



# Flow-Based Concept and Methodology

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Joint NordREG / Nordic TSO workshop on Flow-Based Capacity Calculation

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- Advantages of the FB approach
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# Questions?

- Always welcome, do not hesitate to ask!





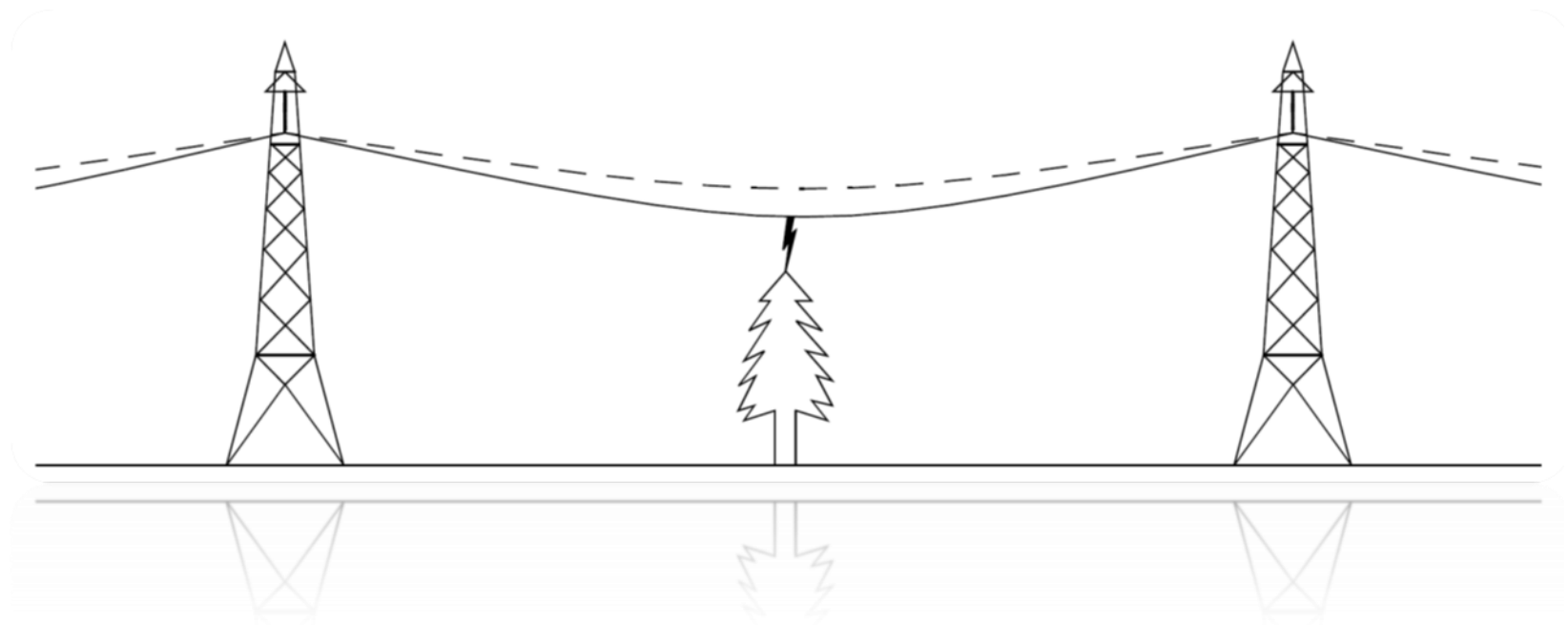
# Congestion management

# What is congestion?



## What is congestion?

- commercial: more capacity requested by the market than is available
- physical: overloaded transmission lines leading to outages



# Congestion management in the broadest sense

determination of  
available  
transmission  
capacity

capacity  
allocation

congestion  
forecast

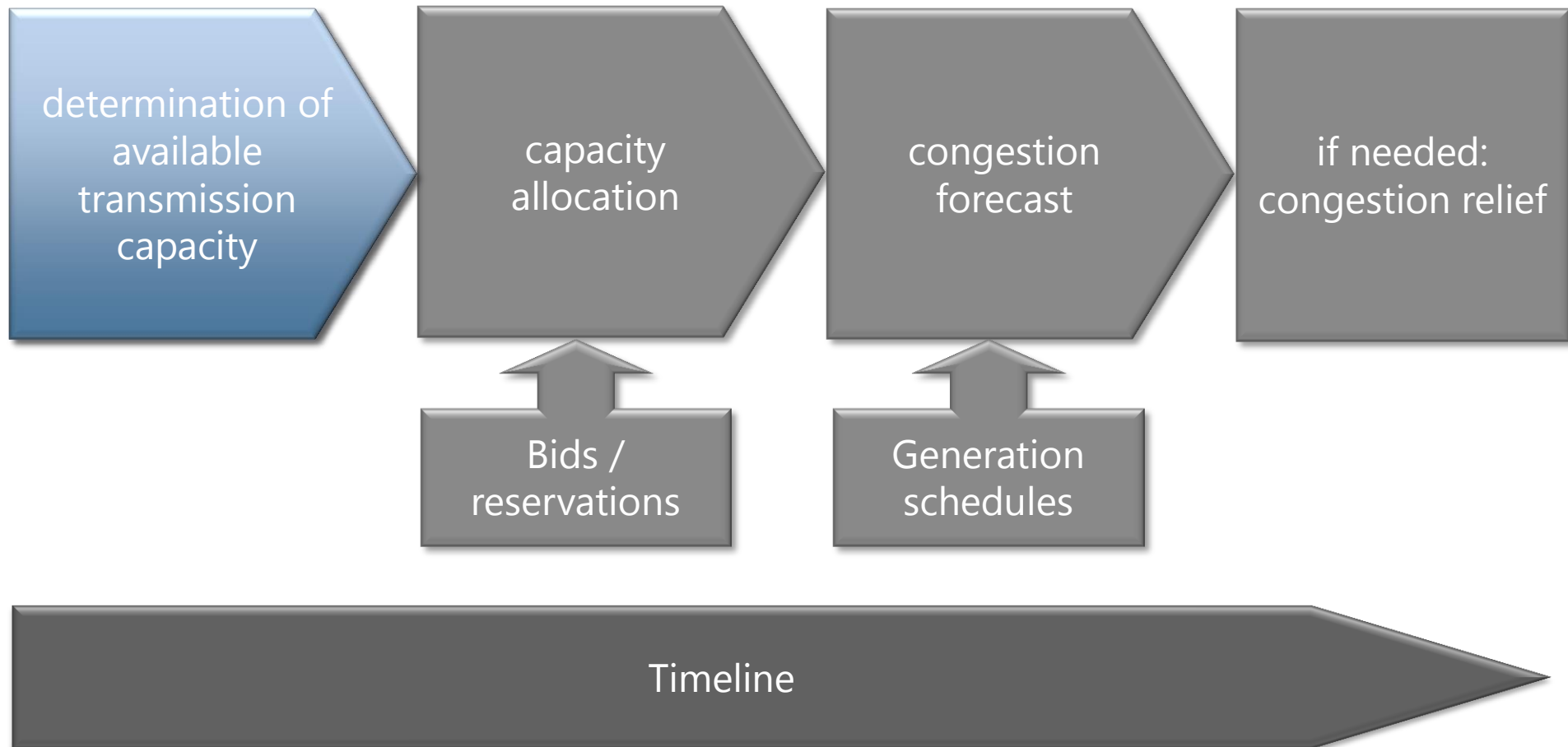
if needed:  
congestion relief

Bids /  
reservations

Generation  
schedules

Timeline

# Congestion management in the broadest sense





# Network Code on Capacity Allocation & Congestion Management

network codes.eu

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entsoe  
European Electricity Commission

q

### CONNECTION CODES

- › Requirements for Generators
- › Demand Connection Code
- › High Voltage Direct Current Connections

### OPERATIONAL CODES

- › Operational Security
- › Operational Planning & Scheduling
- › Load Frequency Control & Reserves

### MARKET CODES

- › Capacity Alloc. & Congestion Management
- › Forward Capacity Allocation
- › Electricity Balancing

#### More about this code

- › NC CACM Timeline
- › News (1)

#### FAQ for this code

- › Introducing the network code
- › The current status of EU markets
- › Market coupling/ day ahead markets
- › Intraday markets
- › Coordinated capacity calculation
- › Bidding zones
- › Benefits of the code
- › Stakeholder involvement
- › Interactions with other network codes

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## The Network Code on Capacity Allocation & Congestion Management (NC CACM)

The NC CACM will help achieve a fully integrated electricity market for Europe by setting out the rules that will introduce a single approach to cross-border electricity trading in Europe. The code sets out rules for capacity allocation – allocating the available cross-border capacity on the electricity transmission infrastructure in day-ahead and intraday timescales, and outlines the way in which capacity will be calculated across the different zones. The CACM code also sets out the rules for congestion management, the management of scarce transmission capacity among the parties requesting use of such capacity.

The NC CACM's objectives

Copyright ENTSO-E

## ENTSO-E CACM network code (final draft, 27 September 2012)

*'There are two permissible approaches when calculating cross zonal capacity: Flow based or coordinated net transmission capacity based. The flow based approach is preferred over the coordinated net transmission capacity approach for day ahead and intraday capacity calculation where interdependencies of cross zonal capacity between bidding zones is high.'*

*'The coordinated net transmission capacity approach may be applied in regions where interdependencies between cross zonal capacity are low and the added value of the flow based method cannot be proven.'*

# Market Coupling: a constrained optimization problem

Determination  
of available  
transmission  
capacity

capacity  
allocation

Bids /  
reservations

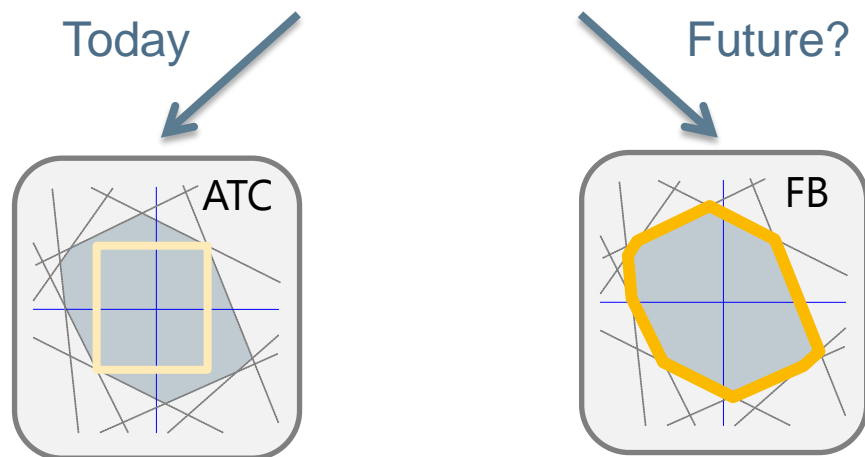
- All the bids of the bidding areas are brought together in order to be matched by a centralized algorithm


- Objective function: Maximize social welfare

- Control variables: Net positions

- Subject to:  $\sum \text{net positions} = 0$

**Grid constraints**

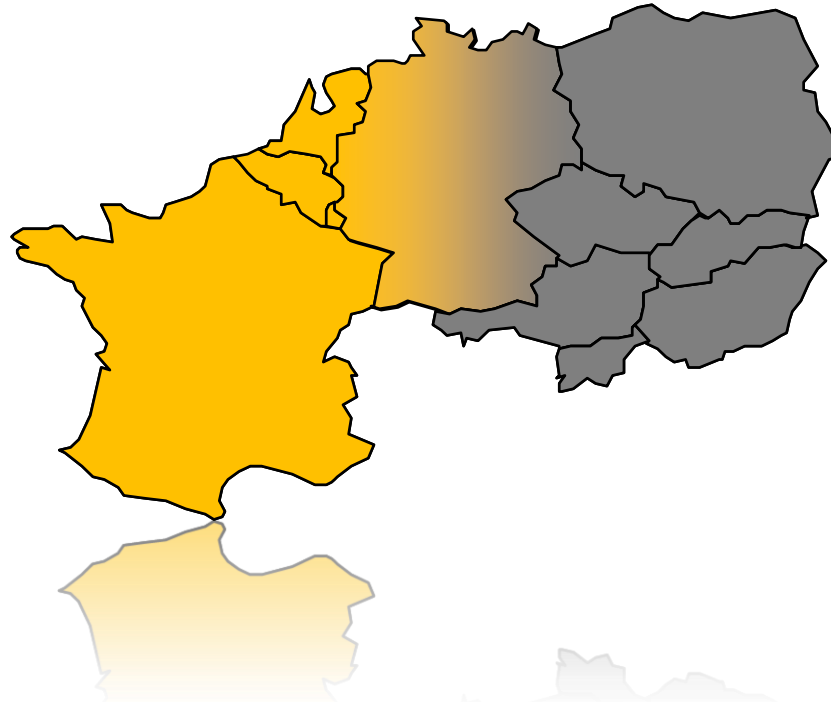




## Flow Based in Europe

# Flow-Based (FB): the 'next-step' coordinated capacity calculation method

## CWE

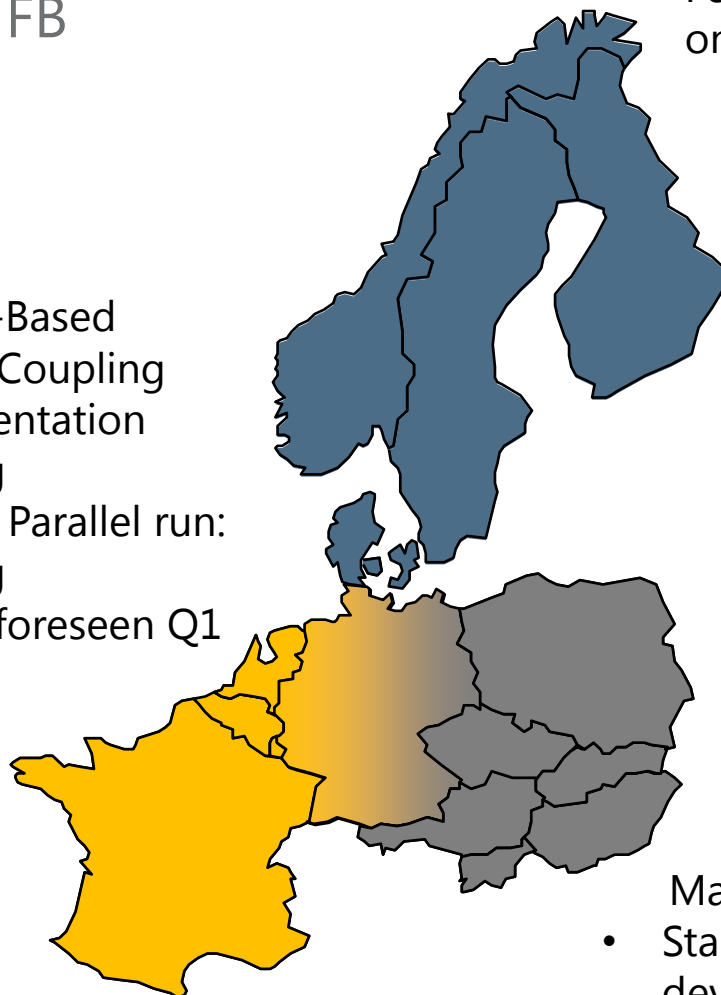


## CEE



After ETSO created the fundament of the flow-based methodology (based on flow gates), the current flow-based methodology (based on critical branches) was developed more or less independently in both CWE and CEE.

# Current status of FB



Flow-Based Market Coupling

- Feasibility study ongoing

### Nordics

- ENERGINET/DK
- SVENSKA KRAFTNÄT
- FINGRID
- Statnett

Flow-Based Market Coupling

- Implementation ongoing
- External Parallel run: ongoing
- Go-live foreseen Q1 2015

### CWE

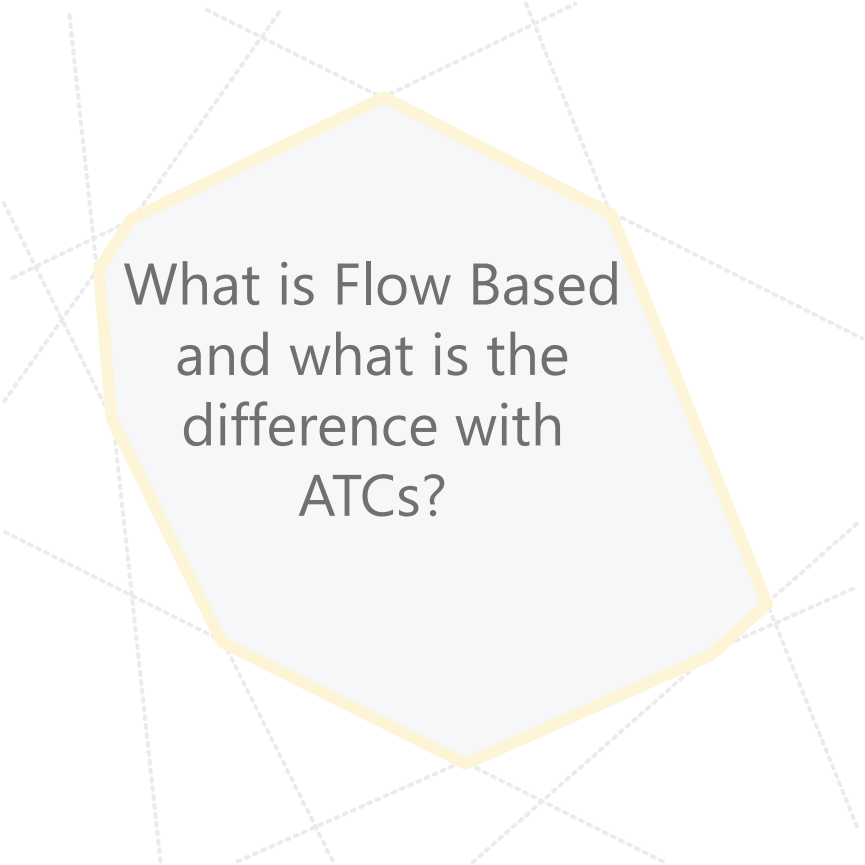
- amprion
- apx power spot exchange
- belpex part of apx
- creos
- elia Powering a world in progress
- EPEXSPOT EUROPEAN POWER EXCHANGE
- Rte Réseau de transport d'électricité
- Tennet Taking power further
- TRÄNSNET BW

Flow-Based Market Coupling

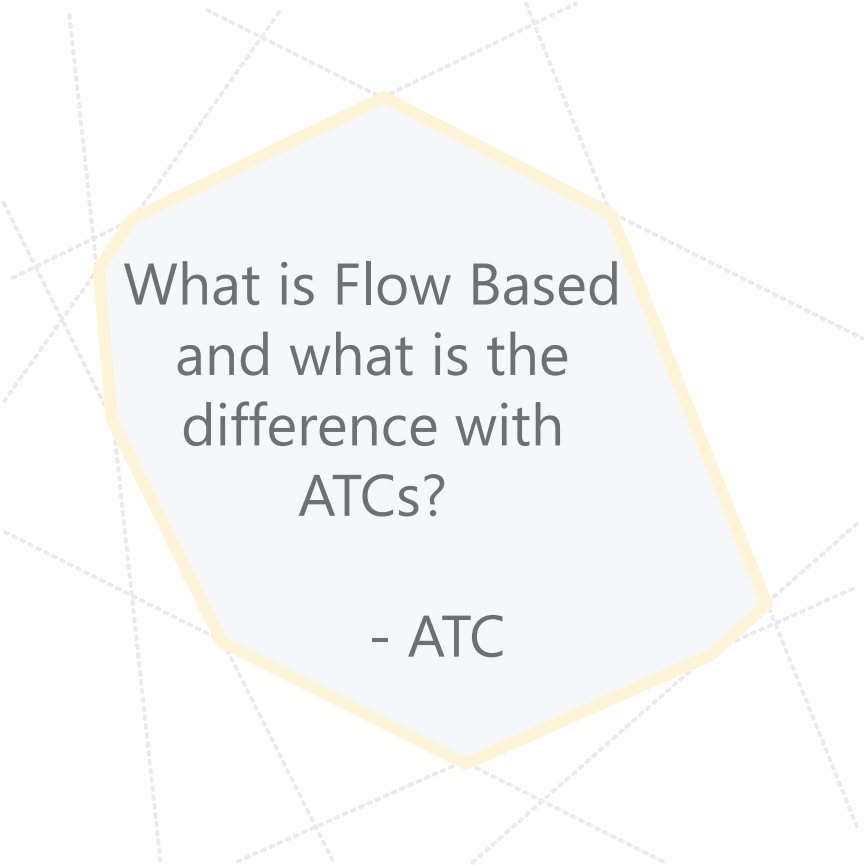
- Started FB development for FB explicit auctions
- Project ongoing to introduce FBMC

### CEE

- cao
- 50hertz
- APG
- ceps, a.s.
- ELES
- MAVIR
- PSE
- seps
- Tennet Taking power further



What is Flow Based  
and what is the  
difference with  
ATCs?



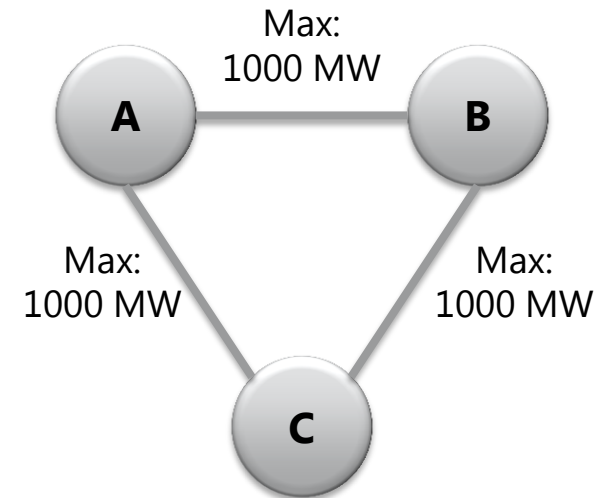
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- ATC



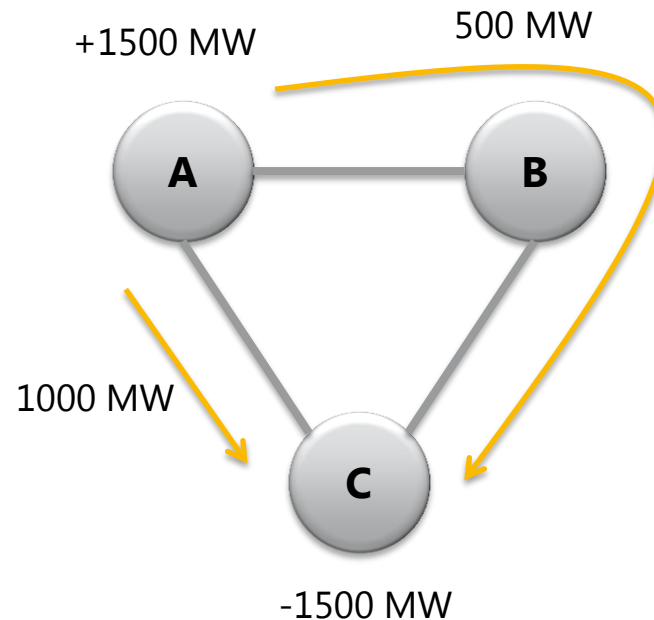
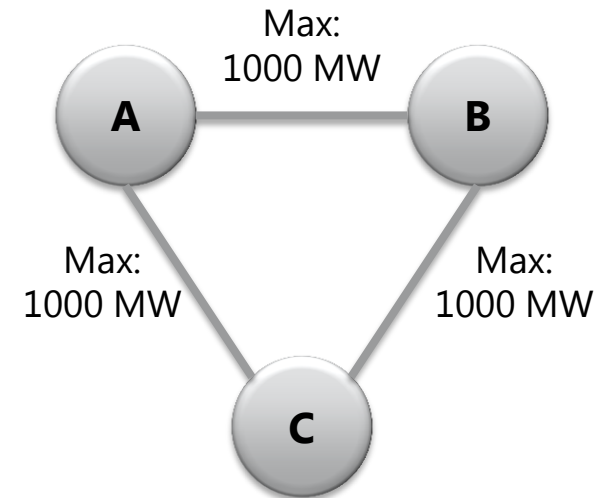
## An example three-node network

- Let's consider a three-node network
  - Equal impedances
  - Max flow on the branches: 1000 MW



## An example three-node network

- Let's consider a three-node network
  - Equal impedances
  - Max flow on the branches: 1000 MW
- The maximum export from A to another bidding area amounts 1500 MW:

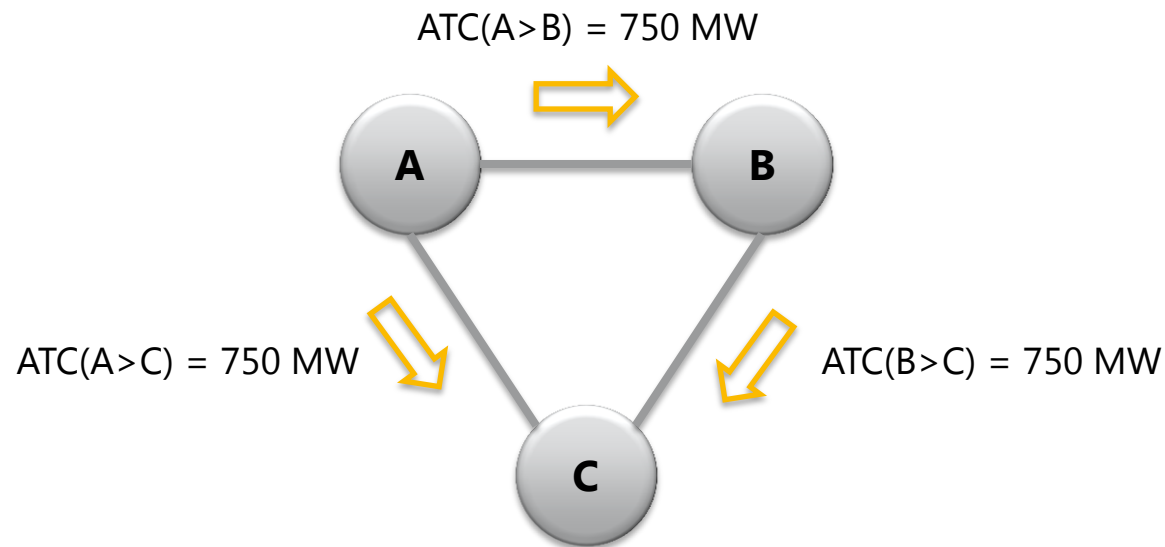


## An example three-node network: ATCs

- ATCs are determined by the TSOs to facilitate the market while safeguarding the grid
  - An ATC limits a commercial exchange between two bidding areas
  - ATCs are simultaneously feasible

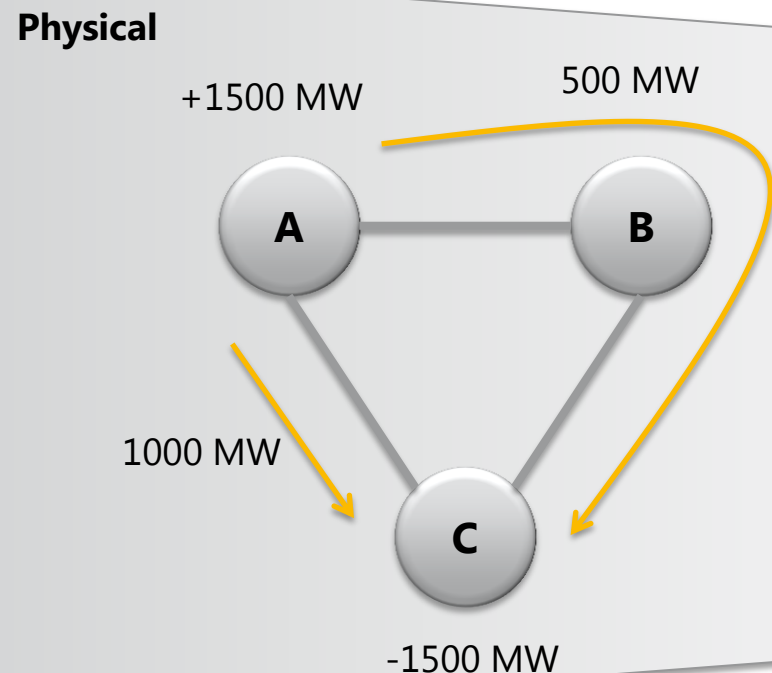
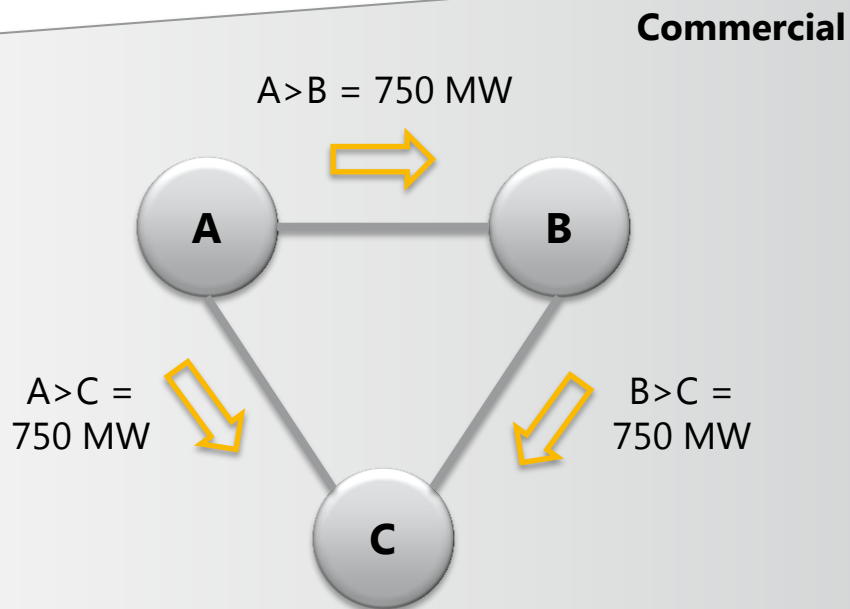
## An example three-node network: ATCs

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  - An ATC limits a commercial exchange between two bidding areas
  - ATCs are simultaneously feasible
- Given the maximum export of bidding area A, the TSO needs to split the 1500 MW export capability into two bilateral exchanges, for example:
  - $ATC(A>B) = 750 \text{ MW}$
  - $ATC(A>C) = 750 \text{ MW}$



# An example three-node network: ATCs and physical flows

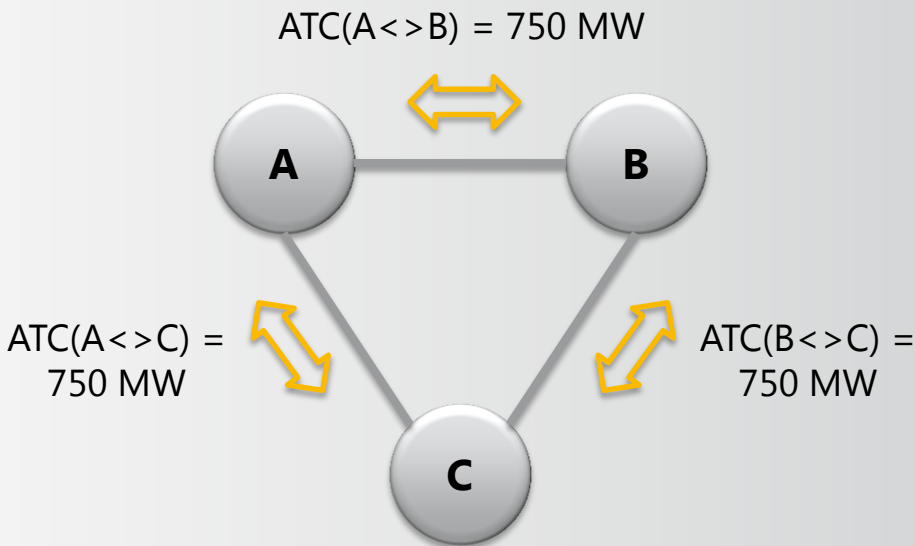
- The following commercial exchanges are feasible given the ATCs:
  - $A > C = 750 \text{ MW}$
  - $A > B = 750 \text{ MW}$
  - $B > C = 750 \text{ MW}$



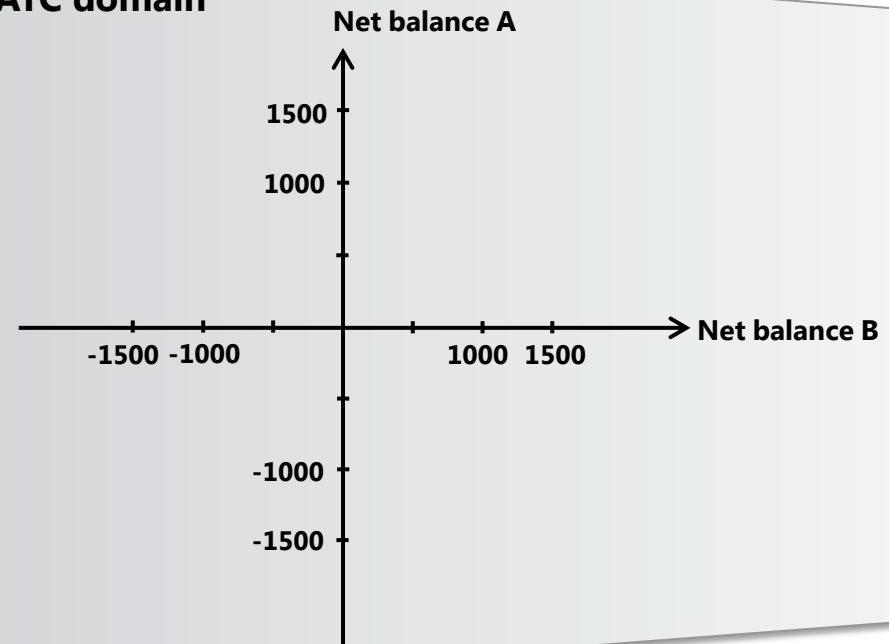
# An example three-node network: ATC domain

- The ATCs in the three-node system define the ATC domain: the import/export positions that the market is allowed to reach under the market coupling while not jeopardizing the grid security

## ATC constraints



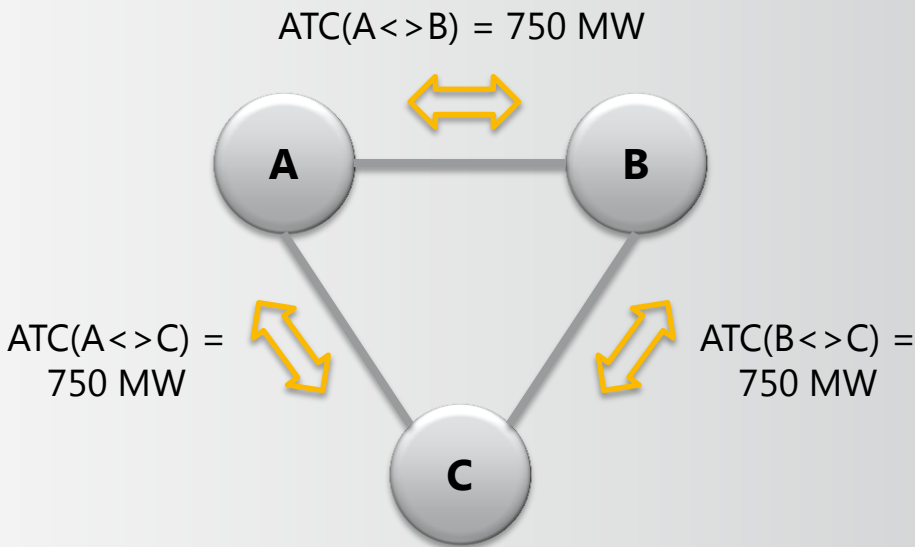
## ATC domain



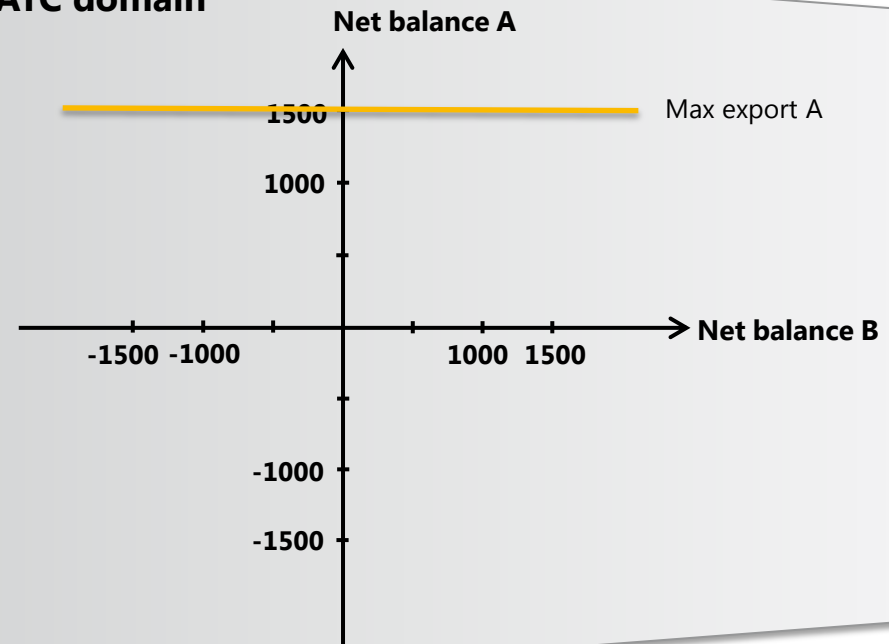
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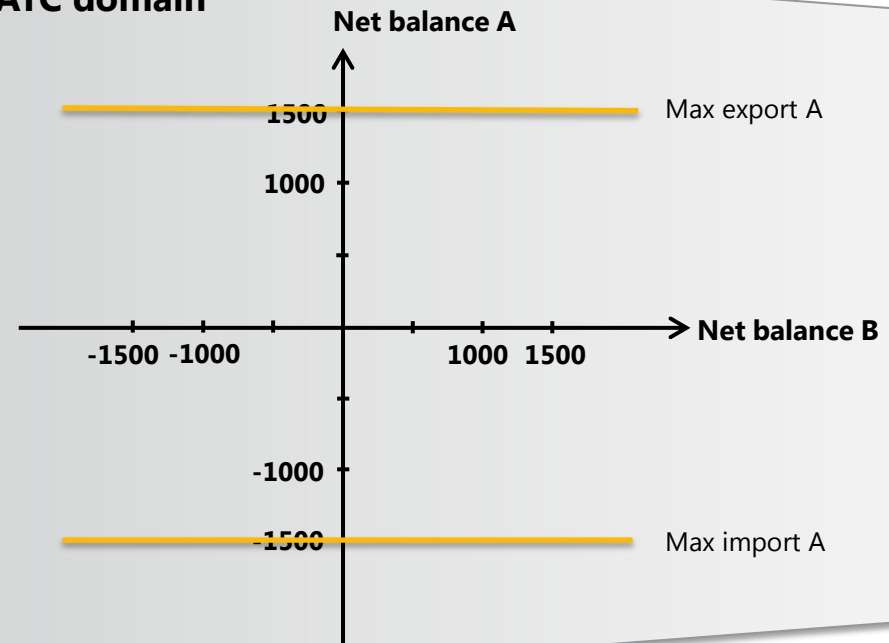
$$\text{ATC}(A \leftrightarrow B) = 750 \text{ MW}$$



$$\text{ATC}(A \leftrightarrow C) = 750 \text{ MW}$$

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### ATC domain





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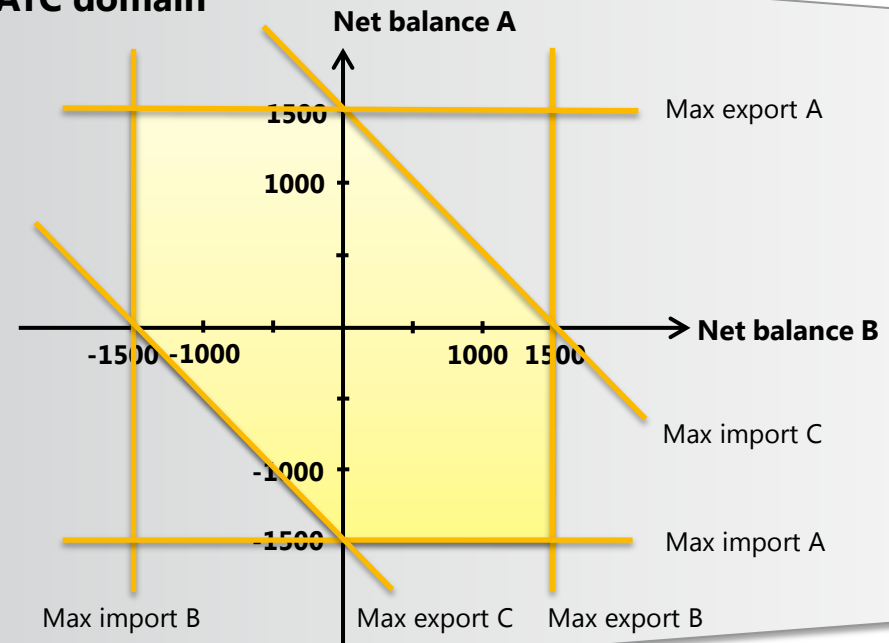
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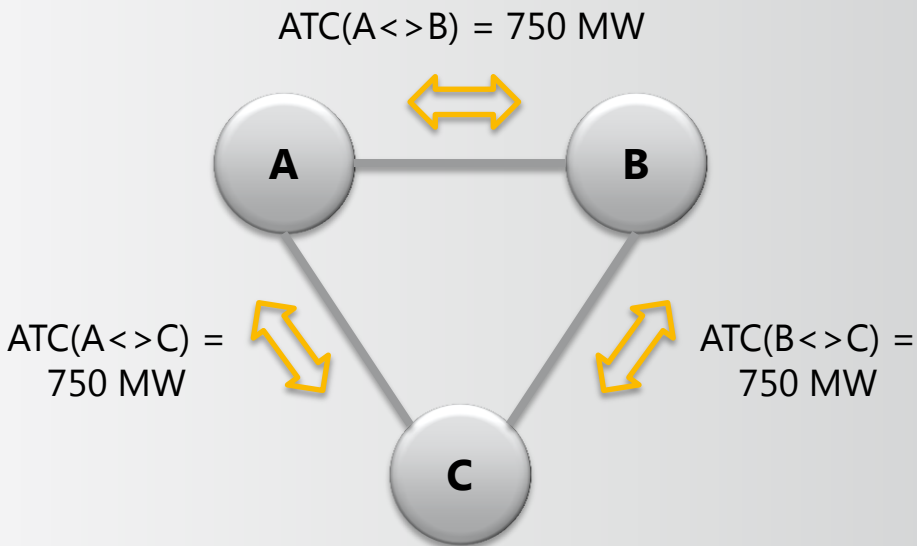
### ATC domain



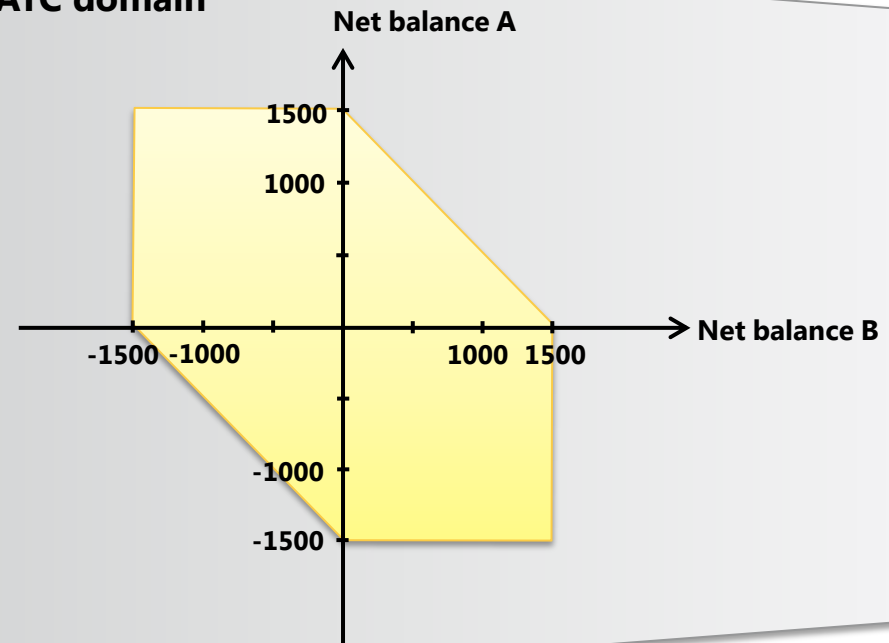
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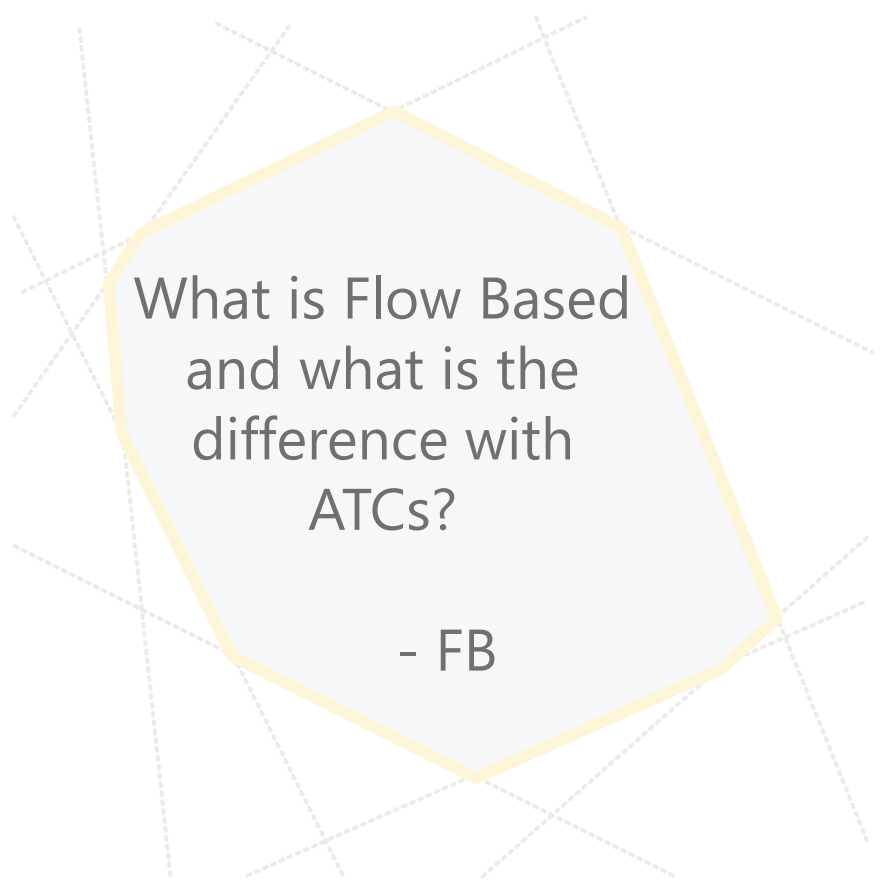
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### ATC constraints



### ATC domain



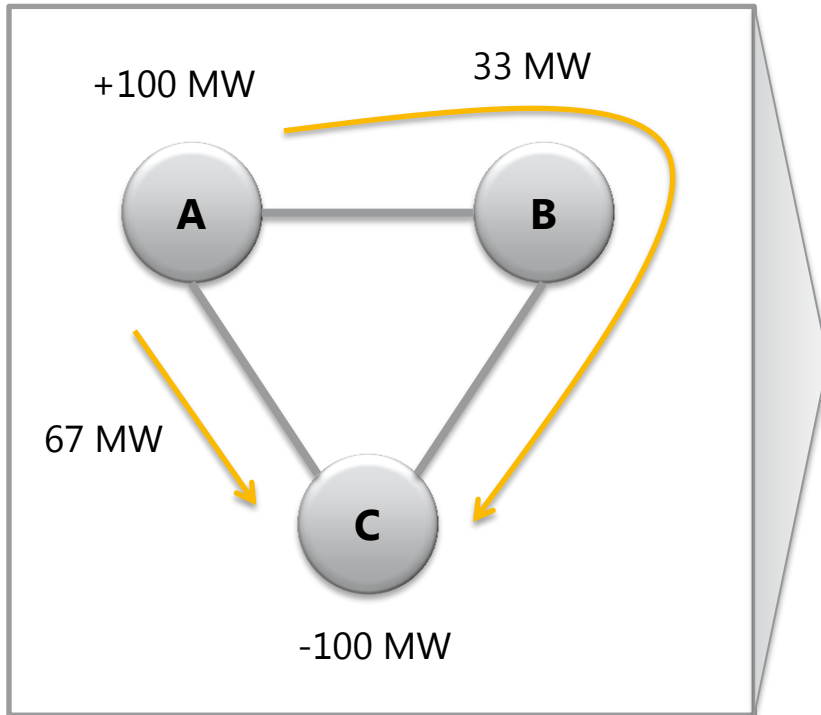


What is Flow Based  
and what is the  
difference with  
ATCs?

- FB

# An example three-node network: FB constraints

- FB constraints are a kind of simplified grid model, reflecting the impact of import/export positions on the flows on the grid

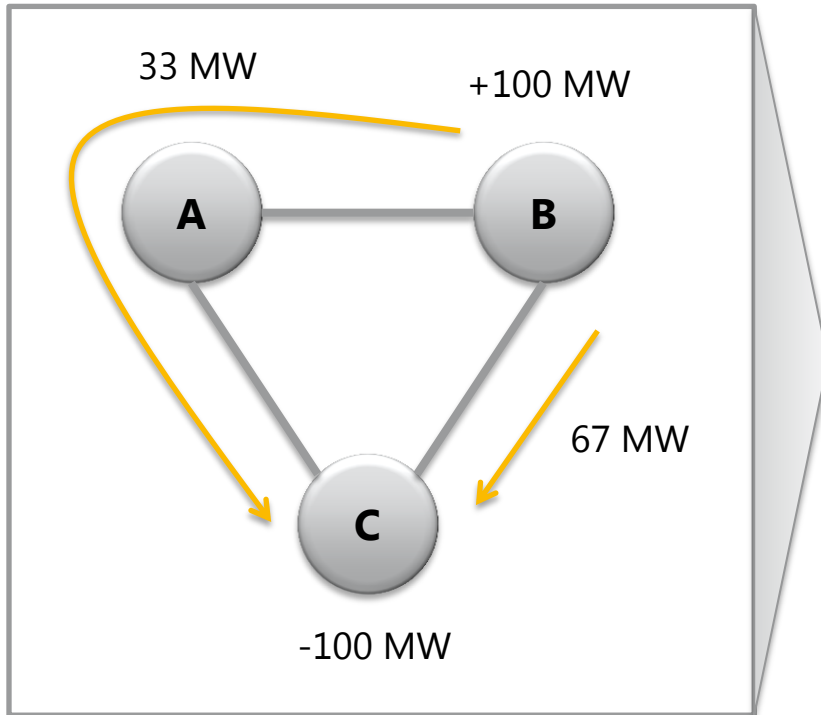


## FB constraints ('grid model'):

Line	Margins	PTDF factors		
	Maximum flow	Influence from area A	Influence from area B	Influence from area C
A>B	1000 MW	33 %		
B>C	1000 MW	33 %		
A>C	1000 MW	67 %		

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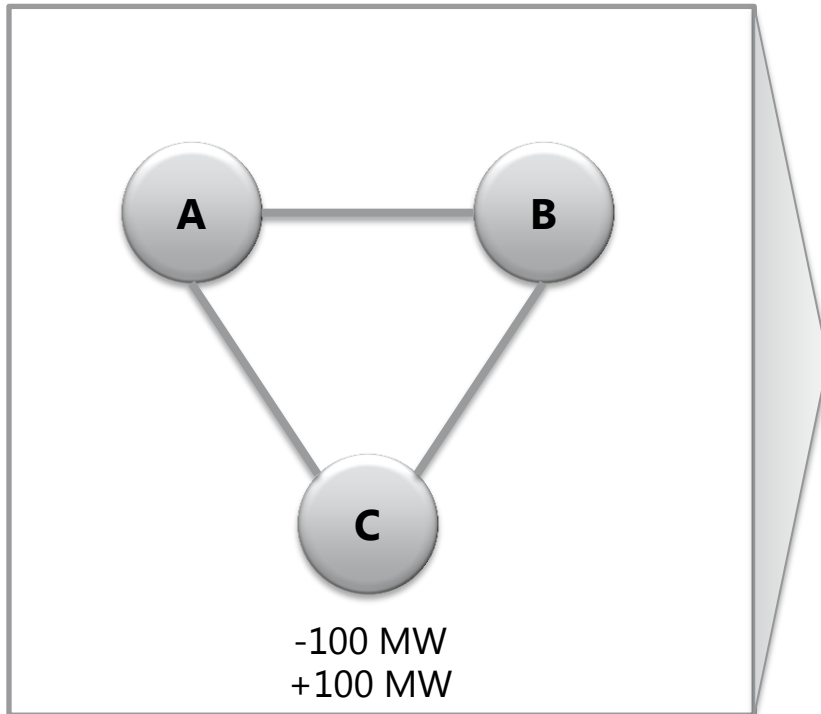


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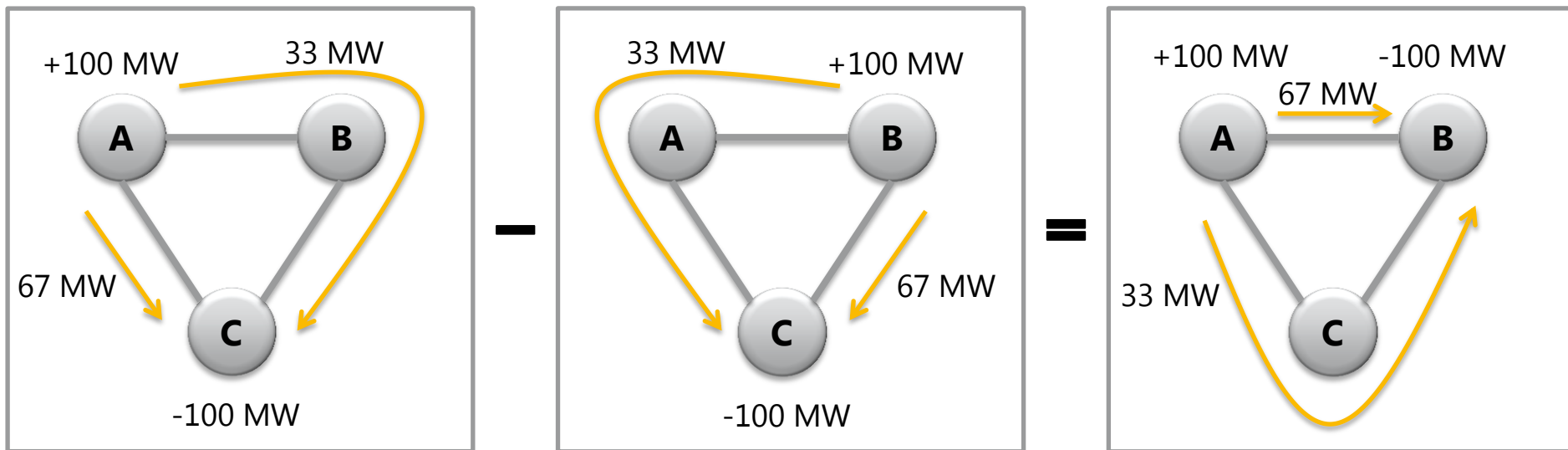


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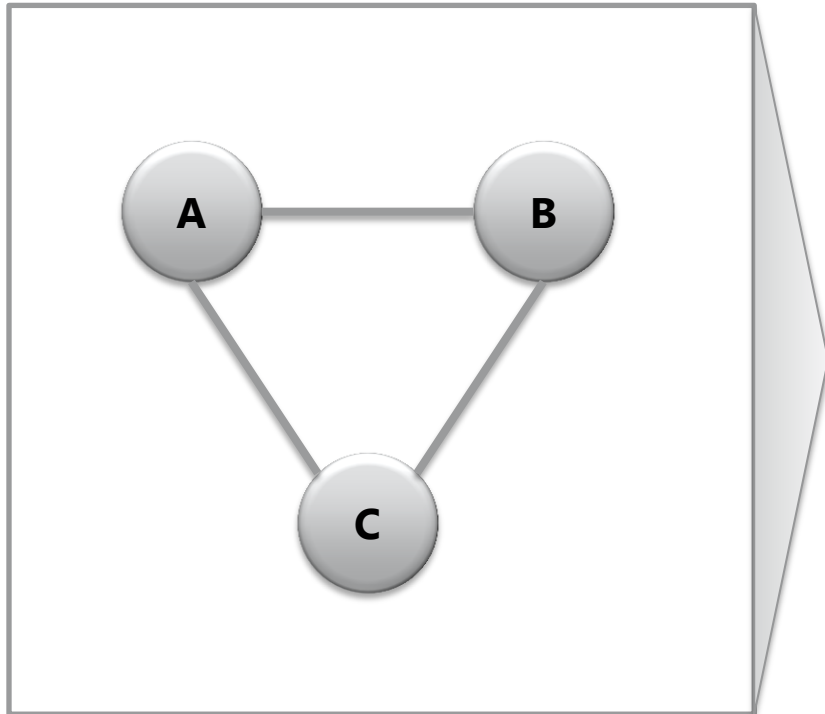
## An example three-node network: FB and the reference node

- An exchange of 100 MW from bidding area A to bidding area B is equivalent to: an exchange of 100 MW from area A to the reference node C – an exchange of 100 MW from area B to the reference node C
- This property holds due to the linearity of the PTDF computation (DC load flow)



## An example three-node network: FB constraints

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B>A	1000 MW	-33 %	33 %	0
C>B	1000 MW	- 33 %	- 67 %	0
C>A	1000 MW	- 67 %	- 33 %	0



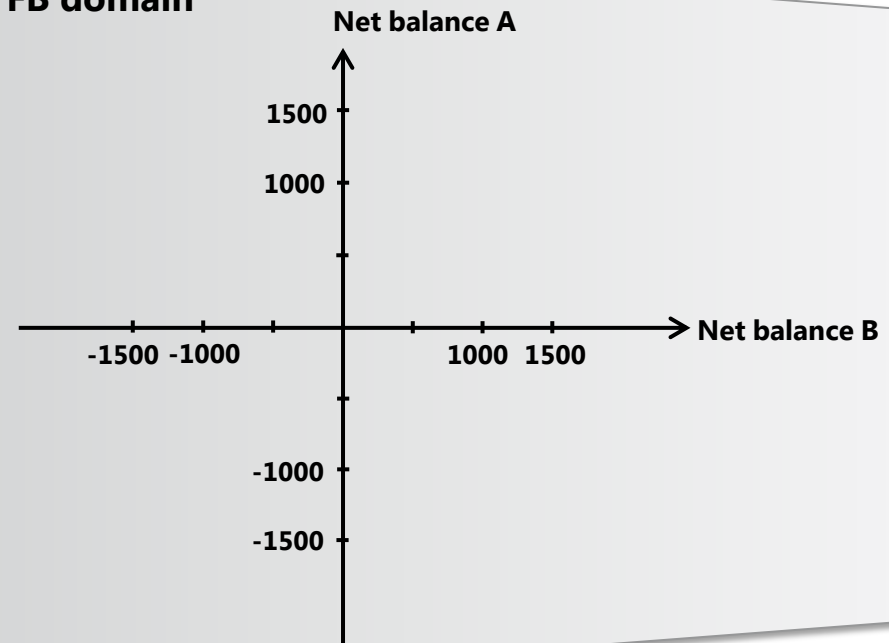
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**FB domain**



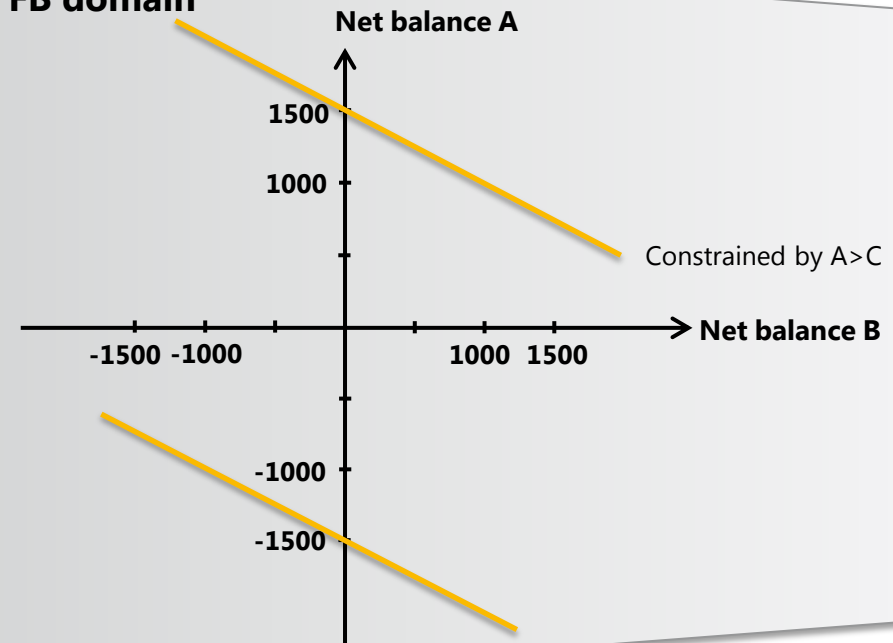
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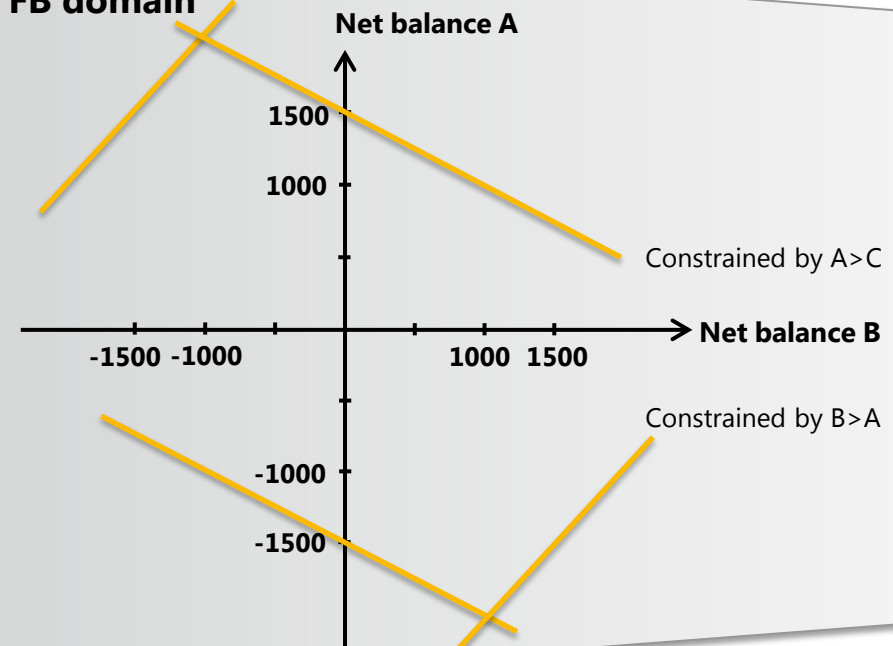
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**FB domain**



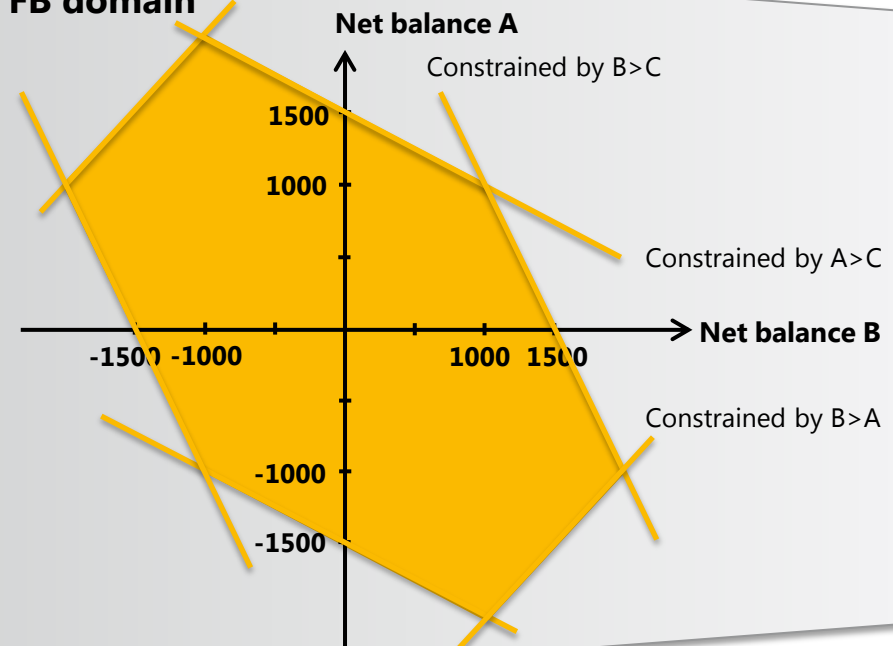
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C>A	1000 MW	- 67 %	- 33 %	0

**FB domain**



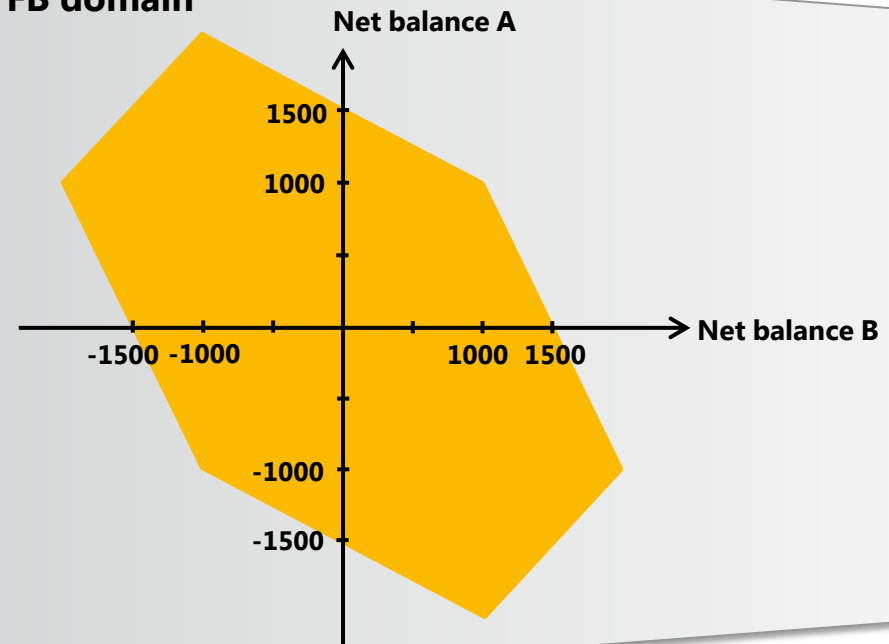
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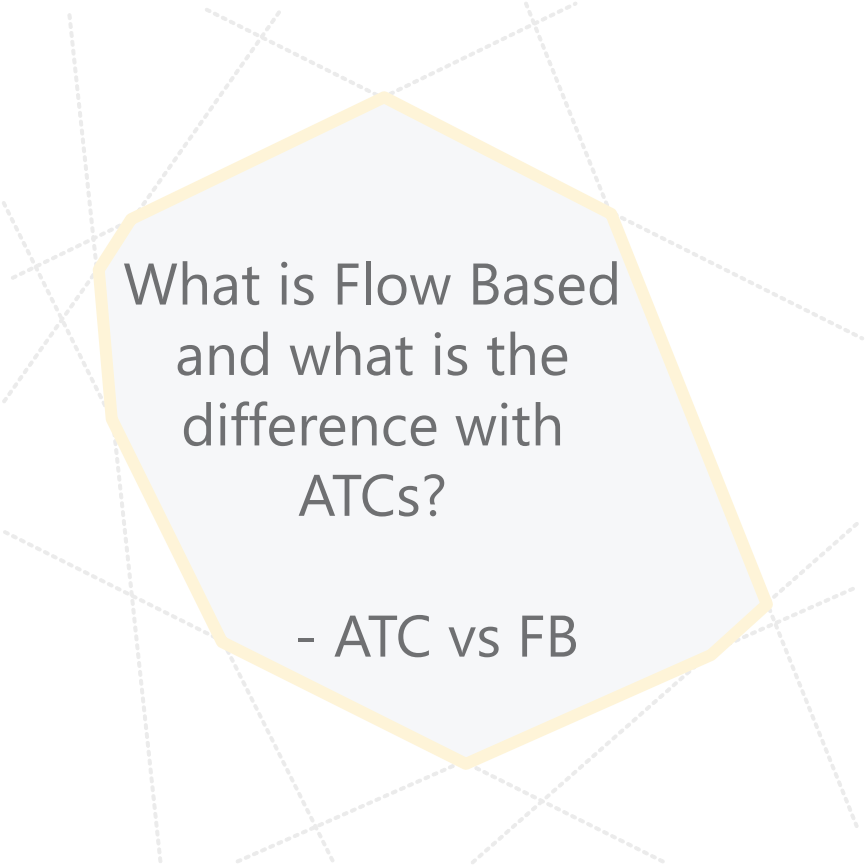
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**FB domain**



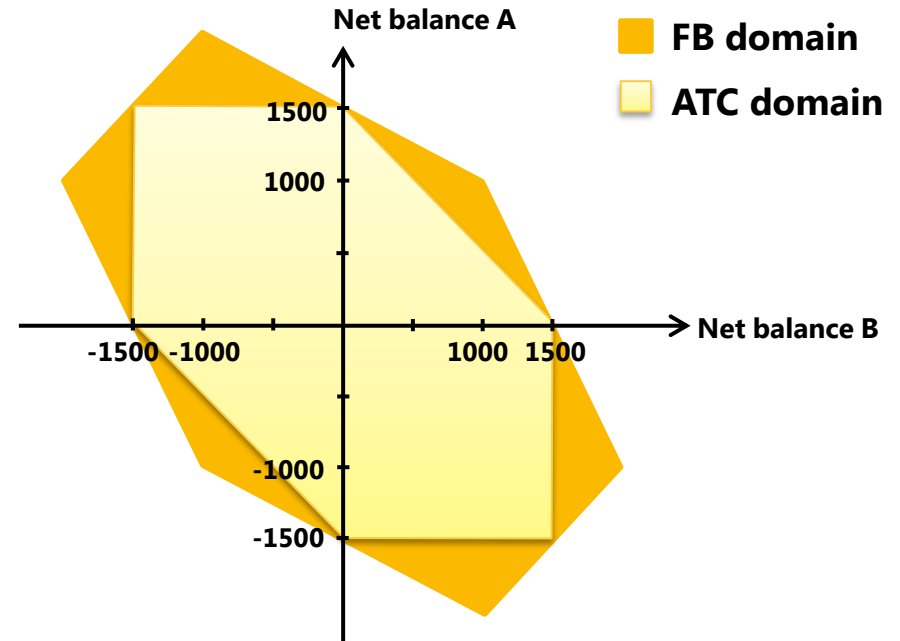


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- ATC vs FB

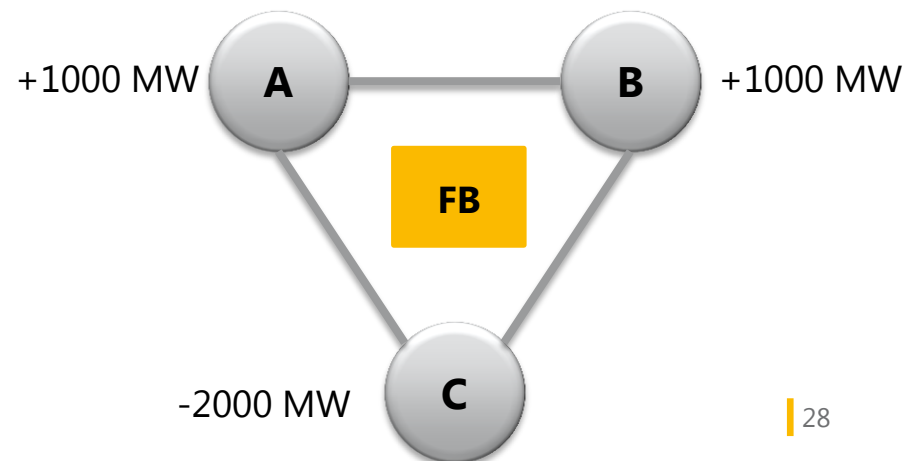
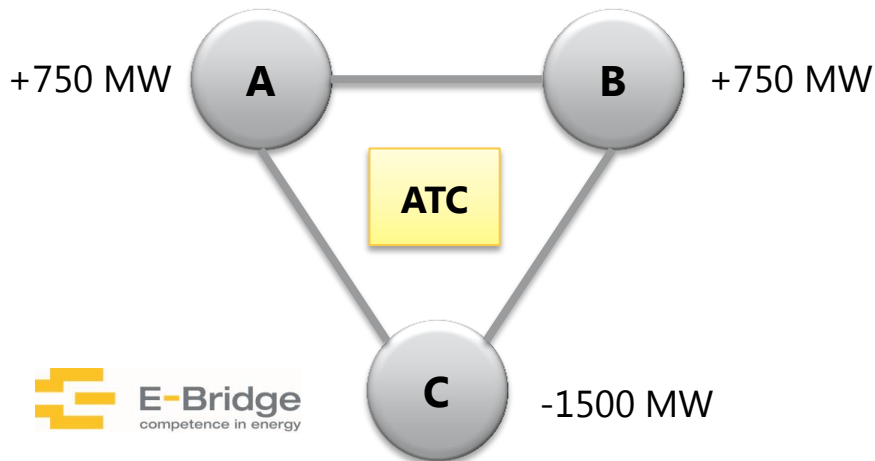
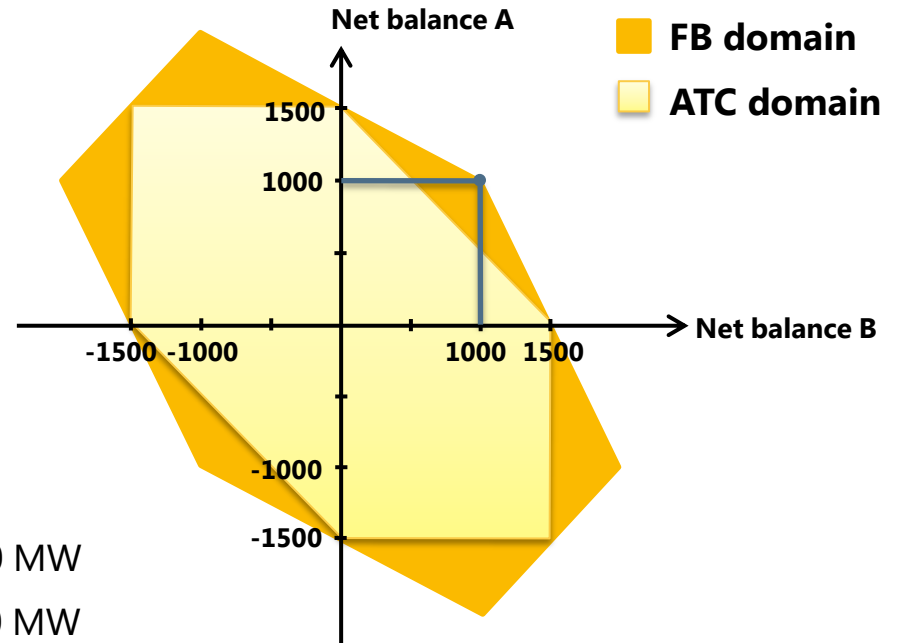
## An example three-node network: ATC vs FB domain

- In FB capacity split is not a choice of the TSO, but is market driven (at the time of allocation)
- FB offers more trading opportunities with the same level of security of supply




# An example three-node network: ATC vs FB domain

- In FB capacity split is not a choice of the TSO, but is market driven (at the time of allocation)
- FB offers more trading opportunities with the same level of security of supply
- Example:
  - ATC: North-South exchange limited to 1500 MW
  - FB: North-South exchange possible of 2000 MW








## Advantages of the FB approach

## Advantages of the FB approach

- In FB capacity split is not a choice of the TSO, but is market driven (at the time of allocation)
    - More efficient and flexible use of the grid
  - FB offers more trading opportunities with the same level of security of supply
    - More price convergence / smaller price differences
    - Higher social welfare
    - Income redistribution: Less congestion income and more producer and consumer surplus
  - FB offers the possibility to have the DC cables efficiently embedded in the allocation mechanism, by providing a fair competition for the use of the scarce AC capacity
- Flow-based market coupling provides an efficient allocation mechanism in which all exchanges that are subject to the allocation mechanism compete with one another for the use of the scarce capacity



## FB allocation and price formation

## Prices under a FBMC

- FBMC optimization

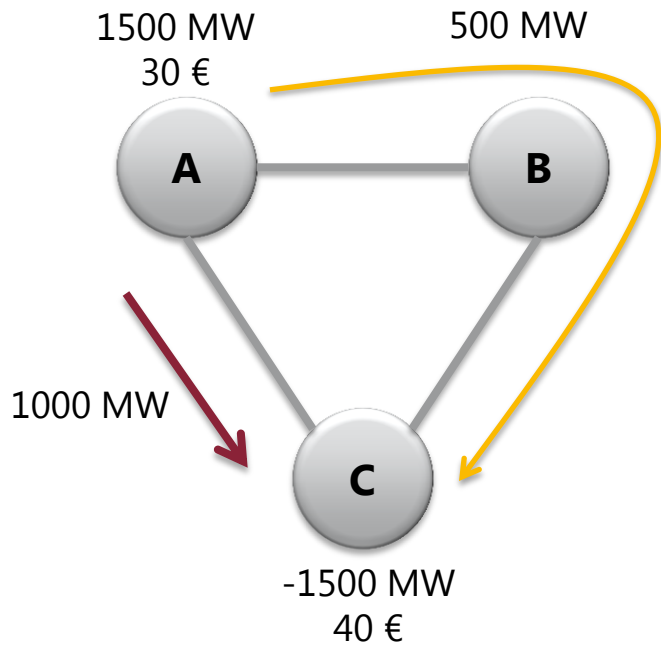
- Objective function: Maximize social welfare
- Control variables: Net positions
- Subject to:  $\sum$  net positions = 0  
**Grid constraints**

- In case of congestion, the grid constraint receives a shadow price ( $\mu$ ): the increase of the objective function (being the social welfare) when the constraint is relieved with 1 MW

- Price relation under FB:

$$MCP_i - MCP_j = \sum_{cb} (PTDF_j^{cb} - PTDF_i^{cb}) \cdot \mu_{cb}$$

# Prices under a FBMC: an example



Line	Maximum flow	Influence from area A	Influence from area B	Influence from area C
A>B	1000 MW	33 %	- 33 %	0
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A>C	1000 MW	67 %	33 %	0
B>A	1000 MW	-33 %	33 %	0
C>B	1000 MW	- 33 %	- 67 %	0
C>A	1000 MW	- 67 %	- 33 %	0

- Price relation under FB:

$$MCP_C - MCP_A = (PTDF_A - PTDF_C) \cdot \mu$$

- Shadow price equals  $\mu = 15 \text{ €/MW}$

$$40 - 30 = (0.67 - 0) \cdot 15$$

- Price in area B:

$$MCP_B - MCP_A = (PTDF_A - PTDF_B) \cdot \mu$$

$$MCP_B - 30 = (0.67 - 0.33) \cdot 15$$

$$MCP_B = 35$$

## Prices under a FBMC: consequences

- In case there is no congestion, all bidding zones have the same price
- In case of congestion, the prices of the bidding zones are set in accordance to their electrical impact on the binding constraint (i.e. the PTDF factors)

Questions?



**E-Bridge Consulting B.V.**

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