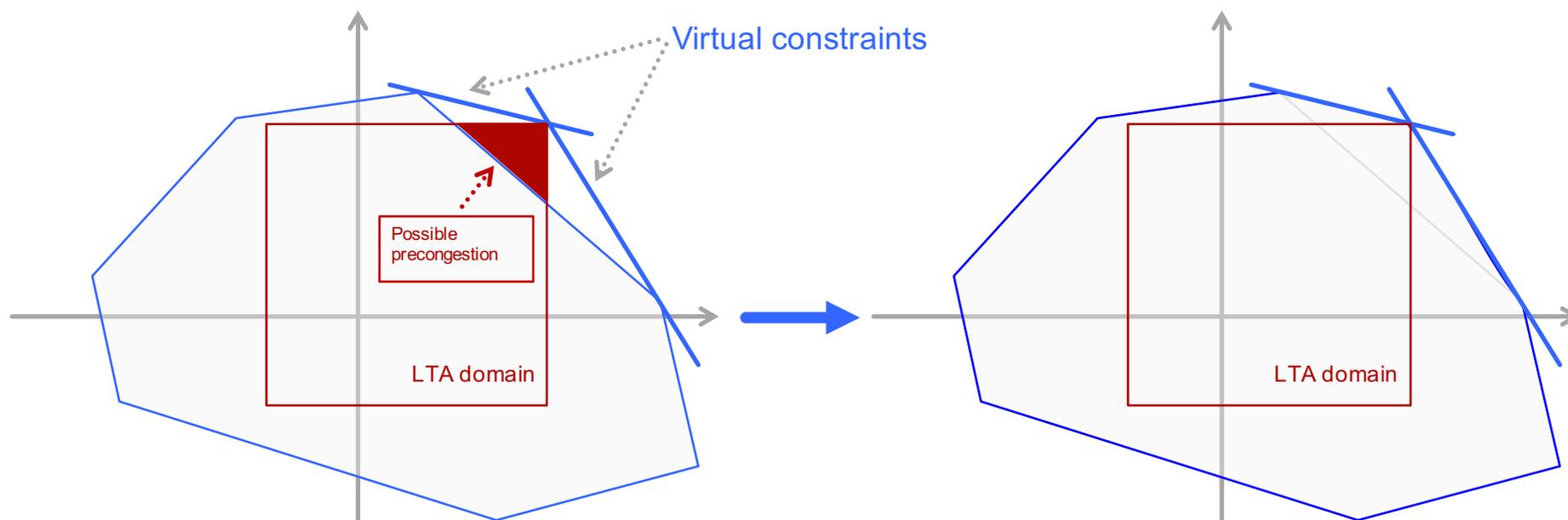


2. Capacity calculation approach

LTA Inclusion

In case the LTA values (calculated in a coordinated manner) are not fully covered by the flow-based domain, a method called “LTA inclusion algorithm” is applied in two steps.

The first step is to increase the *RAM* of limiting CNEs using the *FAV* concept until a certain threshold value, if desired by the respective TSO. If this is not sufficient, a second step consists in creating virtual constraints and replacing the CNEs or CNECs for which the RAM_i is negative.





II. CAPACITY CALCULATION PROCESS

1. Creation of a common grid model

- Forecast of net positions
- Individual Grid Model (IGM)
- Common Grid Models (CGM)

2. Regional calculation of cross-zonal capacity

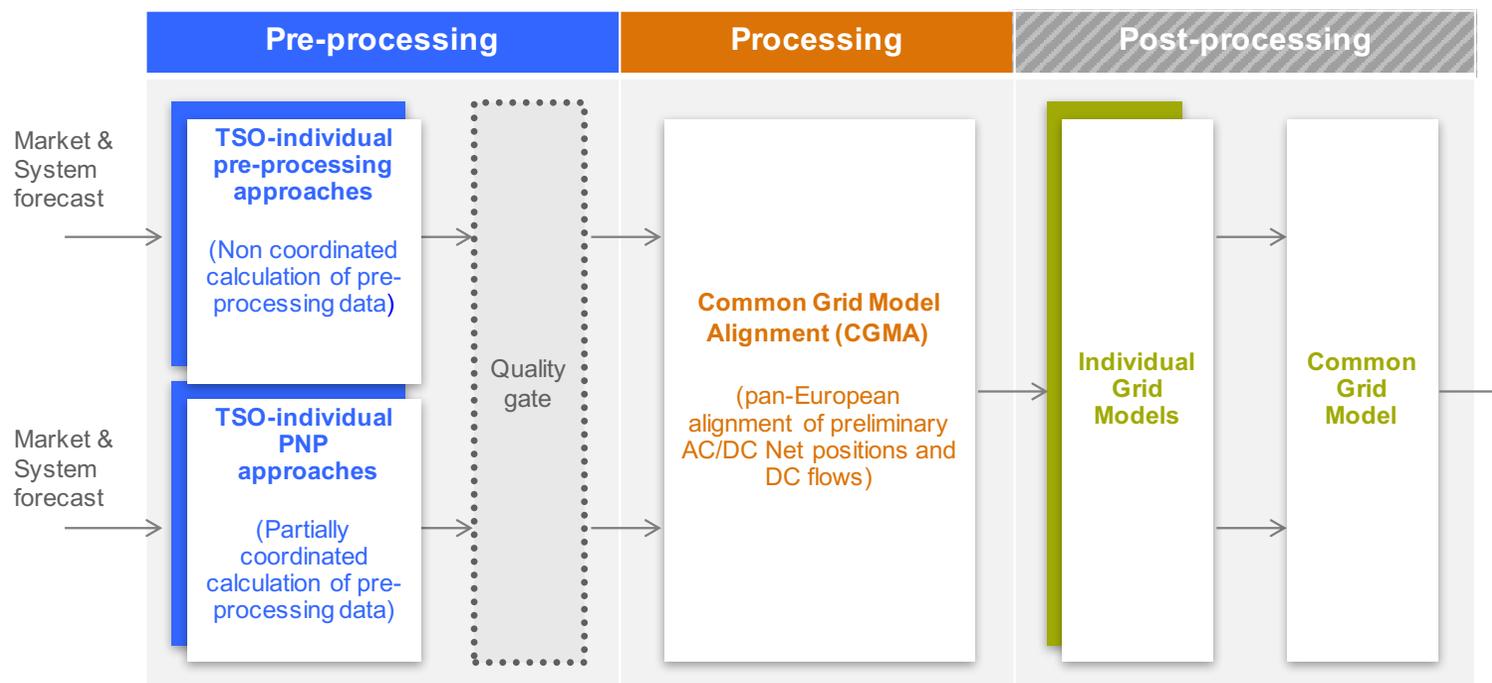
- Optimisation of cross-zonal capacity using RAs
- Calculation of the final flow-based domain

3. Back-up & Fallback processes

- Backups and replacement process
- Fallback flow-based parameters
- ATC for Shadow Auctions



Forecasting of net positions



Pre-Processing Data (PPD) of CGMA are based on either an individually or regionally coordinated forecast. Basically the coordinated approach shall yield a better indicator about the final Net Position (NP) than an individual forecast. Therefore, TSOs in Core CCR agreed to prepare the PPD in a coordinated way.

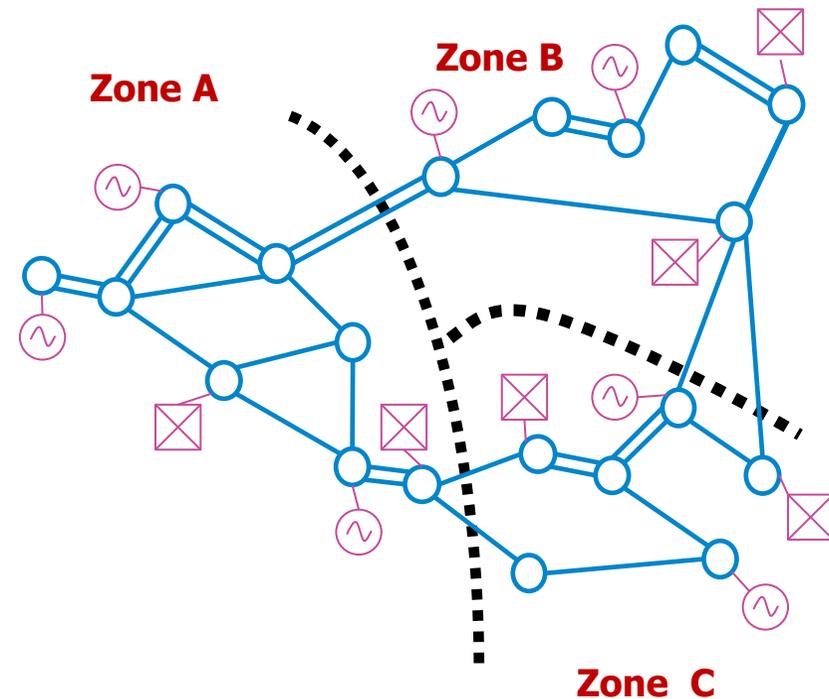


Individual Grid Model

All TSOs develop scenarios for each market time unit and establish the IGM. This means that Core TSOs create hourly D-2 IGMs for each day. The scenarios contain structural data, topology, and forecast of:

- Intermittent generation;
- Load;
- Dispatchable generation;
- Flows on direct current lines.

Before performing the merging process, IGMs are adjusted to match the Balanced Net Positions and Balanced flows on DC links according to the result of CGMA. For this purpose the GSKs are used.





Common Grid Model

The individual TSOs' IGMs are merged to obtain a CGM according to the CGMM. The process of CGM creation is performed by the merging agent and comprises the following services:

- Check the consistency of the IGMs (quality monitoring);
- Merge D-2 IGMs and create a CGM per market time unit;
- Make the resulting CGM available to all TSOs.



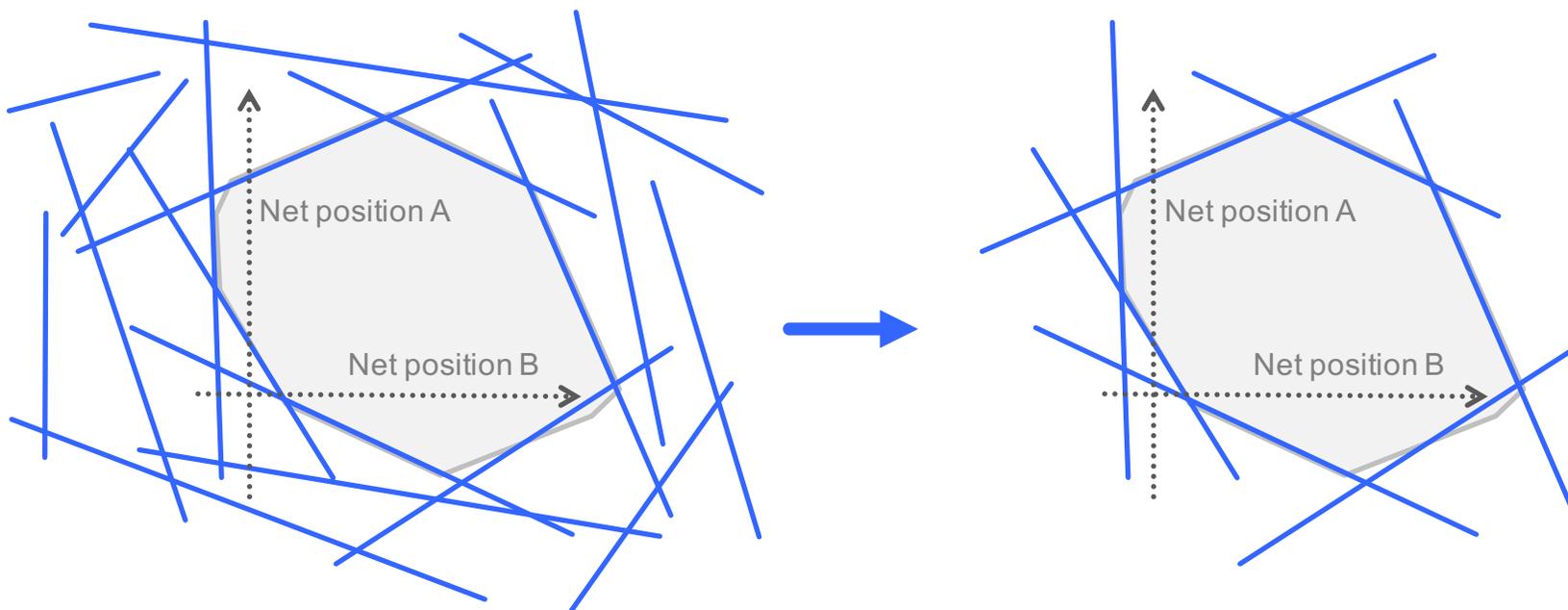
Remedial Action Optimization

- Multiple RAs can be combined in order to accommodate the expected market preferences and thus optimize cross-zonal capacities;
- Due to the trade-off nature of RAs (flow reduction on some CNECs while increase on other CNECs), a (reproducible) optimization is performed that ensures that all defined RAs are applied in an optimal way;
- The output of the RAO lists CNEs and Contingencies, including the selected RAs to be considered when computing the final PTDF and RAM for market coupling.



Calculation of the final flow-based domain

Although from the TSO point of view, all flow-based parameters are relevant and do contain information, not all flow-based parameters are relevant for the Market Coupling mechanism. Indeed, only those constraints that are most limiting the net positions need to be respected in the Market Coupling: the non-redundant constraints (or the “presolved” domain).



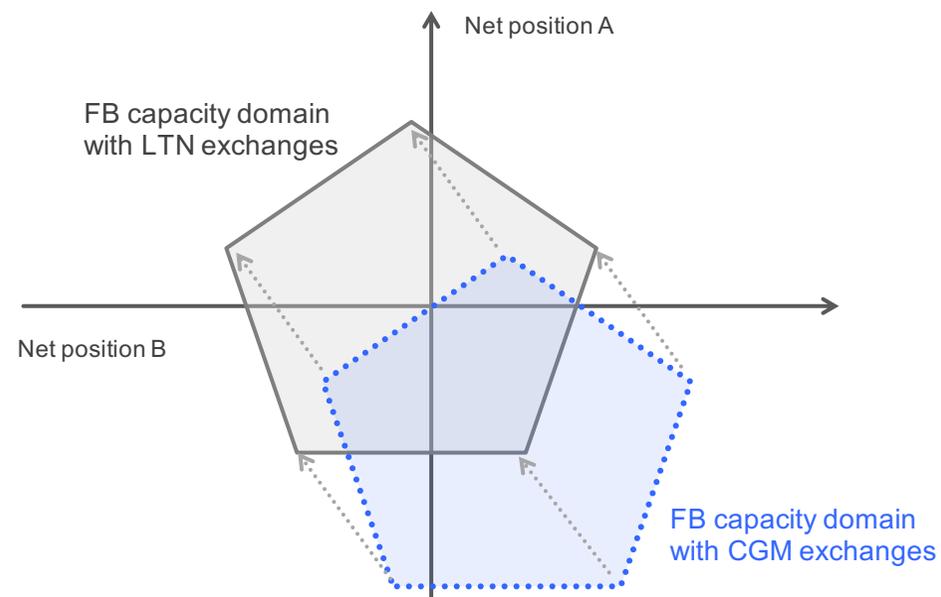


Calculation of the final flow-based domain

As the reference flow (F_{ref}) is the physical flow computed from the D-2 CGM, it reflects the loading of the CNEs and CNECs given the forecast commercial exchanges. Therefore, this reference flow has to be adjusted to take into account the effect of the *LTN* (Long Term Nominations) of the MTU instead.

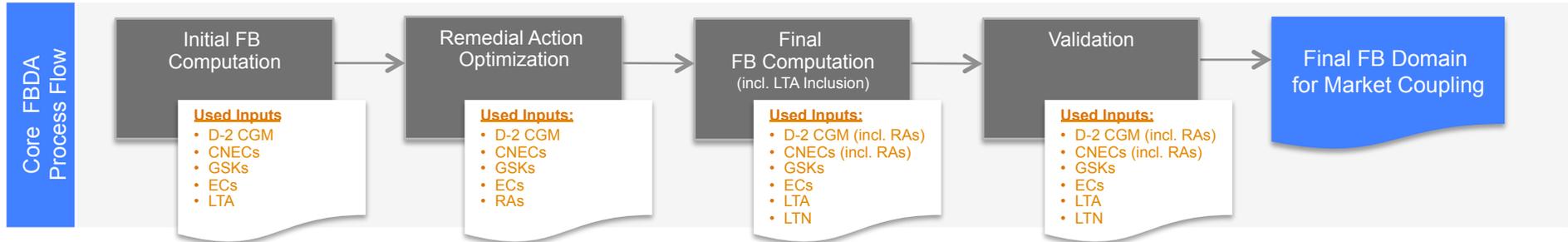
$$F_{LTN} = F_{ref} + \sum_1^n PTDF_k \times (NP_{k,LTN} - NP_{k,ref})$$

$$RAM_{LTN} = F_{max} - FRM - FAV - F_{LTN}$$





To summarise

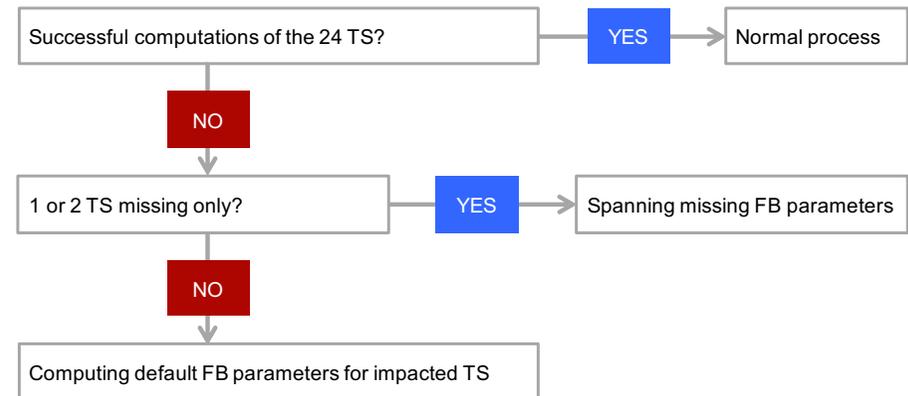
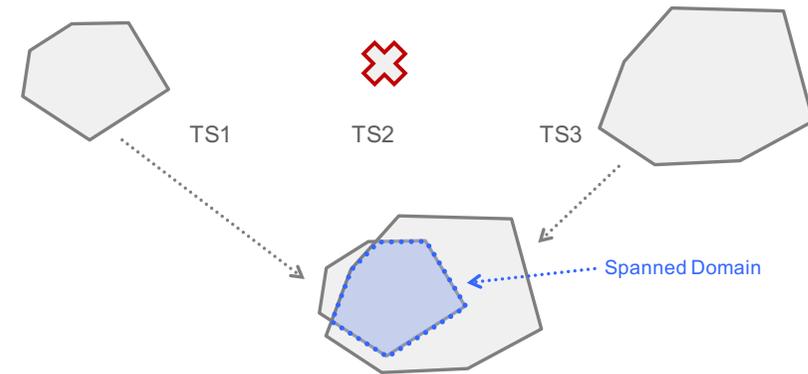




Spanning and FB fallback parameters

In some circumstances, it can be impossible for TSOs to compute flow-based parameters according to the process and principles.

1. TSOs can directly replace missing flow-based parameters by using a so-called “spanning method”. These spanning principles are only valid if a few timestamps are missing (up to 2 consecutive hours).
2. In case of impossibility to span the missing parameters, TSOs will deploy the computation of “Fallback flow-based parameters”.



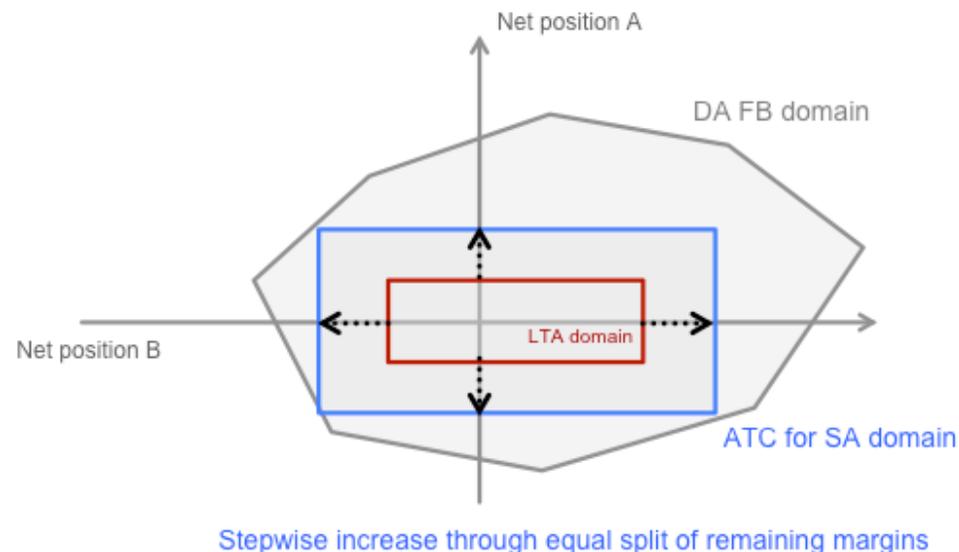


3. Back-up and fallback processes

ATC for Shadow Auctions

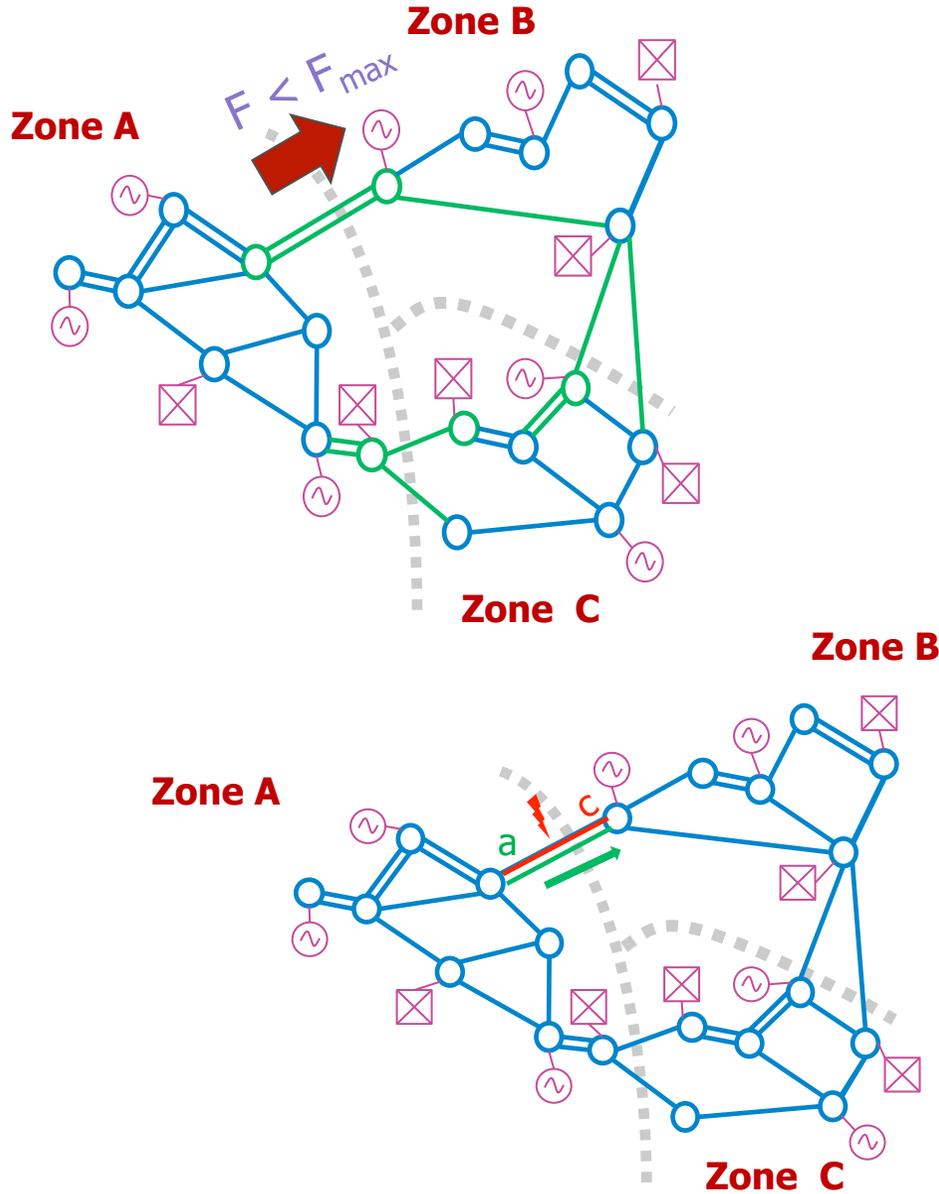
As a result of FB CC, flow-based domains are determined for each MTU as an input for the FB MC process. In case the latter fails, the flow-based domains will serve as the basis for the determination of the ATC values that are input to the Shadow Auctions (SAATC).

As the selection of a set of ATCs from the flow-based domain leads to an infinite set of choices, an algorithm has been designed that determines the SA ATC values in a systematic way. It is based on an iterative procedure starting from the minimum NTC domain.





Legend



Legend

-  Consumption node
-  Generation node
-  Two parallel lines
-  One line
-  Monitored line
-  Bidding zone border
-  Electricity flow
-  Electricity flow
-  Outage