Price Coupling of Regions

Stakeholder Forum on Electricity Network Code Developments

5th September 2013, Belfast

What is the Price Coupling of Regions (PCR)?

❑Initiative to develop a price coupling algorithm embedded in a common system solution (PMB), with the goal that this infrastructure, including the algorithm, will be used for European Price Coupling.

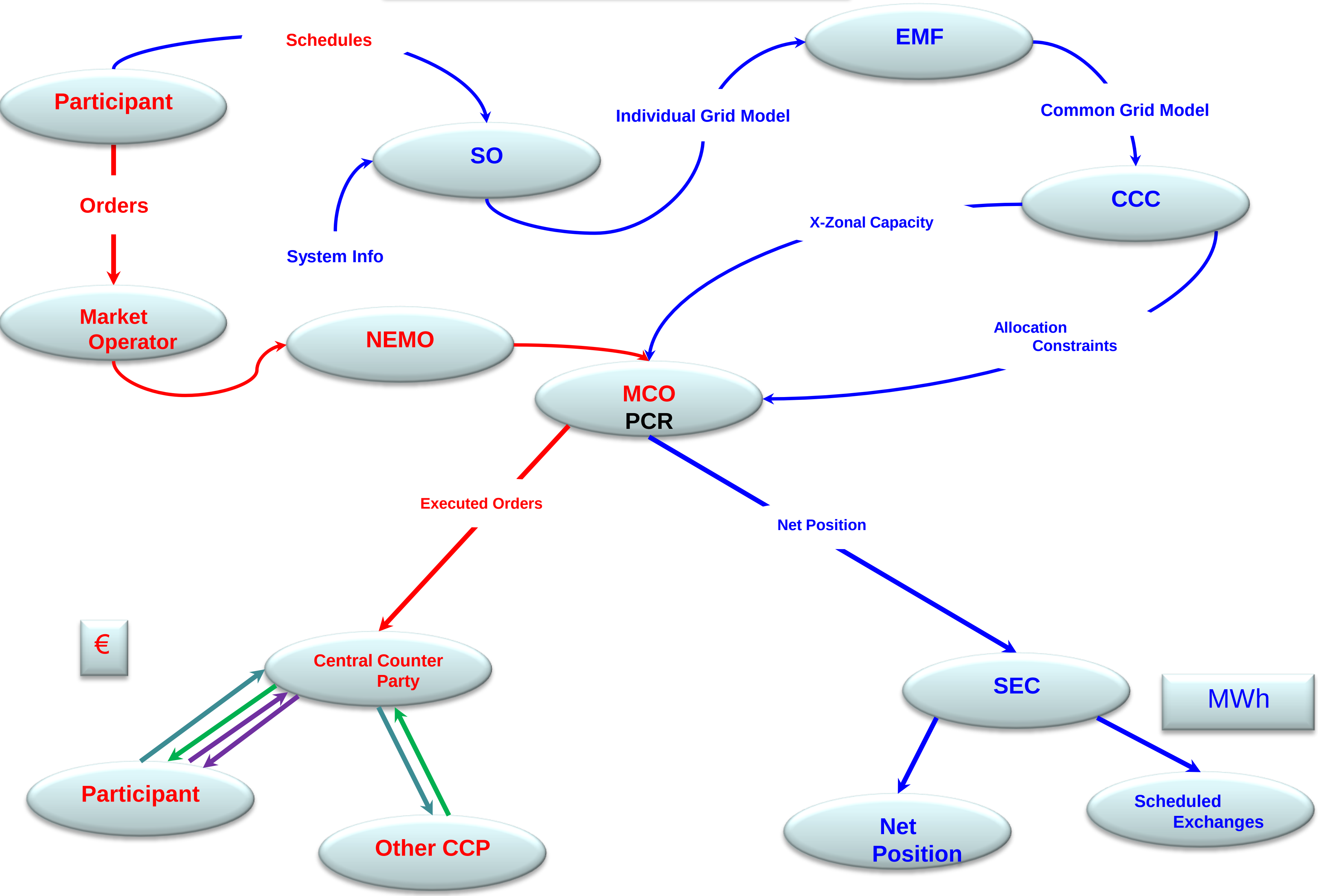
❑Currently, there are seven members - APX, Belpex, EPEX SPOT, GME, Nord Pool Spot, OMIE and OTE. SEMO is an associate member.

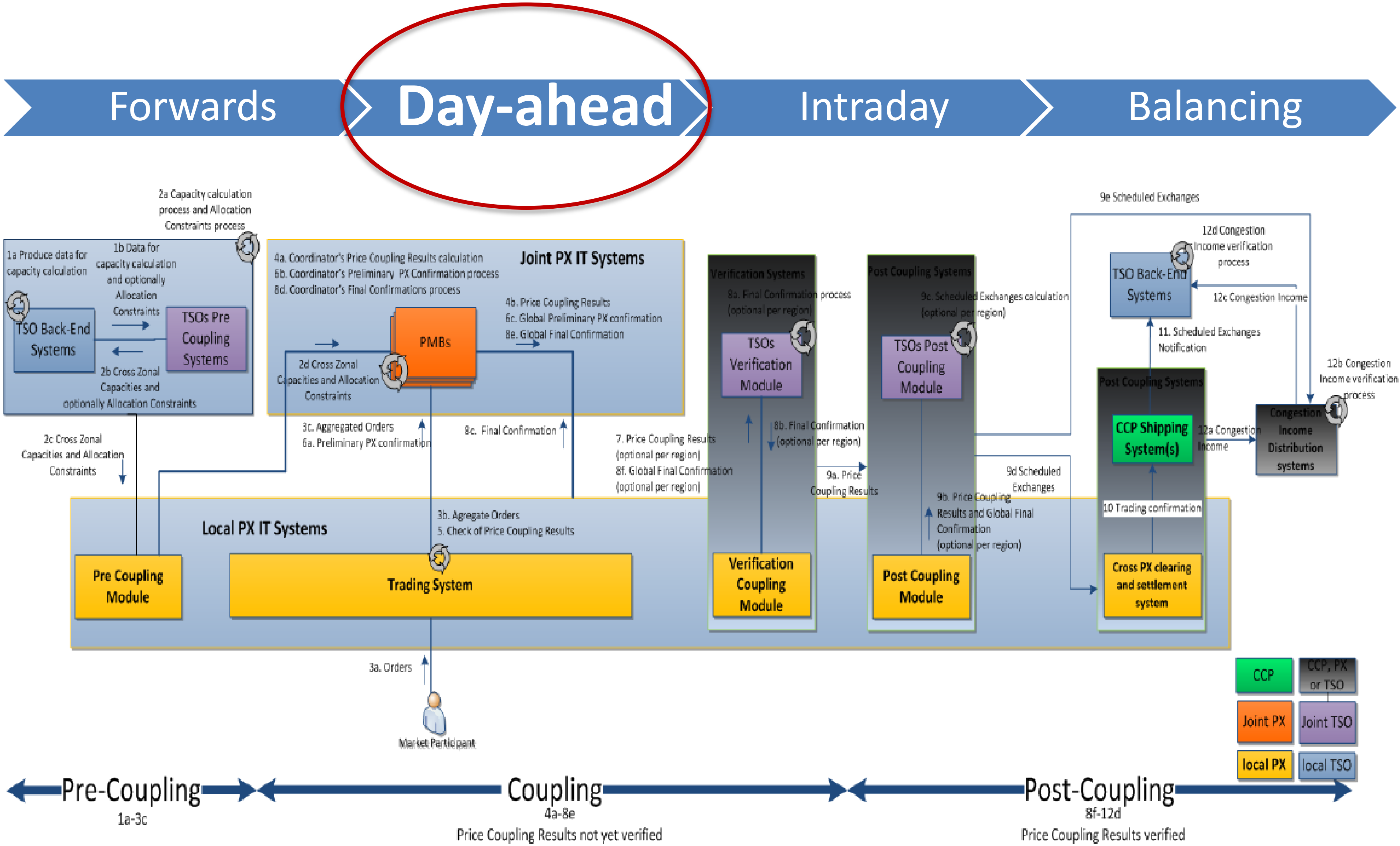
❑The PCR parties signed the PCR Cooperation Agreement and PCR Co-ownership Agreement in June 2012. PCR is open to other market operators that want to join.

❑The NWE regions (CWE, Nordic-Baltic and GB) will use this PCR infrastructure, including the algorithm, for price coupling within NWE.

❑ It is envisaged that this algorithm will be used as the Price Coupling Algorithm, as described in the Capacity Allocation and Congestion Management Network Code.

Day-Ahead Process Flow





Forwards
Day-ahead
Intraday
Balancing
2a Capacity calculation process and Allocation Constraints process
1a Produce data for capacity calculation
1b Data for capacity calculation and optionally Allocation Constraints
TSO Back-End Systems
TSOs Pre Coupling Systems
2b Cross Zonal Capacities and optionally Allocation Constraints
4a. Coordinator's Price Coupling Results calculation
6b. Coordinator's Preliminary PX Confirmation process
8d. Coordinator's Final Confirmations process
Joint PX IT Systems
4b. Price Coupling Results
6c. Global Preliminary PX confirmation
8e. Global Final Confirmation
PMBs
2d Cross Zonal Capacities and Allocation Constraints
3c. Aggregated Orders
6a. Preliminary PX confirmation
8c. Final Confirmation
2c Cross Zonal Capacities and Allocation Constraints
7. Price Coupling Results (optional per region)
8f. Global Final Confirmation (optional per region)
Verification Systems
8a. Final Confirmation process (optional per region)
TSOs Verification Module
8b. Final Confirmation (optional per region)
9a. Price Coupling Results
Post Coupling Systems
9c. Scheduled Exchanges calculation (optional per region)
TSOs Post Coupling Module
9b. Price Coupling Results and Global Final Confirmation (optional per region)
9d Scheduled Exchanges
9e Scheduled Exchanges
12d Congestion Income verification process
TSO Back-End Systems
12c Congestion Income
11. Scheduled Exchanges Notification
12b Congestion Income verification process
Post Coupling Systems
CCP Shipping System(s)
12a Congestion Income
Congestion Income Distribution systems
10 Trading confirmation
Cross PX clearing and settlement system
Local PX IT Systems
3b. Agregate Orders
5. Check of Price Coupling Results
Pre Coupling Module
Trading System
Verification Coupling Module
Post Coupling Module
3a. Orders
Market Participant
CCP
CCP, PX or TSO
Joint PX
Joint TSO
local PX
local TSO
Pre-Coupling
1a-3c
Coupling
4a-8e
Price Coupling Results not yet verified
Post-Coupling
8f-12d
Price Coupling Results verified

EUPHEMIA:
Description and functioning

PRICE COUPLING OF REGIONS

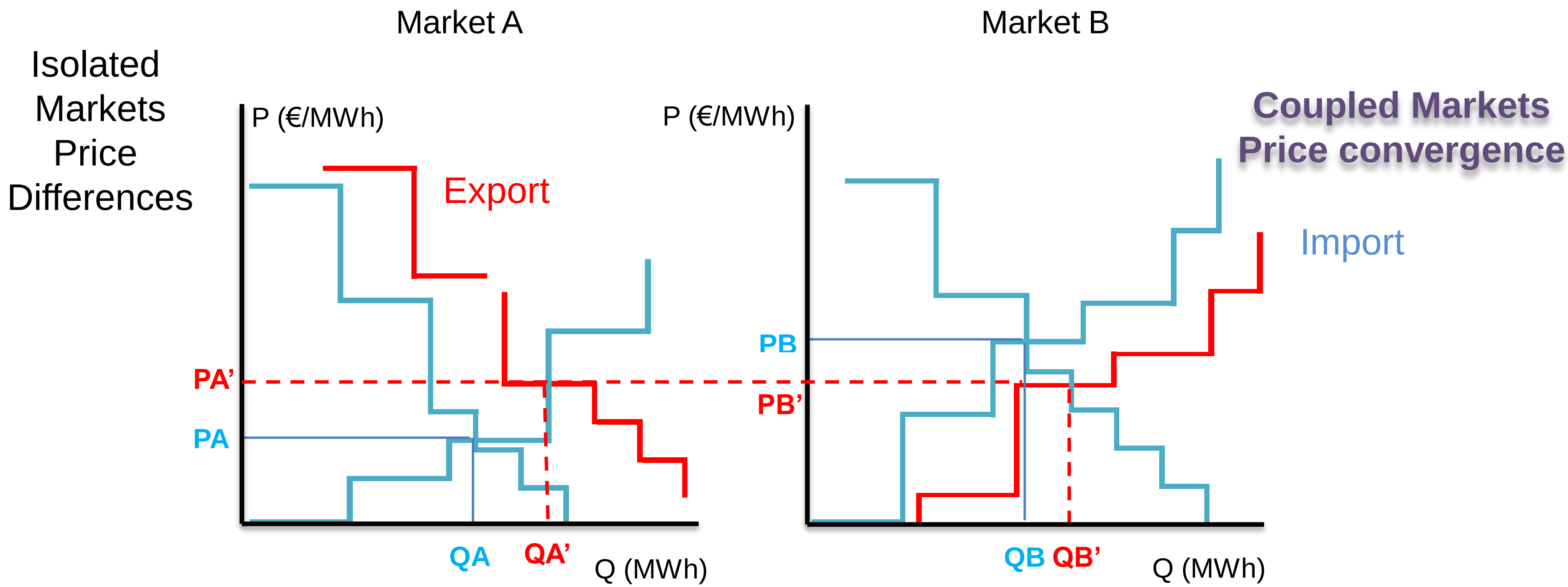
Date: 22 April 2013

Supported by

INTRODUCTION

PCR can have two functions:

- **For Power Exchanges:** **Most competitive price will arise & Overall welfare increases**



- **For TSOs:** **Efficient capacity allocation**

PRICE COUPLING OF REGIONS

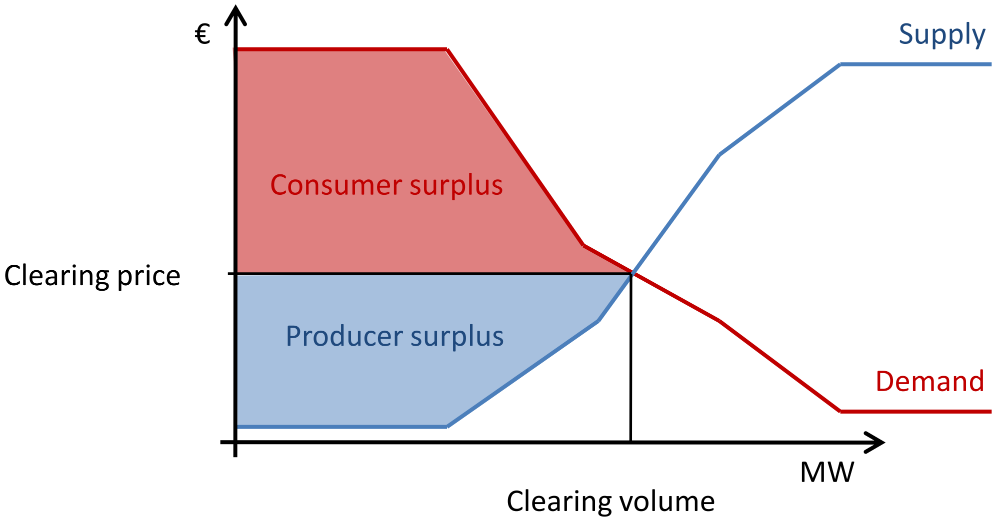
ALGORITHM EUPHEMIA

- EUPHEMIA is an algorithm that solves optimally the market coupling problem.
  - EUPHEMIA means: Pan-European Hybrid Electricity Market Integration Algorithm.
  - Hybrid: It is hybrid because it supports both ATC-based and flow-based network models, both standalone and in combination.

- It maximizes the welfare of the solution

CLEARING PRICES

For one hour in a single Bidding Zone where all lines are uncongested:



- The intersection is the point where, for the same volume, the marginal price the buyers are ready to pay is equal to the marginal price the producers are asking

- But it is also the point where the shaded area (=welfare) is maximal.

PRICE COUPLING OF REGIONS

EUPHEMIA MODELISATION

- **LP example: One single market, no blocks.**
  - **Parameters**
    - $Q_{o,h}$: volume corresponding to order o in period h;
    - $P_{o,h}$: price corresponding to order o in period h;
  - **Variables**
    - $x_{o,h}$: acceptance fraction of order o in period h;

Model

$$\max \sum_{h \in H} \left(\sum_{d \in D_h} x_{d,h} \cdot Q_{d,h} \cdot P_{d,h} - \sum_{s \in S_h} x_{s,h} \cdot Q_{s,h} \cdot P_{s,h} \right)$$

s.t.

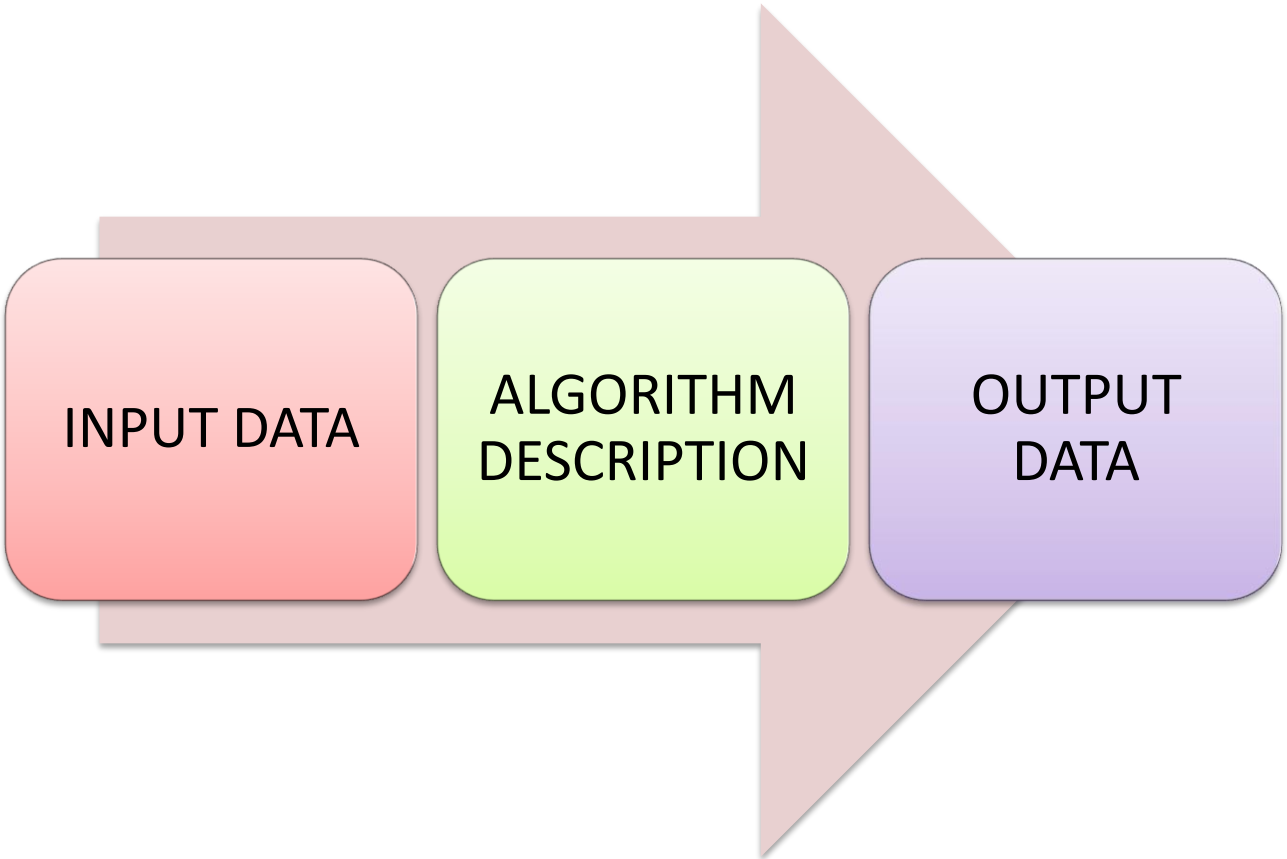
$$\sum_{d \in D_h} x_{d,h} \cdot Q_{d,h} - \sum_{s \in S_h} x_{s,h} \cdot Q_{s,h} = 0 \qquad (\pi_h) \qquad \forall h \in H$$

$$x_{o,h} \le 1 \qquad (\sigma_{o,h}) \qquad \forall h \in H \quad \forall o \in O$$

$$x_{o,h} \ge 0 \qquad \forall h \in H \quad \forall o \in O$$

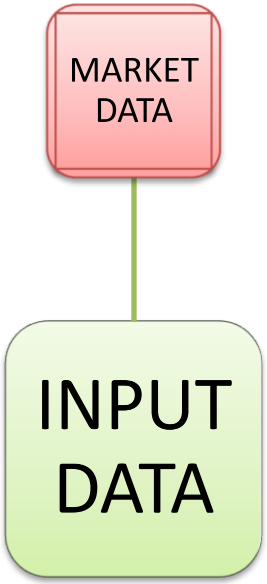
PRICE COUPLING OF REGIONS

1. GENERAL DESCRIPTION



PRICE COUPLING OF REGIONS

INPUT DATA



MARKET DATA

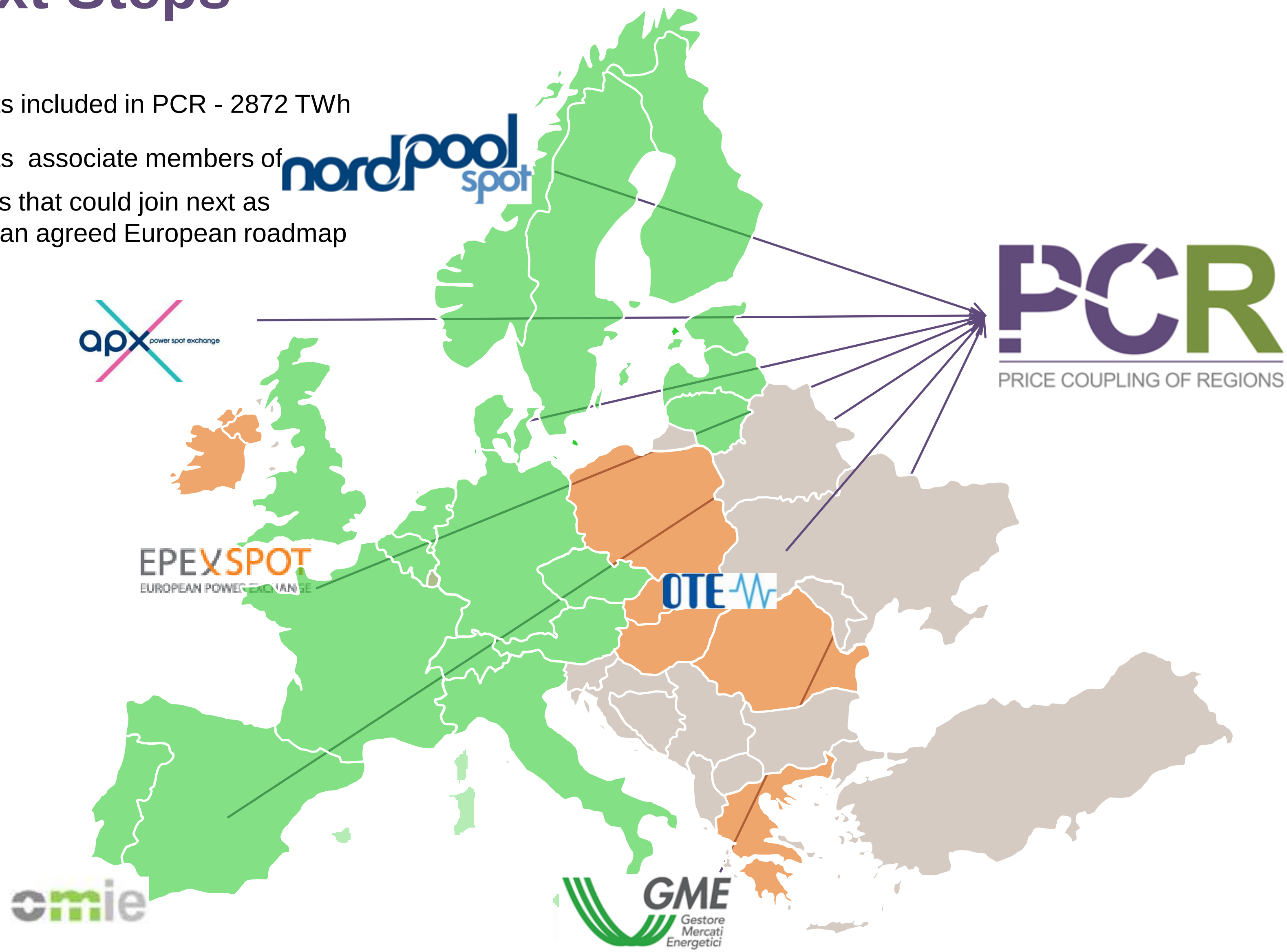
PRICE COUPLING OF REGIONS

Towards Single European Market: Next Steps

Markets included in PCR - 2872 TWh

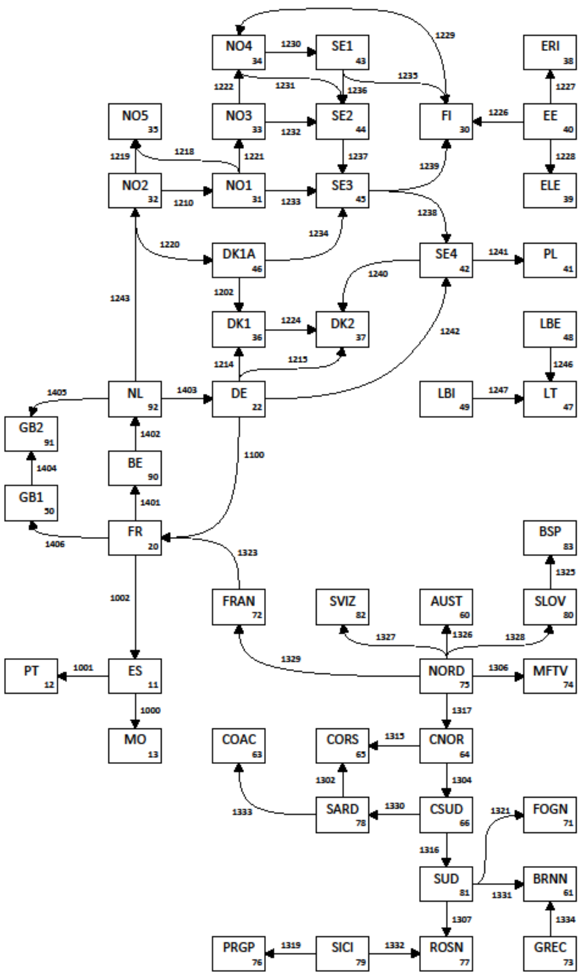
Markets associate members of nordpool spot

Markets that could join next as part of an agreed European roadmap



Euphemia Testing

Example of Euphemia network topology

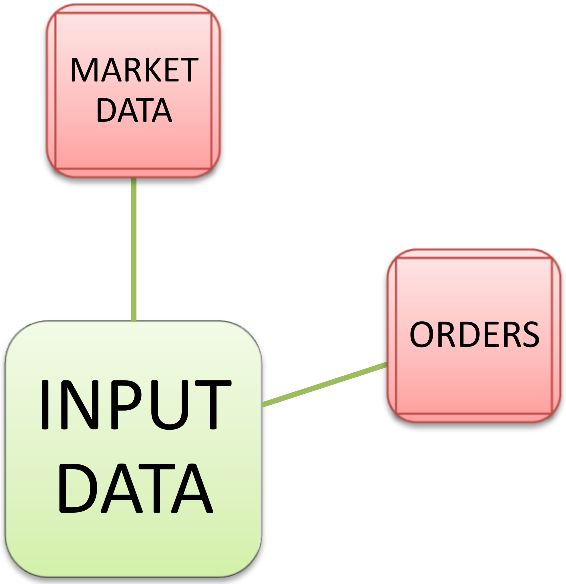


Tested using actual 2011 daily order books:

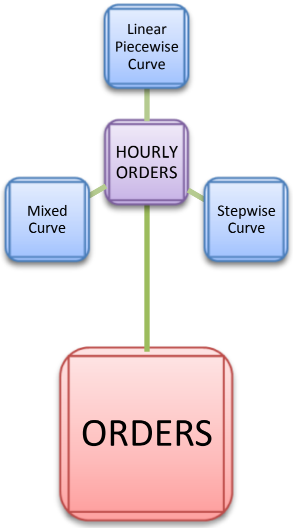
- 44 bidding areas
- 55 ATC lines (3 with losses, 7 with ramping)
- 1250 (regular) block orders (plus 10 flexible and 10 linked)
- 80 complex orders (OMIE)
- 40,000 (non-aggregated) merit orders (GME)
- Total number of breakpoints on aggregated curves: 120,000

PRICE COUPLING OF REGIONS

INPUT DATA



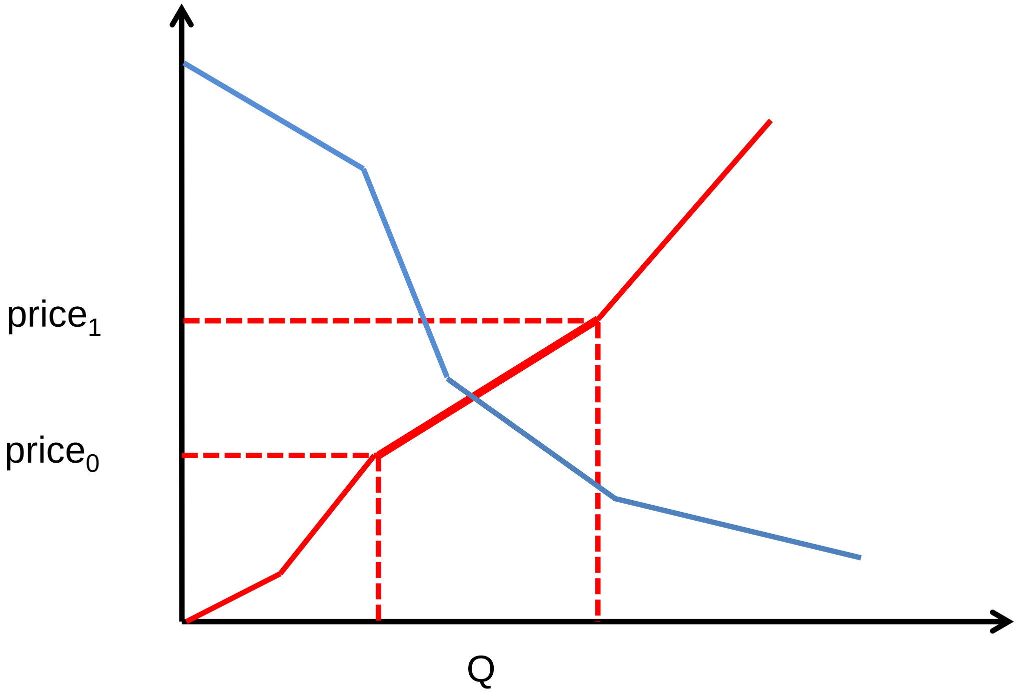
ORDERS


Linear Piecewise Curve
HOURLY ORDERS
Mixed Curve
Stepwise Curve
ORDERS

LINEAR PIECEWISE HOURLY ORDERS

The volume term is delimited by an initial price at which the hourly order starts to be accepted and a final price at which the order is completely accepted.

NORDPOOL and EPEX manages these kind of orders.

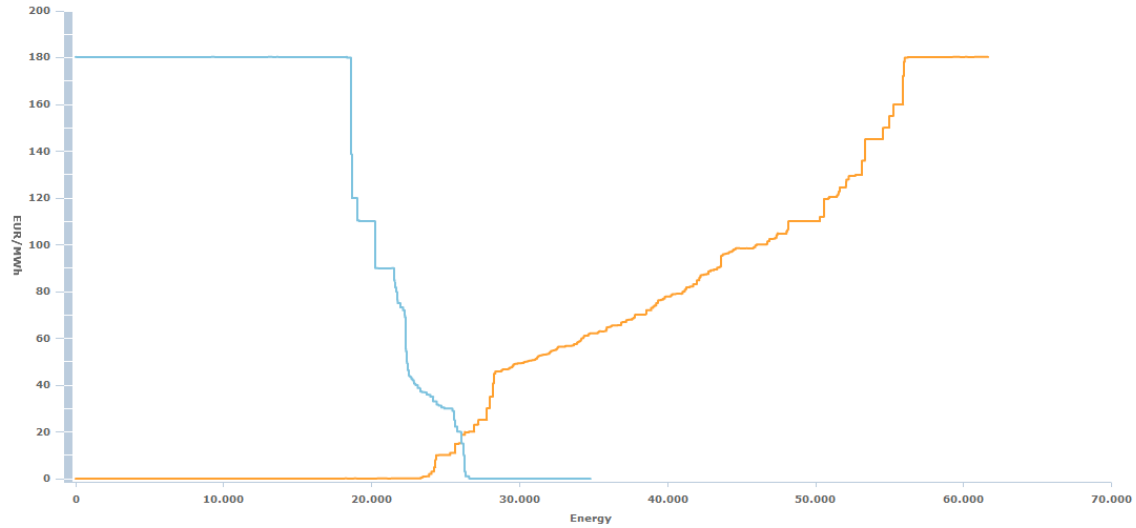


PRICE COUPLING OF REGIONS

STEPWISE HOURLY ORDERS

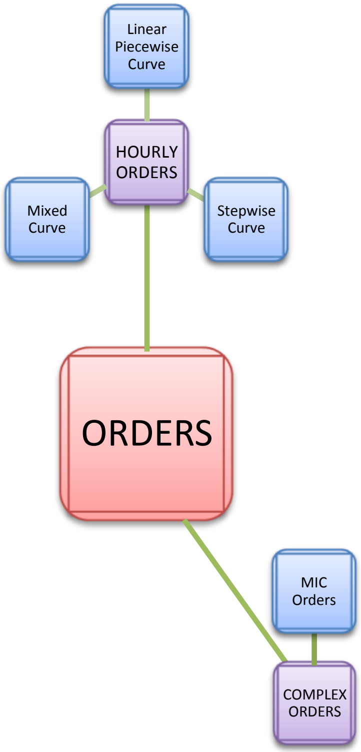
The volume term is delimited by an initial price and a final price which are equal.

OMIE, APX, BELPEX, GME and OTE manage these sort of orders.



PRICE COUPLING OF REGIONS

ORDERS


Linear Piecewise Curve
HOURLY ORDERS
Mixed Curve
Stepwise Curve
ORDERS
MIC Orders
COMPLEX ORDERS

COMPLEX ORDERS. MIC ORDERS

MIC Orders are Stepwise Hourly Orders under an economical condition defined by two terms:

- Tf: Fixed Term in Euros which shows the fixed costs of the whole amount of energy traded in the order.

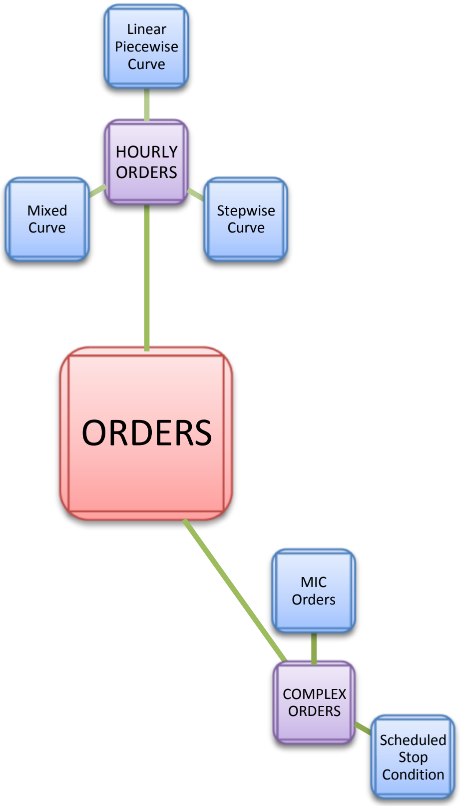
- Tv: Variable Term in Euros per accepted MWh which shows the variable costs of the whole amount of energy traded in the order.

The same acceptance rules for Stepwise Hourly Orders are applied to MIC Orders plus the acceptance of the economic condition which is defined mathematically as:

$$Tf + Tv \cdot (\Sigma_h \Sigma_{o \in h} [q_o \cdot x_o]) \leq \Sigma_h (MCP_h \cdot (\Sigma_{o \in h} [q_o \cdot x_o]))$$

PRICE COUPLING OF REGIONS

ORDERS



Linear Piecewise Curve
HOURLY ORDERS
Mixed Curve
Stepwise Curve
ORDERS
MIC Orders
COMPLEX ORDERS
Scheduled Stop Condition

SCHEDULED STOP CONDITION

- It only applies to deactivated MICs.
-
- It applies to periods declared as Scheduled Stop by the MIC.

- A MIC order can declare a maximum of three periods as Scheduled Stop interval. Periods 1, 2 or 3.

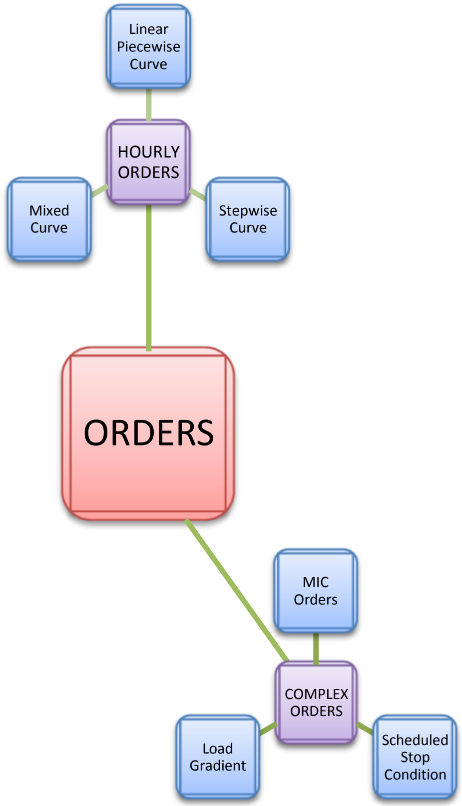
- The hourly sub-orders in the periods declared as Scheduled Stop interval must have decreasing energy as period increases.

- The first hourly sub-order will remain active (although the MIC is deactivated).

- For a deactivated MIC, its active hourly sub-orders corresponding to Scheduled Stop periods will be accepted if they are in/at the money (as any other hourly order).

PRICE COUPLING OF REGIONS

ORDERS



Linear Piecewise Curve
HOURLY ORDERS
Mixed Curve
Stepwise Curve
ORDERS
MIC Orders
COMPLEX ORDERS
Load Gradient
Scheduled Stop Condition

LOAD GRADIENT ORDER

The load gradient condition limits the variation between the accepted volume of an order in a period and the accepted volume of the same order in the adjacent periods.

A Load Gradient Order (LG) is defined by the next terms:

- ***Increase Gradient:*** Maximum increase gradient in MWh.
- ***Decrease Gradient:*** Maximum decrease gradient in MWh.

LG Orders must fulfill the following gradient condition:

$$(\Sigma_{o \in h+1} [q_o \cdot x_o]) \leq (\Sigma_{o \in h} [q_o \cdot x_o]) + \text{Increase Gradient}$$

$$(\Sigma_{o \in h+1} [q_o \cdot x_o]) \geq (\Sigma_{o \in h} [q_o \cdot x_o]) - \text{Decrease Gradient}$$

NEW CONDITION!!

PCR

PRICE COUPLING OF REGIONS

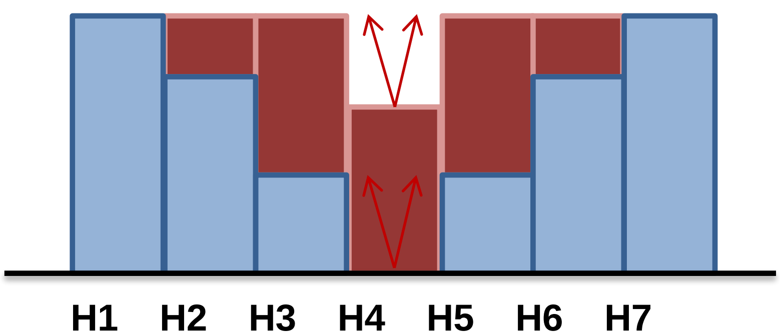
LOAD GRADIENT ORDER

Orders with LG condition will behave like orders without LG as long as no load gradient limit is binding in the optimal solution.

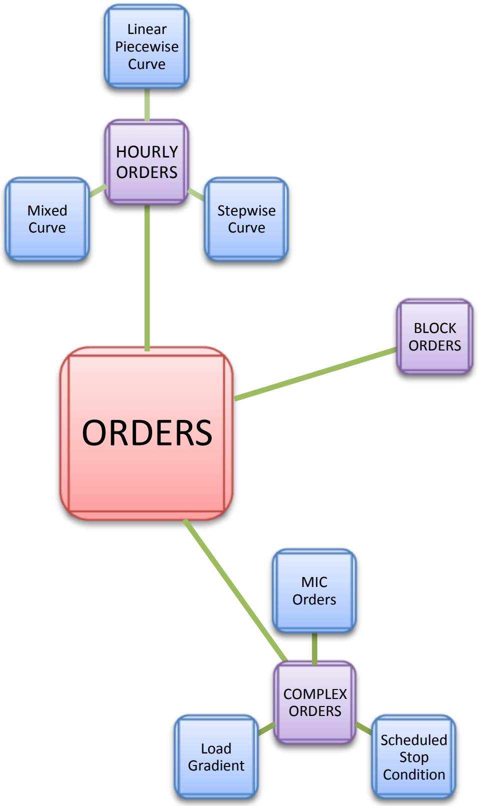
In the presence of active load gradients, hourly supply orders which are out-of-the-money might be accepted if these conditions are fulfilled:

- The money loss incurred will be at least compensated by other adjacent hourly supply orders.
- The compensating orders belong to the same LG order.

NEW CONDITION!!

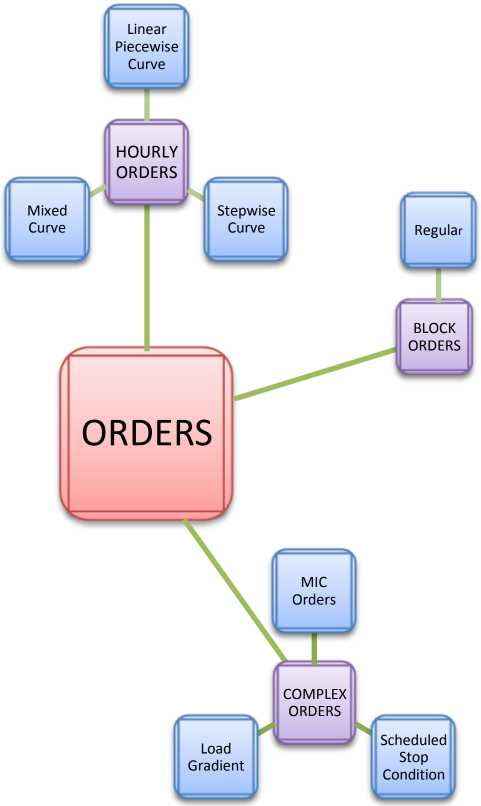


ORDERS



PRICE COUPLING OF REGIONS

ORDERS



PRICE COUPLING OF REGIONS

REGULAR BLOCK ORDERS

A participant can submit a Block order made up of:

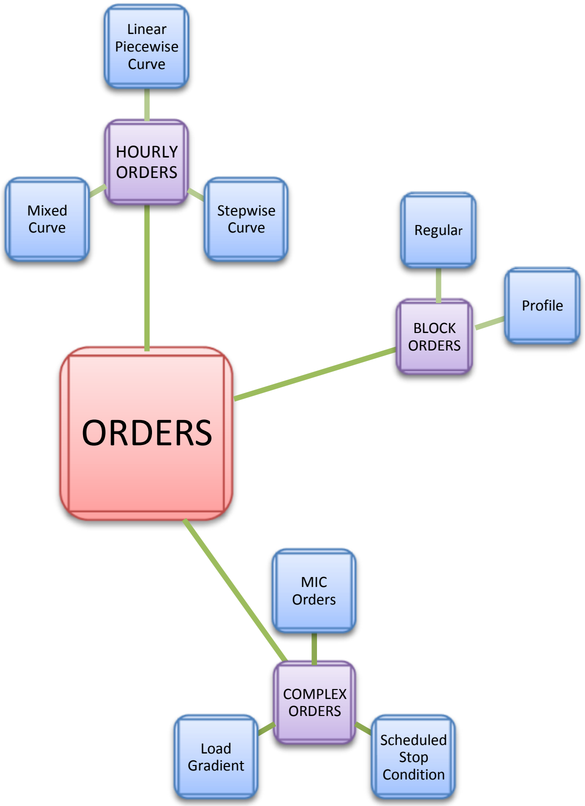
- Block type (buy or sell).
- Block Price: Fixed price limit.
- Block Volume: Volume of the block.
- Block Period: Consecutive hours over which the block spans.

A Block order cannot be accepted partially. Actually, it is either totally rejected or accepted when several blocks have the same characteristics.

BLOCK DESCRIPTION	BLOCK PERIOD	BLOCK PRICE	BLOCK VOLUME
BLOCK B	Hours 1-24	40 Euros	-200 MWh
BLOCK S	Hours 8-12	40 Euros	50 MWh

PCR
PRICE COUPLING OF REGIONS

ORDERS



PRICE COUPLING OF REGIONS

PROFILE BLOCK ORDERS

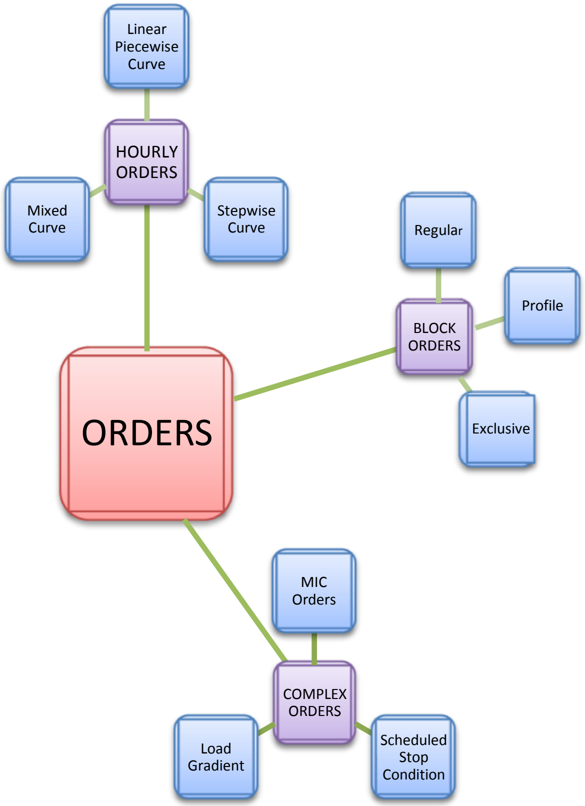
A Profile Block Order is a particular sort of Regular Block Order in which the kill or fill condition is associated with an acceptance percentage. The participant can submit a Block order made up of:

- Block type (buy or sell).
- Block Period: Hours over which the block spans.
- Block Price: Fixed price limit.
- Minimum Acceptance Ratio: Minimum volume acceptance ratio in case the block is accepted.
- Block Volume: Volume of the block.

BLOCK DESCRIPTION	BLOCK PERIOD	BLOCK PRICE	MINIMUM ACCEPT RATIO	BLOCK VOLUME
SELL BLOCK A	Hours 1-24 Hours 8-12	40 Euros	50%	80 MWh 220 MWh

PRICE COUPLING OF REGIONS

ORDERS



PRICE COUPLING OF REGIONS

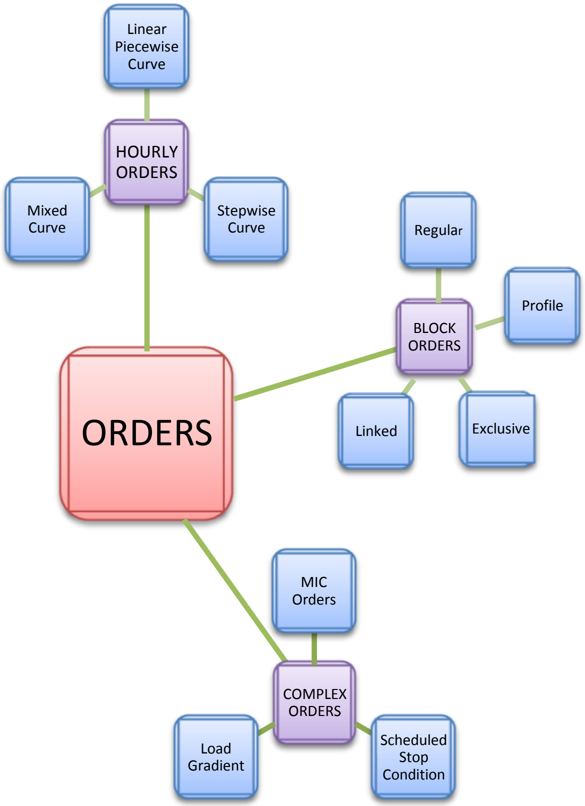
EXCLUSIVE BLOCK ORDERS

An Exclusive group is defined as:

- A set of Profile Block Orders in which the sum of the acceptance ratios cannot exceed 1.
- The acceptance rules of Profile Block Orders are totally applied.
- There is no limit on the number of blocks that belong to the same Exclusive Group.
- There is a special case in which profile blocks are defined to have a minimum acceptance ratio of 1 (fill-or-kill). This fact implies that at most one of the blocks inside this Exclusive Group can be accepted.

PCR
PRICE COUPLING OF REGIONS

ORDERS



PRICE COUPLING OF REGIONS

LINKED BLOCK ORDERS

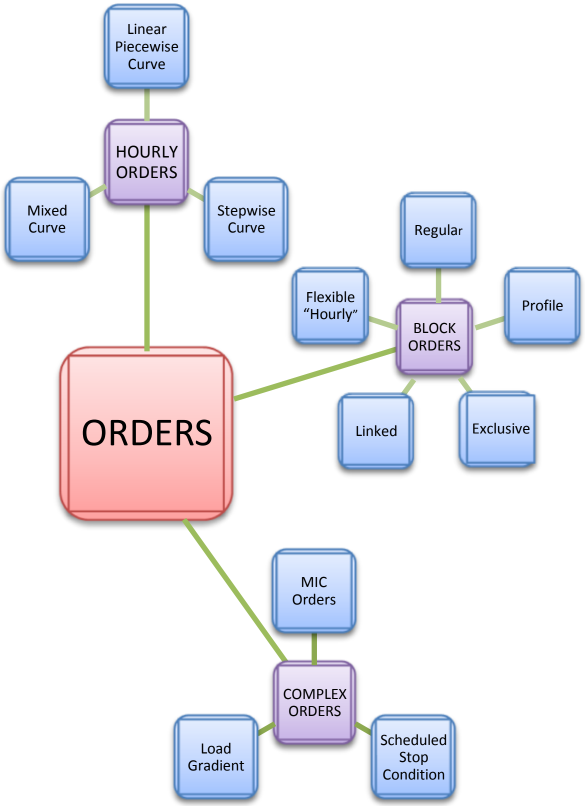
Regular and Profile Block orders may be linked together:

- The acceptance of individual Block Orders depends on the acceptance of other Block Orders.

Two kinds of Linked Regular Blocks:

- *Parent Block*
- *Child Block*

ORDERS



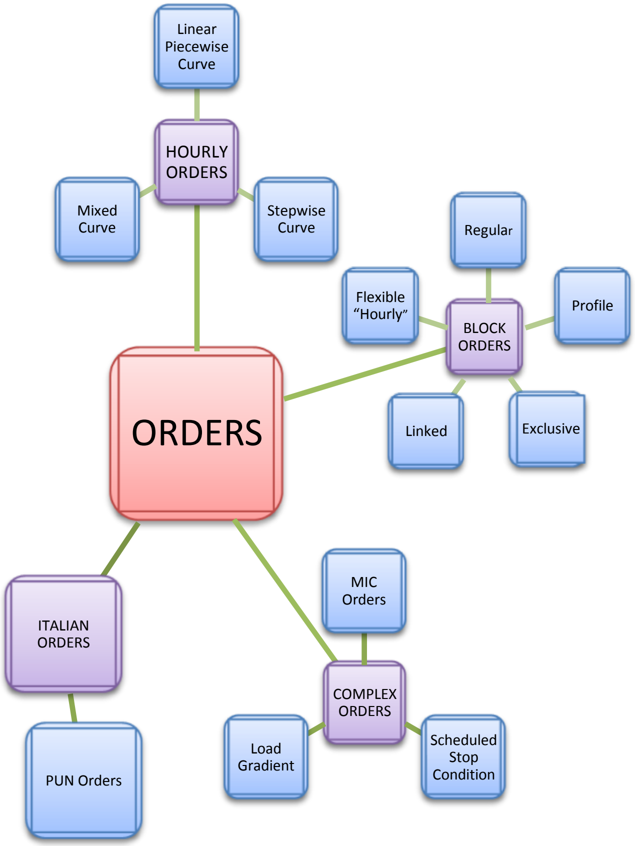
Linear Piecewise Curve
HOURLY ORDERS
Mixed Curve
Stepwise Curve
Regular
Flexible "Hourly"
BLOCK ORDERS
Profile
ORDERS
Linked
Exclusive
MIC Orders
COMPLEX ORDERS
Load Gradient
Scheduled Stop Condition

FLEXIBLE HOURLY BLOCK ORDERS

- A Flexible Hourly Order is a Regular Block Order which lasts only one period. The period is said to be flexible and will be determined by the algorithm.
- In case of acceptance, it will only occur in one hour, but the hour is flexible and that means it is not defined by the participant.
- The acceptance rules of regular Block Orders are totally applied.

PRICE COUPLING OF REGIONS

ORDERS



Linear Piecewise Curve
HOURLY ORDERS
Mixed Curve
Stepwise Curve
Regular
Flexible "Hourly"
BLOCK ORDERS
Profile
ORDERS
Linked
Exclusive
MIC Orders
ITALIAN ORDERS
COMPLEX ORDERS
Load Gradient
Scheduled Stop Condition
PUN Orders

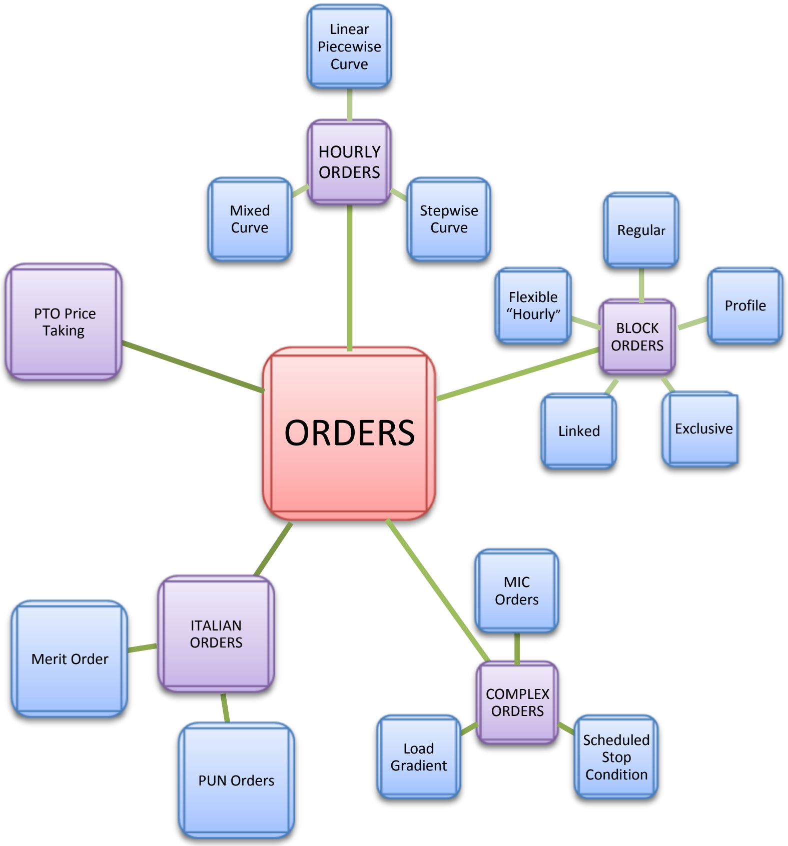
PUN REQUIREMENT

Prezzo Unico Nazionale (PUN)

- National demand of Italy (with the exception of storage pumps) is submitted to a single purchase price (PUN), regardless of its location
- This price must ensure that the revenues coming from the consumers paying the PUN must be equal the revenues that would have come from consumers with zonal prices (minimum tolerance accepted)
- Acceptance/rejection of buying bids subject to PUN must respect the following conditions
  - Buying bids in-the-money (Offered price > PUN) are fully accepted
  - Buying bids out-of-the-money (Offered price < PUN) are fully rejected
  - Buying bids at-of-the-money (Offered price < PUN) can be curtailed
- In order to respect the aforementioned requirements, PUN and zonal prices must be calculated simultaneously (PUN cannot be calculated ex-post)

PCR
PRICE COUPLING OF REGIONS

ORDERS



PRICE COUPLING OF REGIONS

PUN ORDERS

In GME:

- Selling offers receive their Bidding Zone marginal price.
- Some of the buying bids pay their Bidding Zone price. These are called no-PUN bids, related to pump plants **and buying bids on cross-border capacities**
- The rest of the buying bids (the ones related to national consumption) pay the common national PUN price which is different from their Bidding Zone price → ***PUN ORDERS***

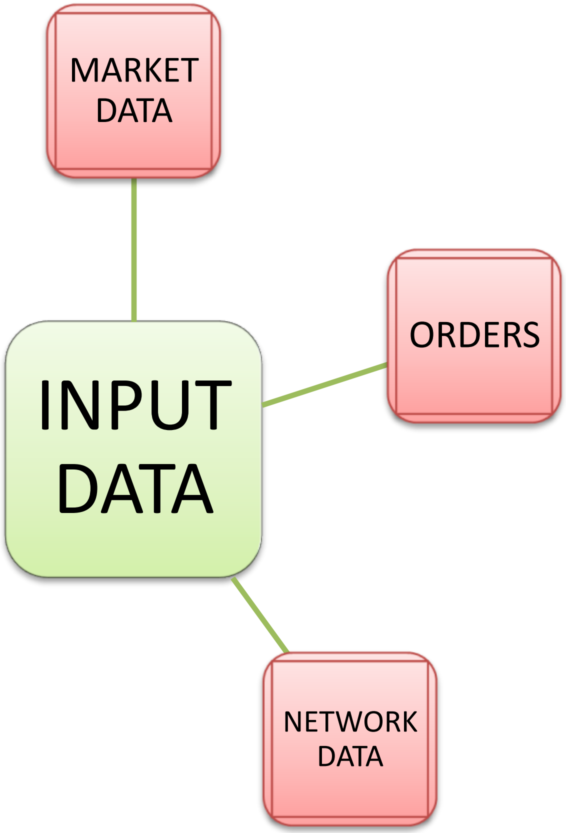
This PUN price is defined as the average price of GME zonal marginal market prices, weighted by the purchase quantity assigned to PUN Orders in each Bidding Zone. That is:

$$P_{PUN} * \Sigma_z Q_z = \Sigma_z P_z * Q_z + \epsilon$$

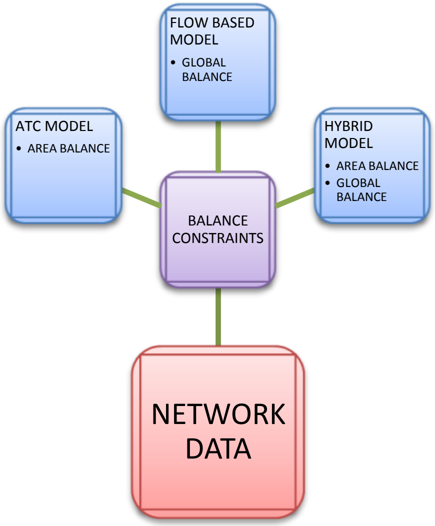
$$-1\,€ \leq \epsilon \leq 5\,€$$

PRICE COUPLING OF REGIONS

INPUT DATA



NETWORK DATA



BALANCE CONSTRAINTS

The energy balance concept is defined as the global supply must be equal to the global demand of all markets involved. Depending on the manner the interconnections are modeled, there are the following:

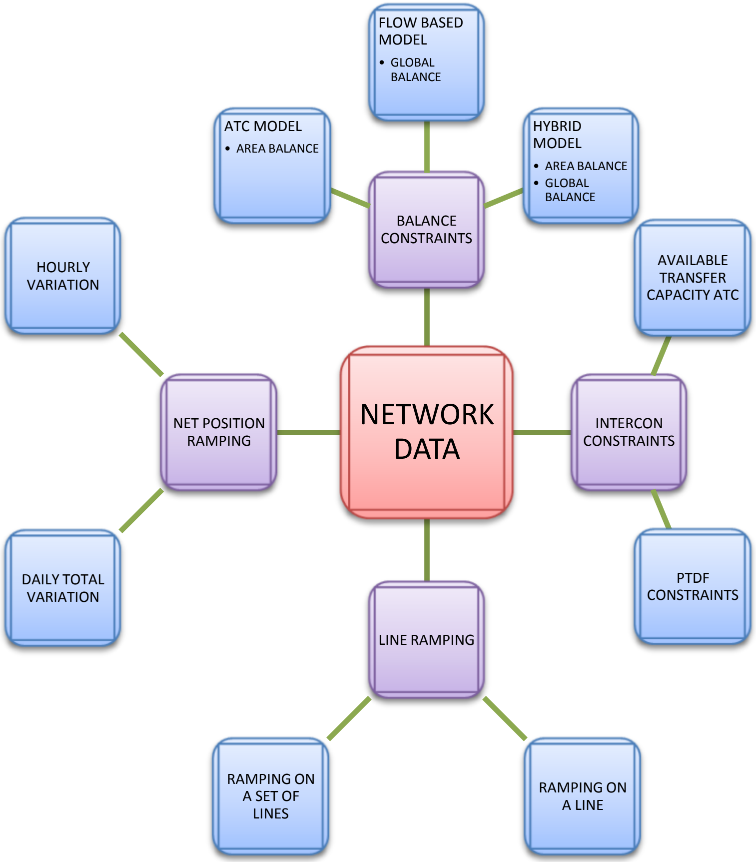
- ***ATC network model:*** Where the interconnection between bidding zones is modeled as if they were connected via a DC cable. The network is described as a set of lines between bidding zones with Available Transfer Capacity (ATC). Each line can support up to its ATC.

- ***Flow-based network model:*** Also known as PTDF model, with the bidding zones connected in a meshed network with AC cables. It expresses the constraints arising from Kirchhoff's laws and physical elements of the network in the different contingency scenarios considered by the TSOs. It translates those into linear constraints on the net positions of the different Bidding Zone in the same Balancing Area.

- ***Hybrid model:*** A mixture between these two.

PRICE COUPLING OF REGIONS

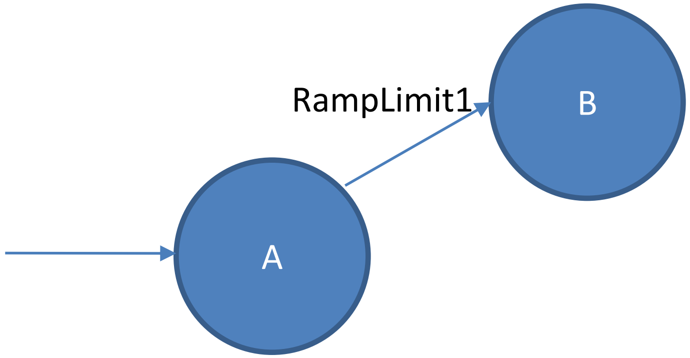
NETWORK DATA



PRICE COUPLING OF REGIONS

INTERCONNECTORS RAMPING

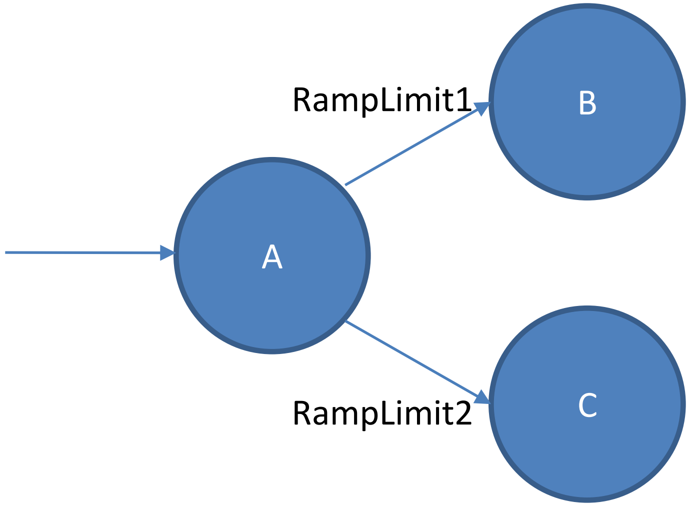
- EUPHEMIA supports ramping limit between two consecutive hours



PRICE COUPLING OF REGIONS

INTERCONNECTORS RAMPING

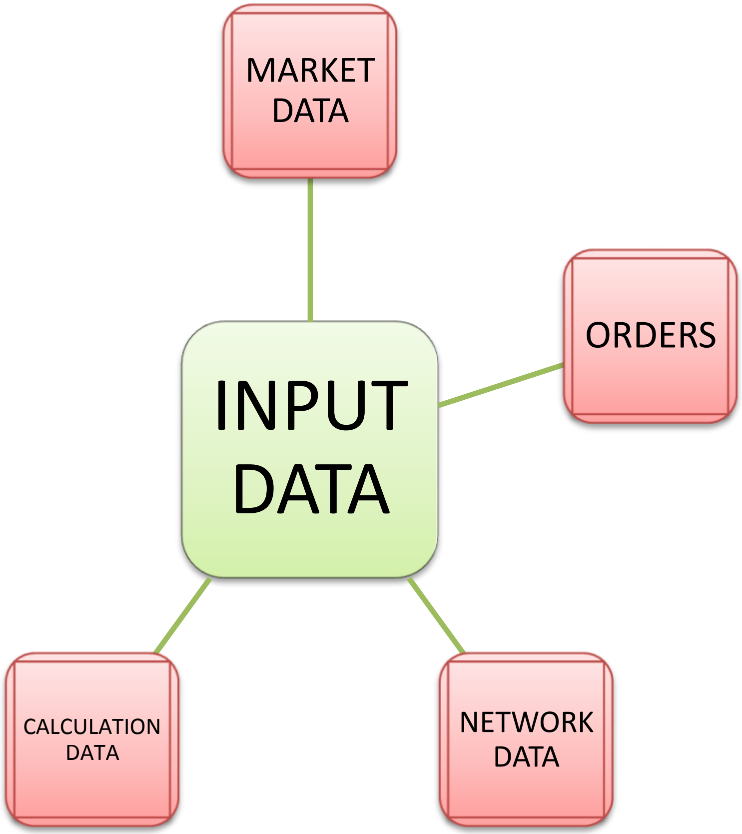
- EUPHEMIA supports ramping limit between two consecutive hours in a list of links



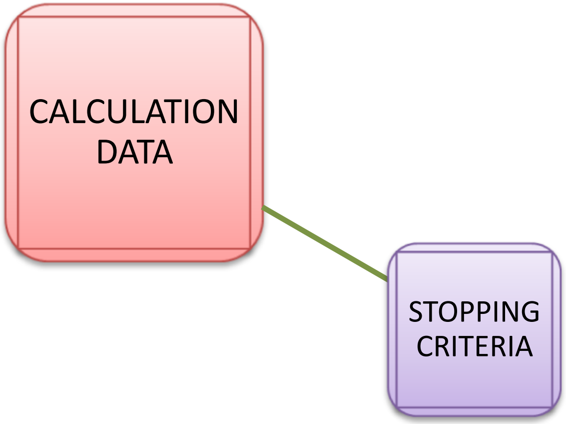
INTERCONNECTORS RAMPING

- EUPHEMIA supports cumulative ramping limit between two consecutive hours in a list of links

INPUT DATA


MARKET DATA
ORDERS
INPUT DATA
CALCULATION DATA
NETWORK DATA

CALCULATION DATA



PRICE COUPLING OF REGIONS

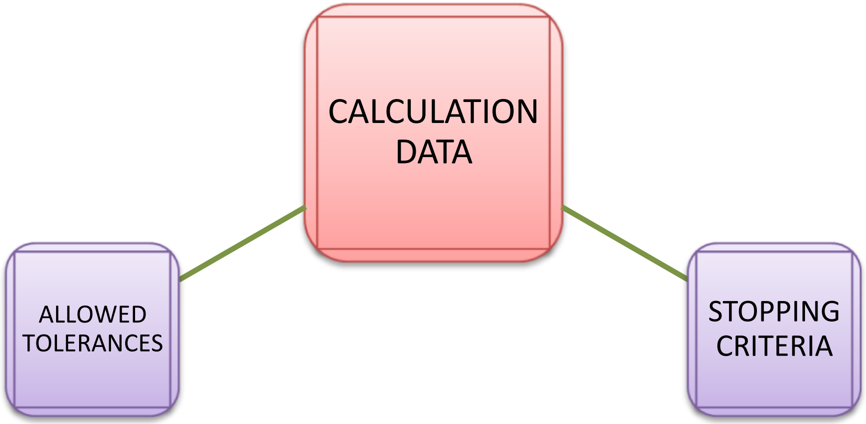
STOPPING CRITERIA

The algorithm will stop calculating whenever one of the following situations is reached:

- The algorithm has explored all branches.
- The time limit has been overtaken.
- The limit number of iterations has been overtaken.

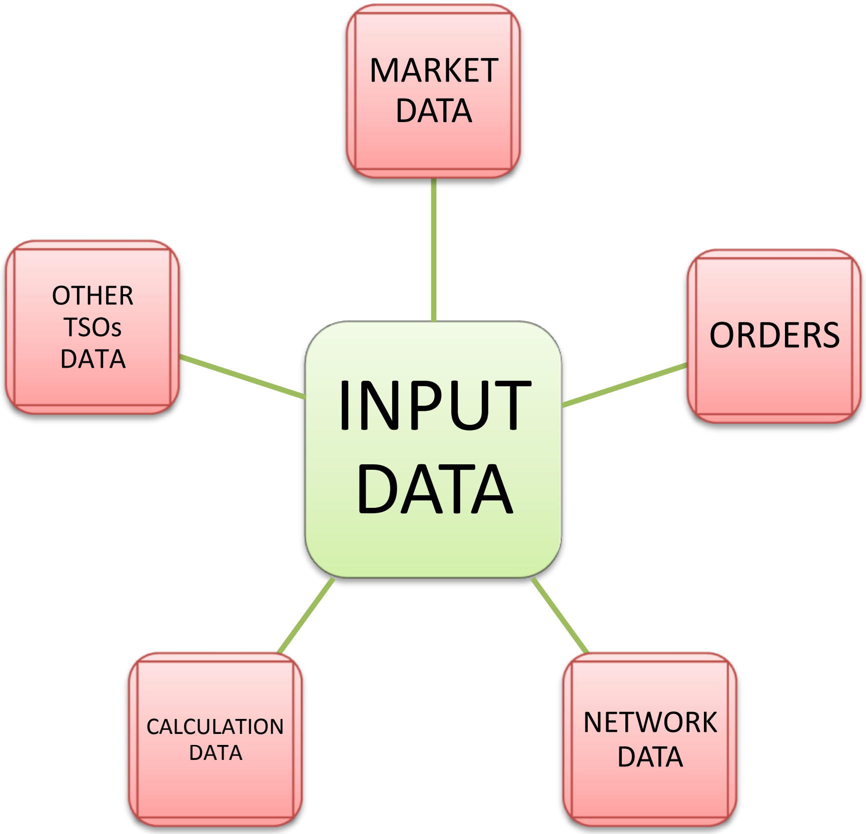
PRICE COUPLING OF REGIONS

CALCULATION DATA



PRICE COUPLING OF REGIONS

INPUT DATA


MARKET DATA
OTHER TSOs DATA
INPUT DATA
ORDERS
CALCULATION DATA
NETWORK DATA

OTHER TSOs DATA

PRICE COUPLING OF REGIONS

TARIFFS

In an ATC or hybrid network model, the DC cables might be operated by merchant companies which differ from TSOs. These companies levy the cost they incur for each passing MW to the cable.

- When the line is congested:

$$(1\text{-loss}_{u,l,h}) * MCP_{to} – MCP_{from} \geq \text{tariff}_{u,l,h}$$

$$(1\text{-loss}_{d,l,h}) * MCP_{from} – MCP_{to} \geq \text{tariff}_{d,l,h}$$

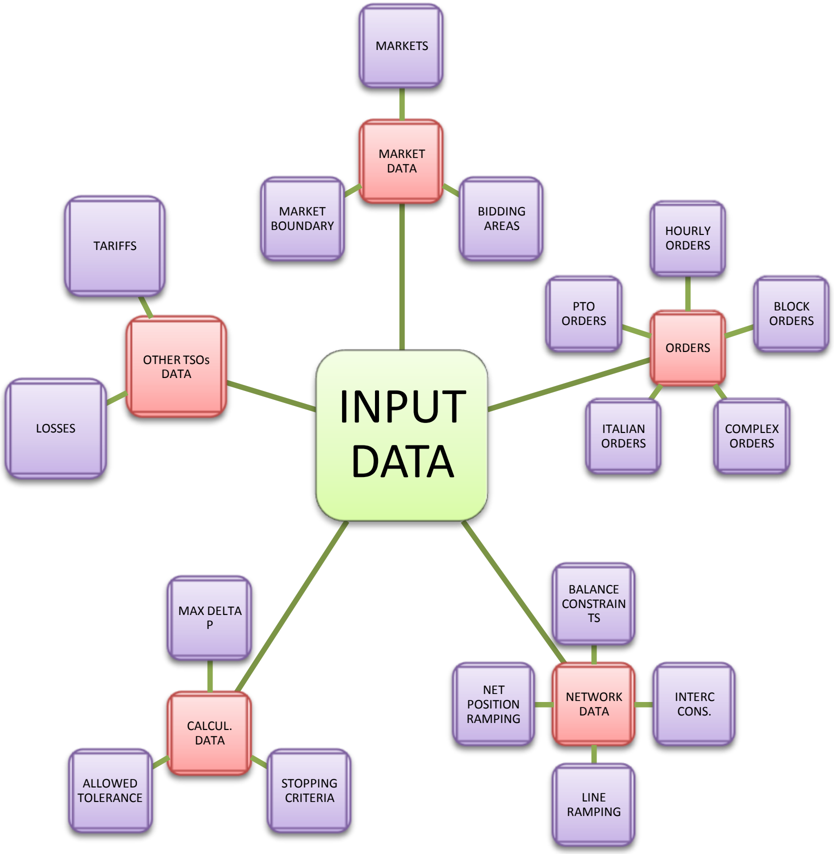
- When the line is uncongested:

$$(1\text{-loss}_{u,l,h}) * MCP_{to} – MCP_{from} = \text{tariff}_{u,l,h}$$

$$(1\text{-loss}_{d,l,h}) * MCP_{from} – MCP_{to} = \text{tariff}_{d,l,h}$$

PCR
PRICE COUPLING OF REGIONS

INPUT DATA



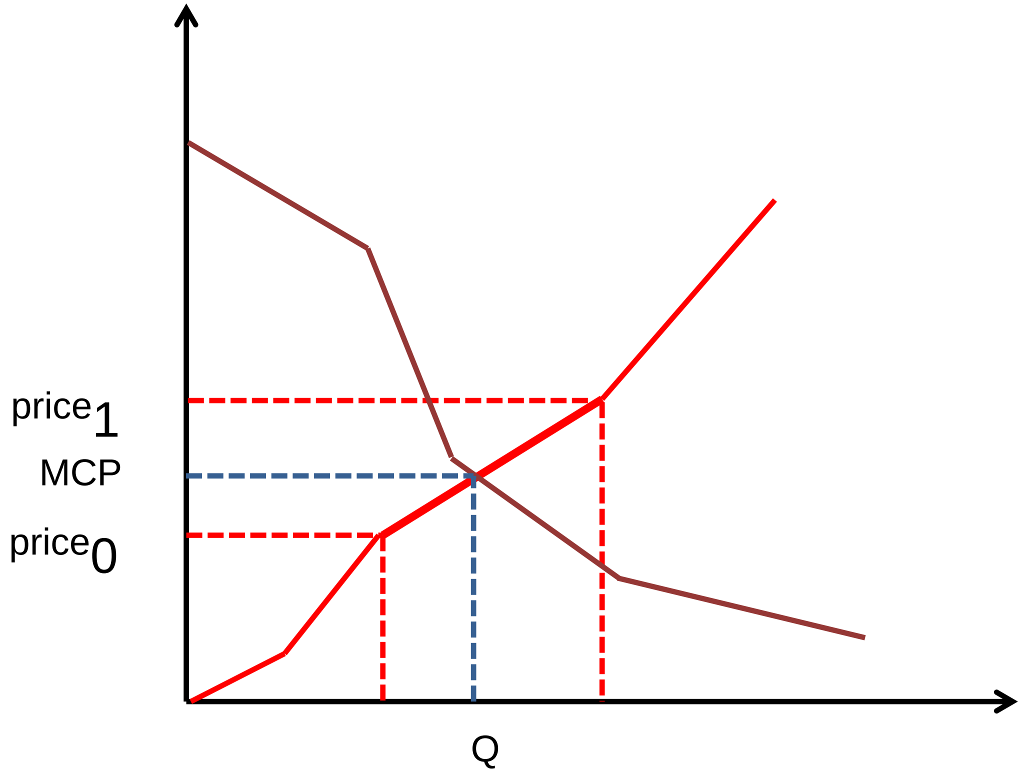
PRICE COUPLING OF REGIONS

ALGORITHM Introduction

HOURLY LINEAR ORDERS

- Linear orders provide two prices
  - $price_0$: at which the order starts to be accepted
  - $price_1$: at which the order is totally accepted
- Therefore
  - $price_0 < price_1$ for supply orders
  - $price_0 > price_1$ for demand orders

HOURLY LINEAR ORDERS



MATCHING LINEAR ORDERS

- EUPHEMIA provides solutions such that
  - Orders in-the-money are fully accepted
    - Supply where $price_0 < MCP$
    - Demand where $price_1 > MCP$
  - Orders out-of-the-money are fully rejected
    - Supply where $price_1 > MCP$
    - Demand where $price_0 < MCP$
  - Orders at-the-money are accepted to the corresponding proportion
    - Acceptance ratio = $(MCP-price_0) / (price_1-price_0)$

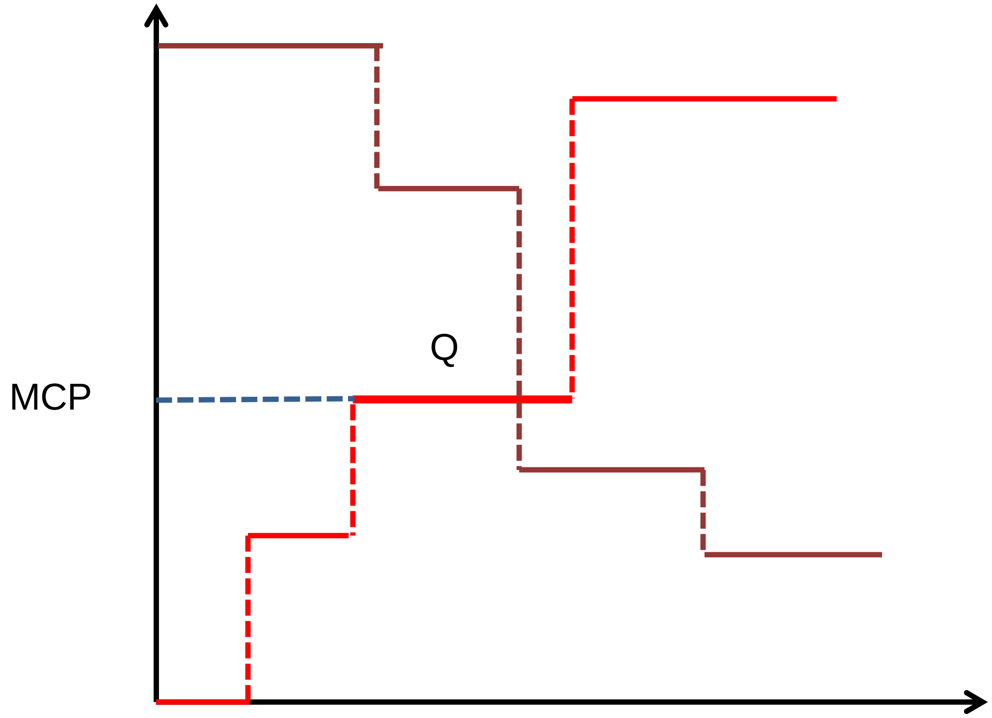
PRICE COUPLING OF REGIONS

HOURLY STEP ORDERS

- Hourly step orders are defined by
  - A side (buy or sell)
  - A volume
  - A limit price
- They express the willingness of a participant to sell/buy up to a certain quantity if the market price is above/below a certain price
- They are provided in the form of an aggregate curve (price-quantity points)

PRICE COUPLING OF REGIONS

HOURLY STEP ORDERS



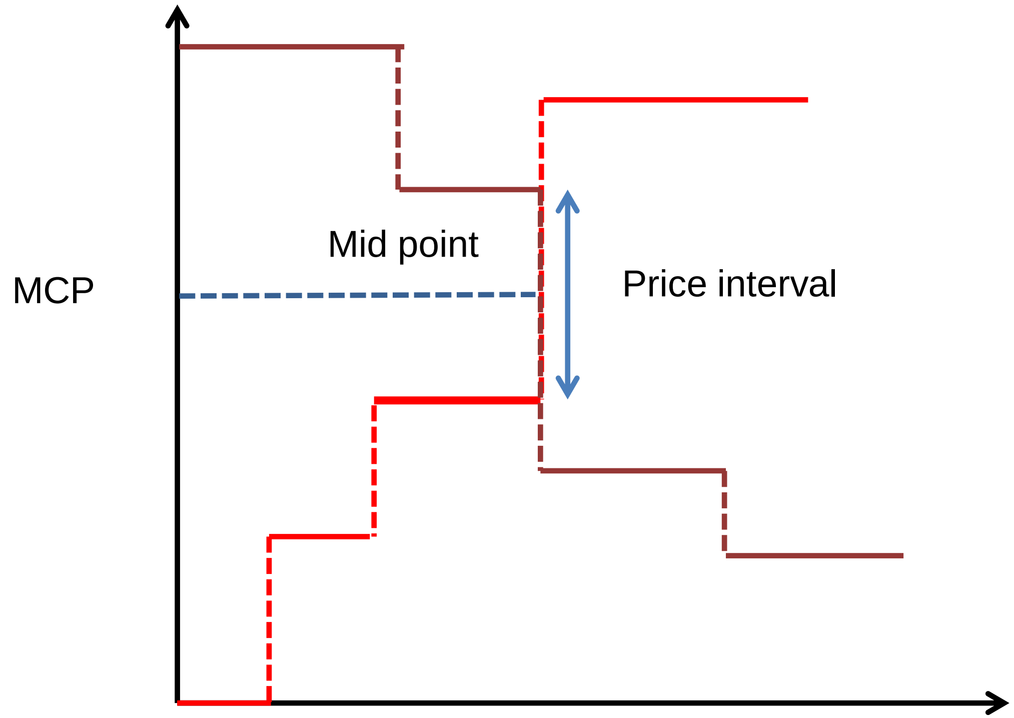
MATCHING STEP ORDERS

- EUPHEMIA provides solutions such that
  - Orders in-the-money are fully accepted
    - Supply at price < MCP
    - Demand at price > MCP
  - Orders out-of-the-money are fully rejected
    - Supply at price > Market Clearing Price (MCP)
    - Demand at price < Market Clearing Price (MCP)
  - Orders at-the-money can be curtailed

PRICE COUPLING OF REGIONS

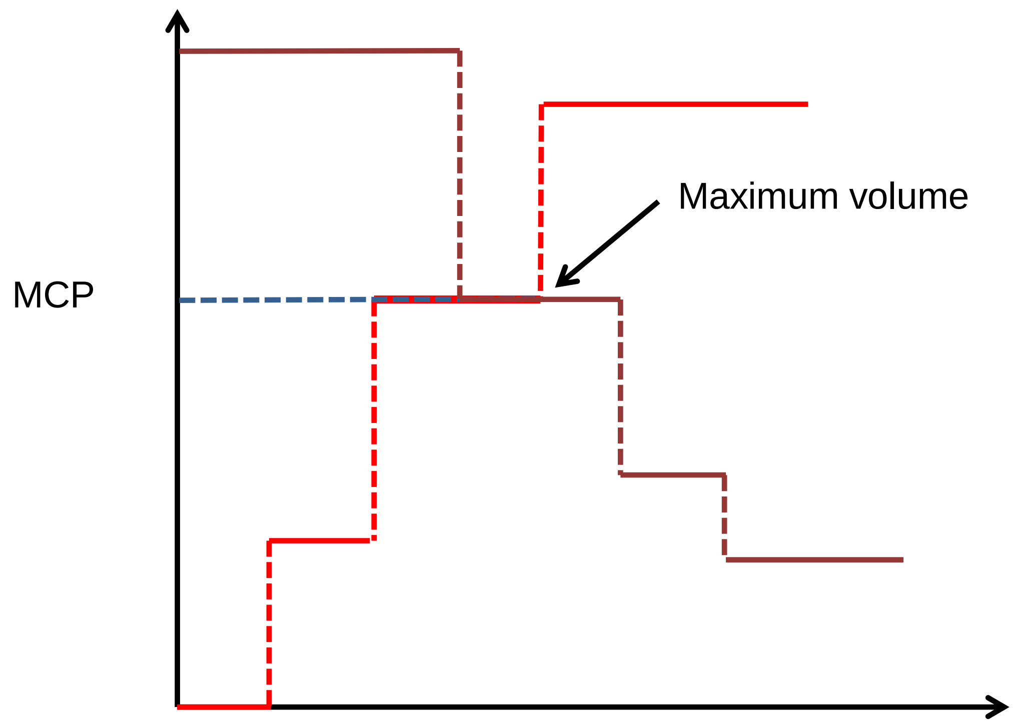
PRICE INDETERMINACY RULE

- Whenever a price interval is admissible
- EUPHEMIA minimizes the distance to the middle of the price interval



VOLUME INDETERMINACY RULE

- Maximize traded volume



BLOCK ORDERS

- Block orders are defined by
  - A side (buy or sell)
  - A volume on each period
  - A limit price
- They express the willingness of the participant to get either accepted in full on several periods or be totally rejected

PRICE COUPLING OF REGIONS

MATCHING BLOCK ORDERS

- EUPHEMIA provides solutions where
  - Block orders that are accepted are in-the-money, i.e. there are no paradoxically accepted blocks (PAB)
    - Weighted average of the *published* MCPs is above limit price for a supply block
    - Weighted average of the *published* MCPs is below limit price for a demand block
  - Block orders that are rejected might sometimes happen to be in-the-money
    - Those are called paradoxically rejected (PRB)

PRICE COUPLING OF REGIONS

EUPHEMIA MAIN IDEA

- For a fixed selection of blocks, the PCR Market Coupling Problem **can be written as a LP** (or QP if linear orders)
  - Solving this problem yields volumes and prices satisfying the Market Rules
  - If there is no Paradoxically Accepted Block with respect to those prices, the block selection and the prices form a feasible solution to the MCP
- The optimal solution between those is the one with the highest welfare

PCR
PRICE COUPLING OF REGIONS

ALGORITHM Description

A case with 3 blocks orders (1)

Block 1	Block 2	Block 3
In = 1 / Out =0		
1	1	0
1	0	1
0	1	1
1	0	0
0	1	0
0	0	1
0	0	0
1	1	1

Welfare
75000
74000
76500
66700
65000
67050
56000
75900

PRICE COUPLING OF REGIONS

A case with 3 blocks orders (2)

- For each block selection
  - Check whether it creates Paradoxically Accepted Blocks

Welfare
75000
~~74000~~
76500
~~66700~~
65000
67050
56000
~~75900~~

PRICE COUPLING OF REGIONS

A case with 3 blocks orders (3)

- Among the selections without PABs, return the one giving the largest welfare

Welfare
75000
No solution
76500
No solution
65000
67050
56000
No solution

A case with 3 blocks orders (4)

Block 1	Block 2	Block 3		Welfare
In = 1 / Out =0				
1	1	0		75000
1	0	1		No solution
0	1	1		76500
1	0	0		No solution
0	1	0		65000
0	0	1		67050
0	0	0		56000
1	1	1		No solution

PRICE COUPLING OF REGIONS

Algorithm

- For each block selection
  - Check whether it creates Paradoxically Accepted Blocks
  - Among the selections without PABs, return the one giving the largest welfare
- But this is not efficient
  - If there are 100 blocks, there are $2^{100} \approx 10^{30}$ possibilities…

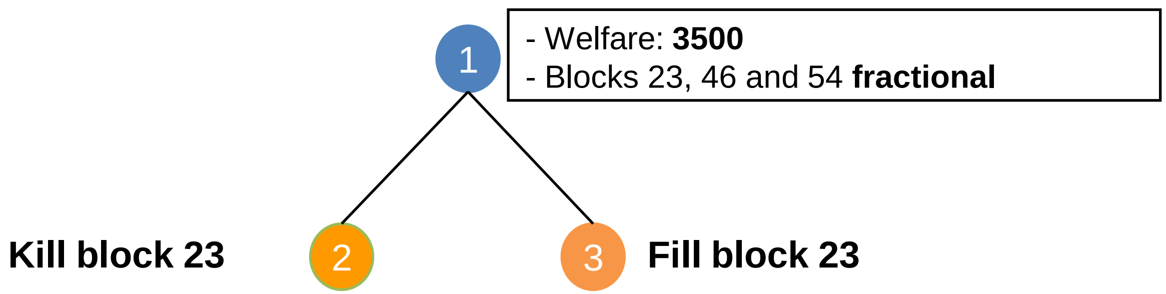
PRICE COUPLING OF REGIONS

BRANCH AND BOUND (1)

- Branch-and-Bound method is a way to
  - Search among all these block selections in a structured way
  - Find feasible solutions quickly
  - Prove early that large groups of these selections cannot hold good solutions
- The idea is as follows
  - Try first without the kill-or-fill requirement
  - If the solution happens to have no fractional block, OK
  - If it has, then
    - Select one block which is fractional
    - Create two subproblems (called *branches*)
      - One where the block is killed
      - One where the block is filled
  - Continue to explore until there is no unexplored branch

PRICE COUPLING OF REGIONS

BRANCH AND BOUND (2)



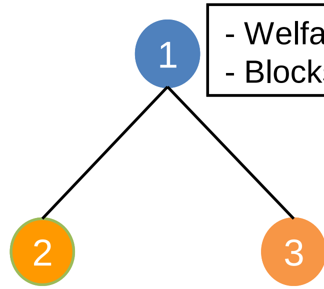
Branching

- Blocks 23, 46 and 54 are accepted fractionally in the current solution
  - Algoritm pick one block (23) and create two subproblems
    - One where the block is forced to be rejected
    - One where the block is forced to be accepted
  - And we try again

fractional

BRANCH AND BOUND (3)

- Welfare: **3500**
- Blocks 23, 46 and 54 fractional



Kill block 23
- Welfare: **3050**
- all blocks integral

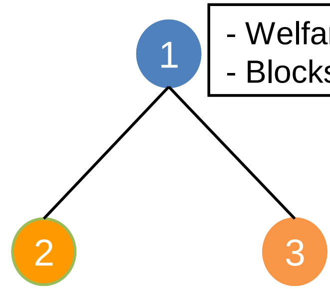
Price Problem

- Once a candidate solution has been found, we check whether there exists prices compatible with
  - Block selection (i.e. no PAB)
- If such prices exist, we have a solution

Has solution!

fractional   New solution found

BRANCH AND BOUND (3)



- Welfare: **3500**
- Blocks 23, 46 and 54 fractional

Kill block 23
- Welfare: **3050**
- all blocks integral, there exist prices
→ feasible solution found

Fill block 23
- Welfare: **3440**
- all blocks integral

Constraint added

- Whenever the block selection is rejected because a block is paradoxically accepted, it is created a new branch with an additional constraint

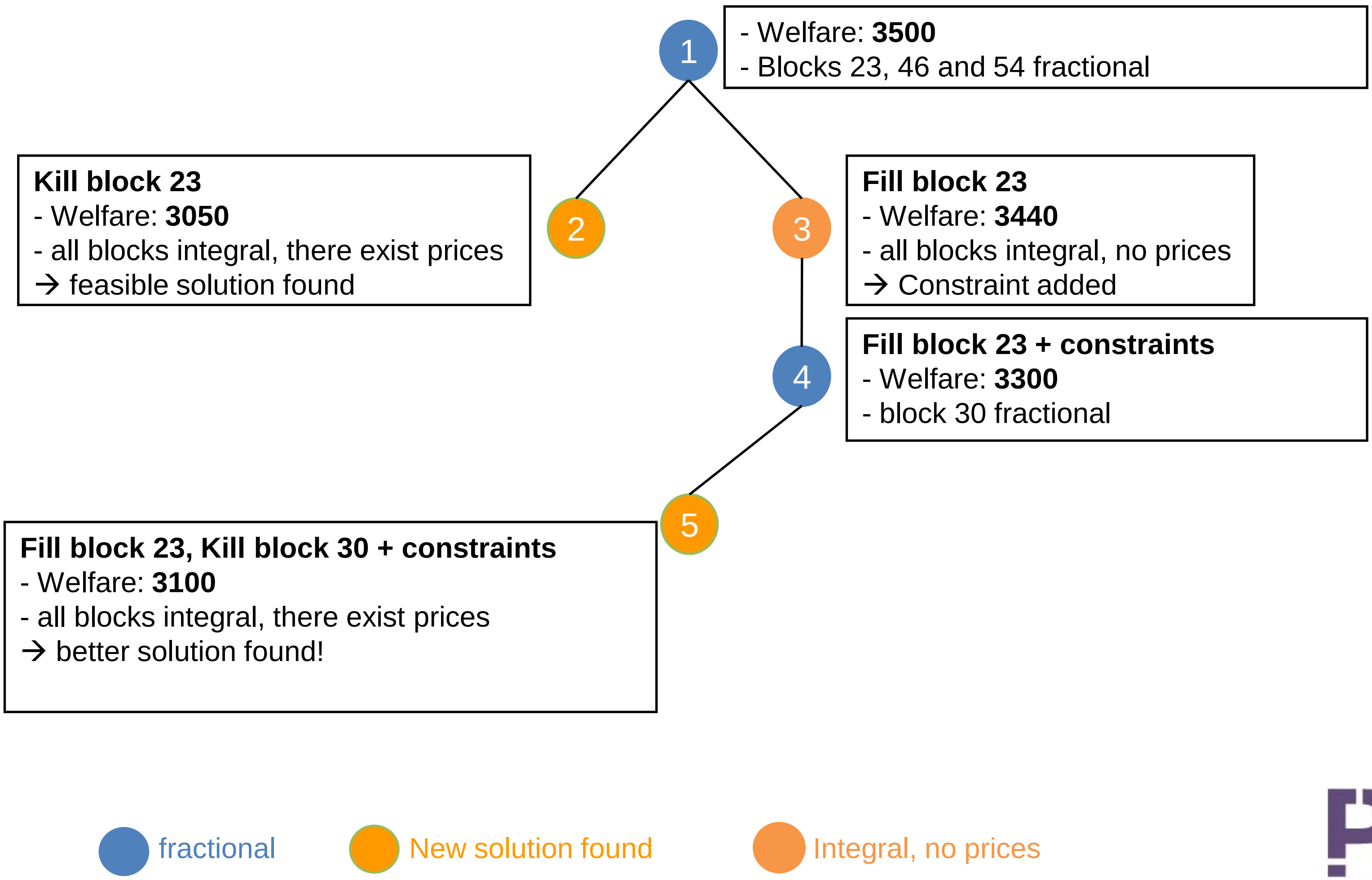
Price Problem

- Once a candidate solution has been found, we check whether there exists prices compatible with
  - Block selection (i.e. no PAB)
- If such prices exist, we have a solution

fractional New solution found Integral, no prices

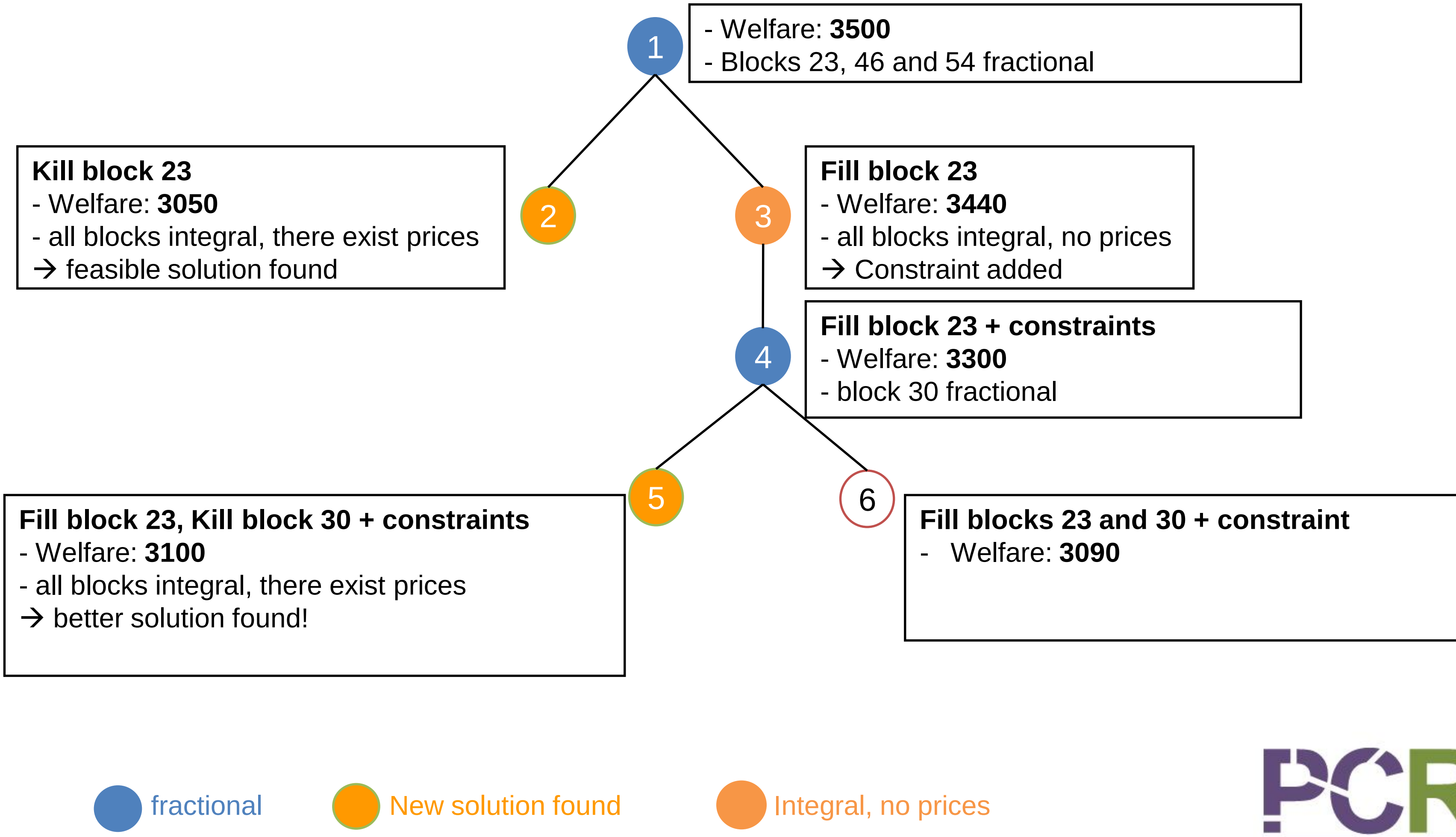
PRICE COUPLING OF REGIONS

BRANCH AND BOUND (4)



PRICE COUPLING OF REGIONS

BRANCH AND BOUND (5)



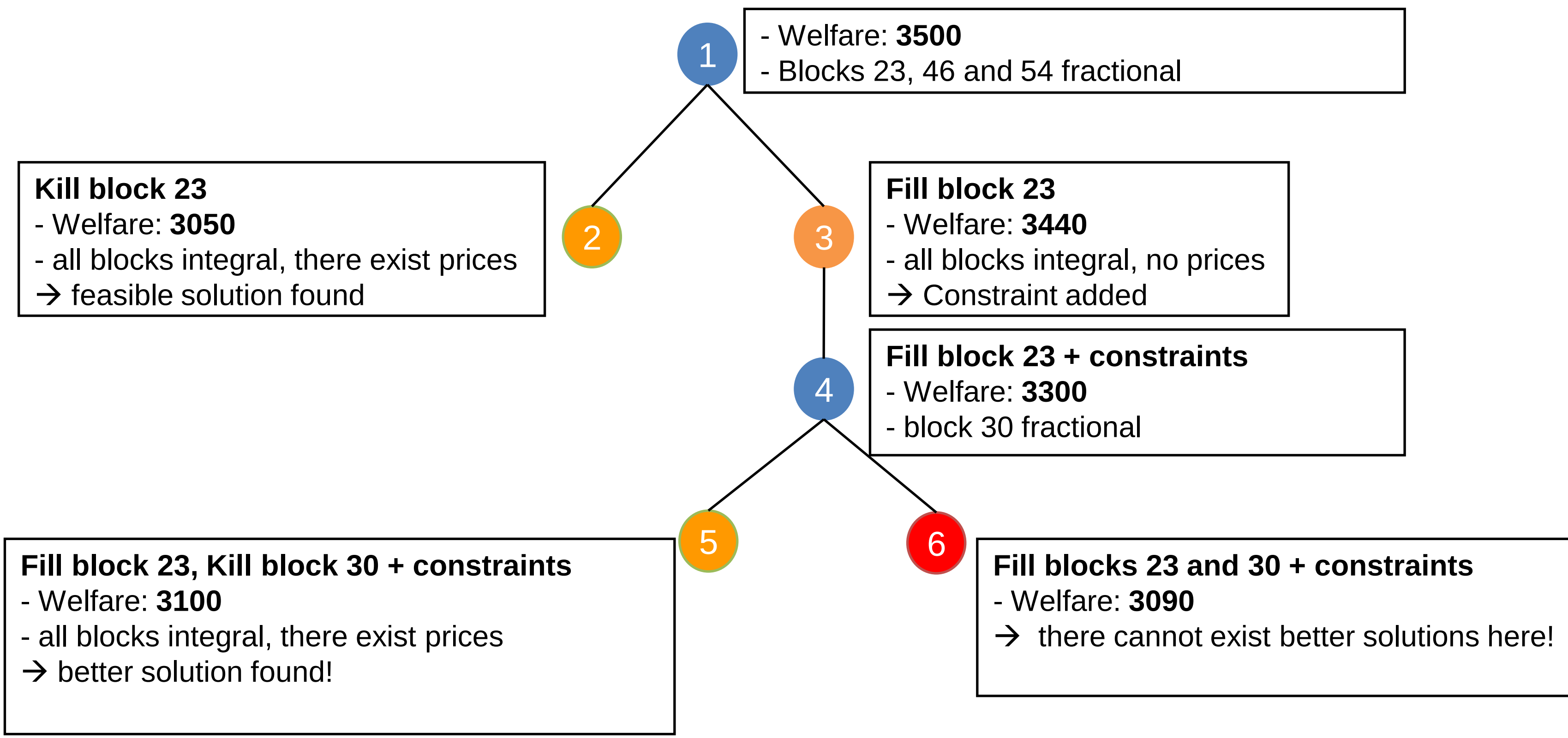
PRICE COUPLING OF REGIONS

BOUNDING

- Suppose we already have a good valid solution (e.g. node 5)
- When exploring one branch (e.g. node 6), we might see that even if we have not yet reached an integer solution, the current solution is not better than the best one we already have.
- Then we can decide to stop exploring this branch, since it will never lead to a better welfare than the current best solution

PRICE COUPLING OF REGIONS

BRANCH AND BOUND (5)



fractional | New solution found | Integral, no prices | Pruned by bound

PRICE COUPLING OF REGIONS

OUTPUT DATA

PRICE COUPLING OF REGIONS

OUTPUT DATA

Euphemia results

- Price per bidding zone
- Net position per bidding zone
- Flows per interconnection
- Matched energy per block, MIC and PUN orders

Iberian Market Results

- Matched energy per Bid Unit

PRICE COUPLING OF REGIONS

Thank You

PRICE COUPLING OF REGIONS