Balancing markets

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Energy Markets
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Introduction

What is balancing?

Maintaining equilibrium between generation and demand, at any moment

Excess supply has to be stored. Storage capacity is limited (mainly hydro storage, e.g. Coo, Plate Taille). An excess induces a frequency increase.
A **lack of supply** implies energy is taken from inertia of rotating machines, which decelerate. A lack induces a frequency decrease.

Some effects of imbalance:

- frequency deviates from 50Hz
- loss of synchronism
- blackout

In case of imbalance, compensation must be fast!
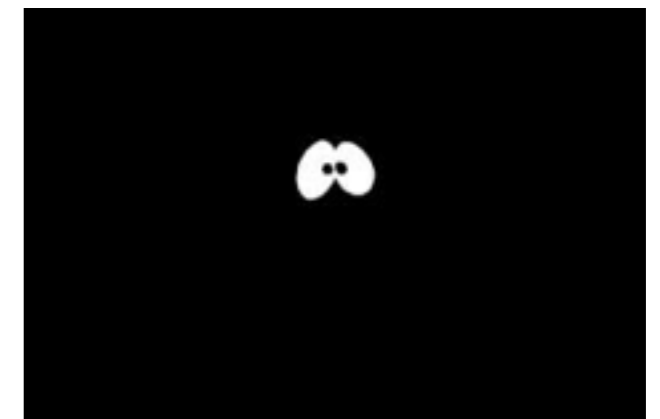
A progressive process

- Planning generation investments, interconnection capacity (adequacy)
- Long term schedules (e.g. Nuclear maintenance/refuelling)
- Forward and long term energy contracts
- Ancillary services provision
- Day ahead market
- Intraday market
- Real time balancing

Balancing and Ancillary Services Markets

According to ENTSO-E:

Balancing: situation after gate closure in which a TSO acts to ensure that demand is equal to supply, in and near real time.

Ancillary services: range of functions which TSOs contract so that they can perform balancing.
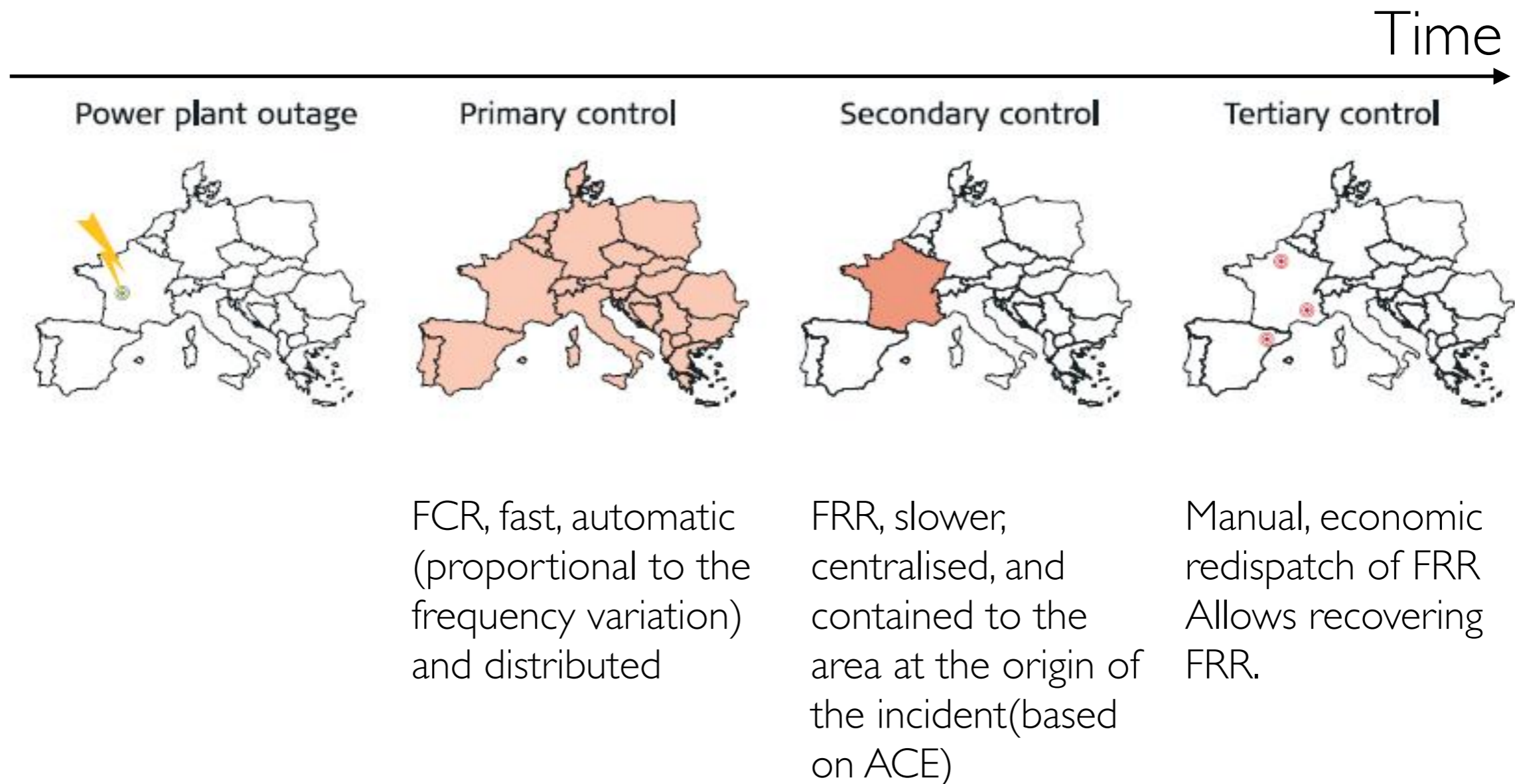
Market: system to ease exchange of ancillary services.

Remark: Distinguish energy trading from service (i.e. balancing capacity) trading!

Some types of services

- **Primary** *aka* "frequency containment" reserve (FCR), to maintain system frequency with automatic and very fast responses proportional to frequency drop.

- **Secondary** *aka* "frequency restoration" reserve (FRR), which can provide additional energy when needed

- Black start capability, to restart a grid following a blackout

- Provision of reactive power, for voltage regulation

Balancing effort in time and space

Time →

Power plant outage	Primary control	Secondary control	Tertiary control

| | FCR, fast, automatic (proportional to the frequency variation) and distributed | FRR, slower, centralised, and contained to the area at the origin of the incident(based on ACE) | Manual, economic redispatch of FRR Allows recovering FRR. |

The Area Control Error (**ACE**) is, for a considered quarter and expressed in MW, the difference between the scheduled and measured values of the interchanges of the Belgian control area, taking into account the effect of frequency bias.

In this lecture

We focus mainly on

- the time period from the ancillary services provision to real time balancing

- FRR, unless stated otherwise

Most observations are based on the Belgian case but similar observations hold for other systems

Trends

Broaden range of services, and widen the range of providers. Do not rely only on generators (classical scheme) anymore, but also use **demand response**, consumers changing their operating patterns. Why? Because share of steerable generation is decreasing with the rise of the exploitation of renewable energy sources (RES).

Increase of harmonisation of the rules for balancing and for using ancillary services in order to improve pan-European competition, thus costs and efficiency. Hence the Notion of **coordinated Balancing Area** http://www.emissions-euets.com/internal-electricity-market-glossary/598-coordinated-balancing-area

How it works

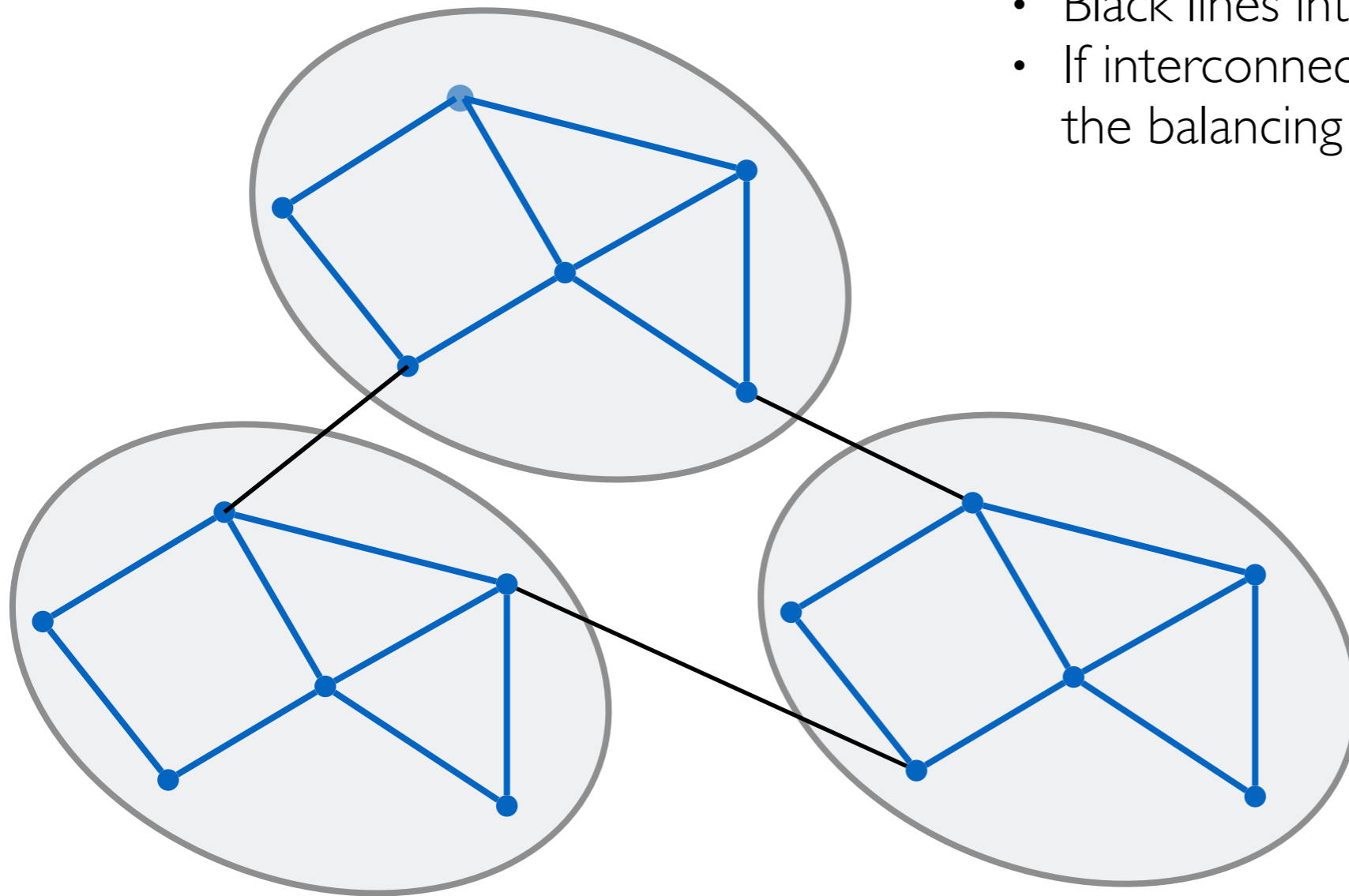# Balancing is achieved through a divide and conquer approach

The synchronous system (e.g. continental Europe) is divided in balancing areas (BAs) (e.g. country). By definition, each balancing area must be in balance. In each zone the balance is imposed through balance responsible parties (BRP), which must all be in balance independently.

In practice each BRP of a balancing area is never perfectly in balance. If the sum of the imbalances of all the BRPs does not cancel out, the TSO responsible of that area has to restore balance, using ancillary services. BRPs are incentivised to be in balance through an economical signal.

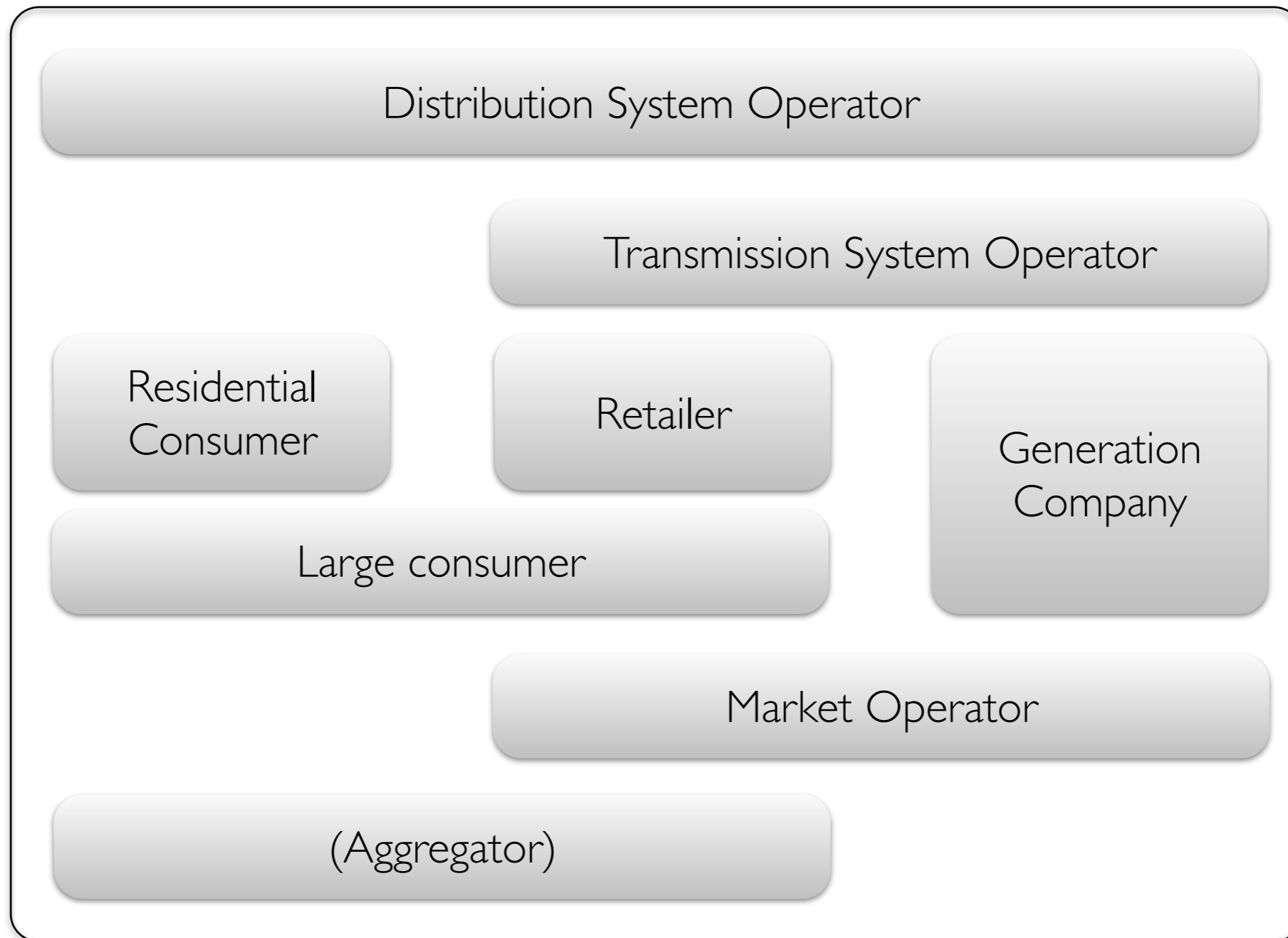(All these concepts will be defined in the next slides)

Example: 3 balancing areas

- Each gray ellipsis represents a BA
- Blue lines are intra-area HV lines
- Black lines interconnect BAs
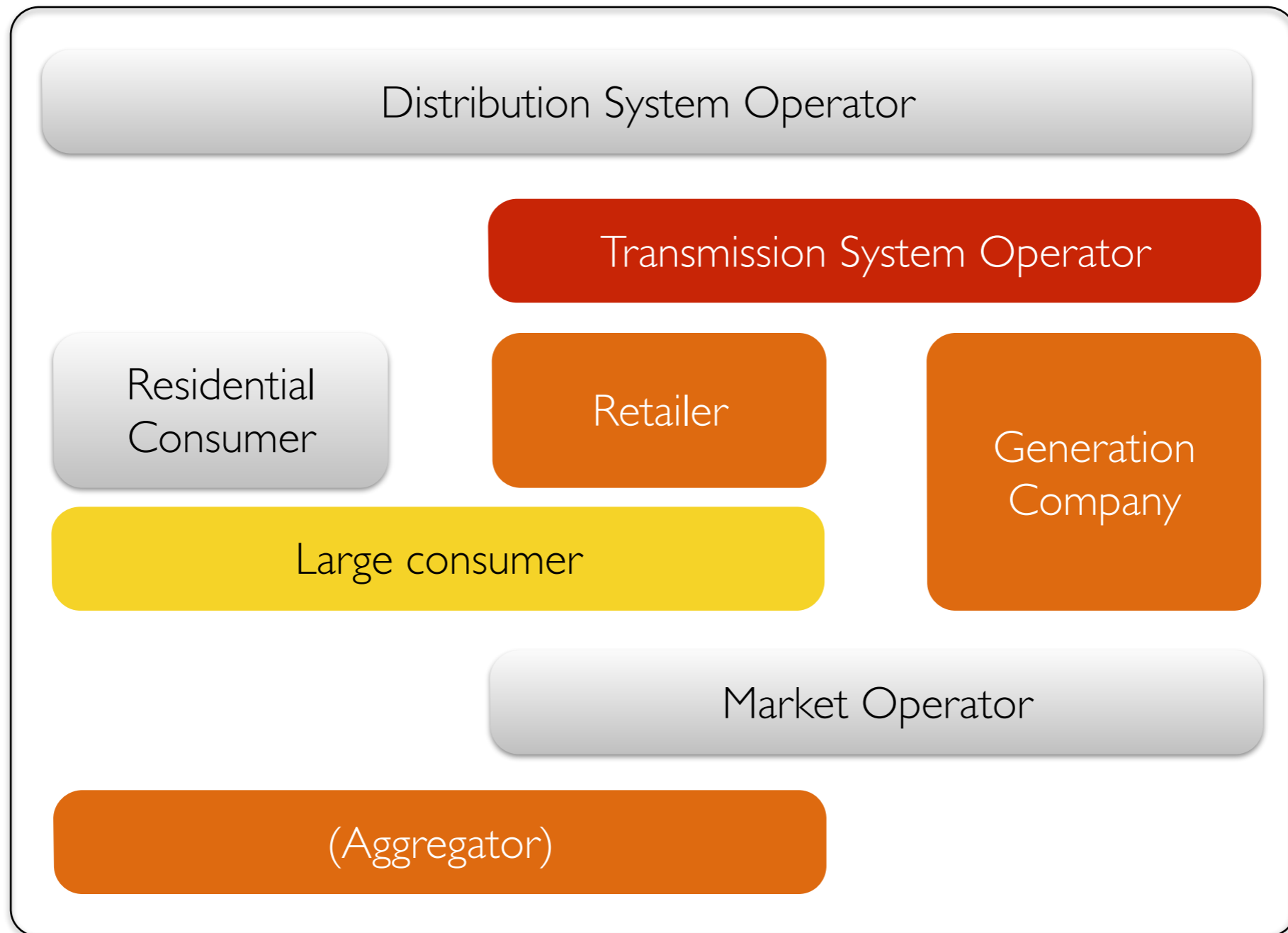- If interconnection lines are HVDC, then the balancing areas are not synchronous

Hence, who has a role in balancing?

Regulator

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Hence, who has a role in balancing?

Regulator

Distribution System Operator

Transmission System Operator

Residential Consumer

Retailer

Generation Company

Large consumer

Market Operator

(Aggregator)

Explanation

- The TSO is responsible for the balance of its BA

- Retailers and generation companies usually take the role of BRP

- Large consumers can sometimes have a BRP role, if they have no retailer

- Aggregators, or BSPs, are third parties who implement and sell services to BRPs or the TSO by aggregating capacity from the demand side.

- Historically, generation companies are (were) providing ancillary services (both upward and downward modulation)

- No role: DSO, end consumer (retailer takes BRP role), Market Operator (except imposing supply vs. demand equilibrium for every exchange)

Balance Responsible Party
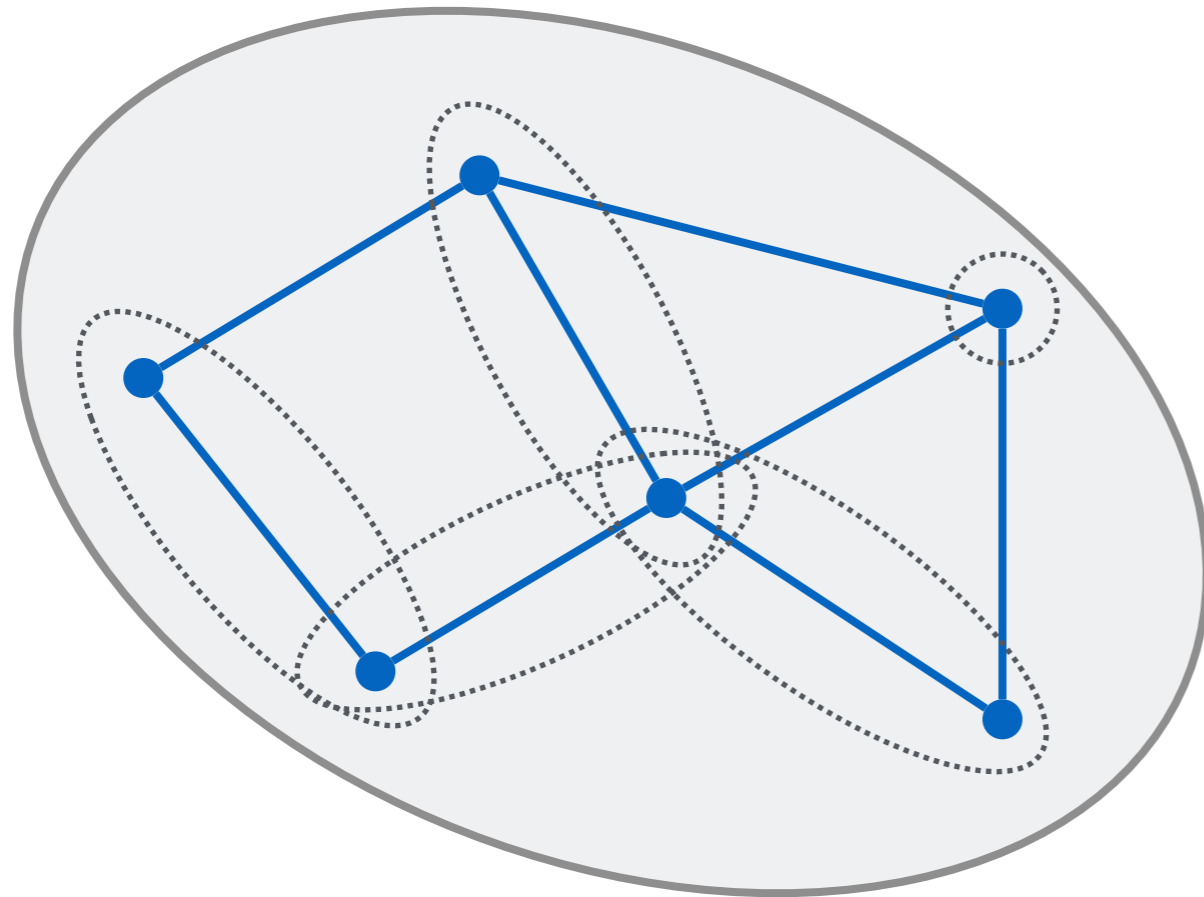
- For instance this BA has 5 BRPS
- Each BRP perimeter is delimited by a dotted ellipsis

- A BRP is an entity responsible for the equilibrium between injection and off take at a set of *points* in the network

- Point: an electrical bus of the HV network (operated by the TSO)

- Imbalance is established on a 15 minutes basis as the integral of the "error signal"

Balance Responsible Party activities

In order to keep his perimeter in balance, a BRP can trade electricity on the HUB/Belpex (cf. lecture on day ahead market), import/export electricity and purchase capacity rights

It must send day-ahead **nominations** to ELIA for load, production, import/export and hub deals on a 15 minutes basis, a day ahead. These nominations must be balanced!

Example of Belgium: *for this winter, if the day ahead nomination is not in balance, and other conditions are met in realtime (cf. http://www.elia.be/en/about-elia/ questions-about-the-risk-of-shortage-in-Belgium#1e), ELIA can ask 4500 euros per MWh of imbalance. Why 4500 euros ?*

Note on nominations in Day ahead

- For **load** and **generation** (independently) a BRP will nominate

  - per access point for grid user directly connected to the HV grid

  - and globally per distribution network. Right now neither the distribution system operator nor the TSO knows accurately the distribution of injections and off takes of a BRP within a distribution system. It makes it difficult to exploit flexibility existing in distribution systems for balancing purposes. Smart meters would help in that respect.

- It will also nominates cross-border exchanges, etc.

CIPU contracts (Belgian case)

The BRP responsible for the injection of each Production Unit (PU) having a capacity greater than 25MW concludes a CIPU-contract. CIPU stands for Coordinated Injection Production Unit.

Practically this means that

(1) The producer makes forecasts of available power and communicates them to Elia.They cover both the long term (a year ahead) and the short term (a day ahead). There are 6 steps in the procedure. The last one corresponds to the process of nominations in D-1.

(2) The producer has the right/obligation to offer ancillary services. Note: there is obviously an arbitrage between selling energy or providing ancillary services from the point of view of the producer, although he has to offer a certain proportion of his capacity.

Types of services, order of activation, etc.

order of activation ⬇

Product &	Description	Capacity component	Energy component	
R2	• Automatically activated • 30″ – 15′ • Up/down	Yearly reservation	• Day Ahead bids • Activation price is ≈ fuel cost based	Pre-contracted reserves
Free Bids	• Manually activated • 15′ • Up/down	- obligation to bid residual margin for power plants ≥ 75MW	• Day Ahead and Intraday energy bids • No price limitation ≈ free prices	Residual flexibility of forward→ ID Energy markets
R3	• Manually activated • 15′ • Up	Yearly reservation	• Day Ahead bids • Price limited by CAP ≈ fuel cost based	Pre-contracted reserves
ICH	• Manually activated • 15′ • Up • **<industrial load**	Yearly reservation	• Limited activations • Fixed price formula	
Inter TSO	• Manually activated • 15′ • Up/Down	- agreement with RTE/TenneT for mutual assistance	• Price defined in contracts • Additional incentive in tariffs under certain circumstances	Emergency reserve with no guarantee

Source: slides from ELIA.

The imbalance measure (Belgian case)

Imbalance of a BRP= (total injections - total off take) in perimeter

The imbalance is then **corrected** based on the activation of balancing services, in one direction or the other, depending on the direction of the activation: when the TSO asks a service from a BRP in one direction, it modifies the nomination of the BRP in the opposite direction.

Example: the initial position of the BRP is at equilibrium (0 MW). If the TSO asks a 50 MW upward modulation, it will correct the position of the BRP at -50 MW (instead of 0 MW). If the BRP really activates the 50 MW, he will recover the equilibrium, and thus will not have to pay an imbalance fee. If it provides more or less reserve, it will be accounted in the imbalance volume and penalised as detailed in the next slide.

The imbalance tariff

Global system

| | | Net Regulation Volume (NRV) | |
		Negative (Net downward regulation)	Positive (Net Upward regulation)
BRP imbalance	Positive	**MDP - α1**	**MIP - β1**
BRP imbalance	Negative	**MDP + β2**	**MIP + α2**

BRP   Tariff

MDP (resp. MIP) is the marginal price of downward (resp. upward) reserve, i.e. the cost of the most expensive downward (res. upward) reserve activated by ELIA in the quarter. The net regulation volume is the total upward volume (GUV) minus the total downward volume (GDV) activated in the quarter: NRV = GUV - GDV. Finally:

$$\beta_1, \beta_2 = 0$$

$$\text{if } SI > 140MW: \quad \alpha_1, \alpha_2 = \frac{\sum_{i=0}^{7} SI_{q-i}^2}{8 * 15}$$

$$\text{else}: \alpha_1, \alpha_2 = 0$$

Notes:
- 140 MW is the quantity of FRR contracted by ELIA every day
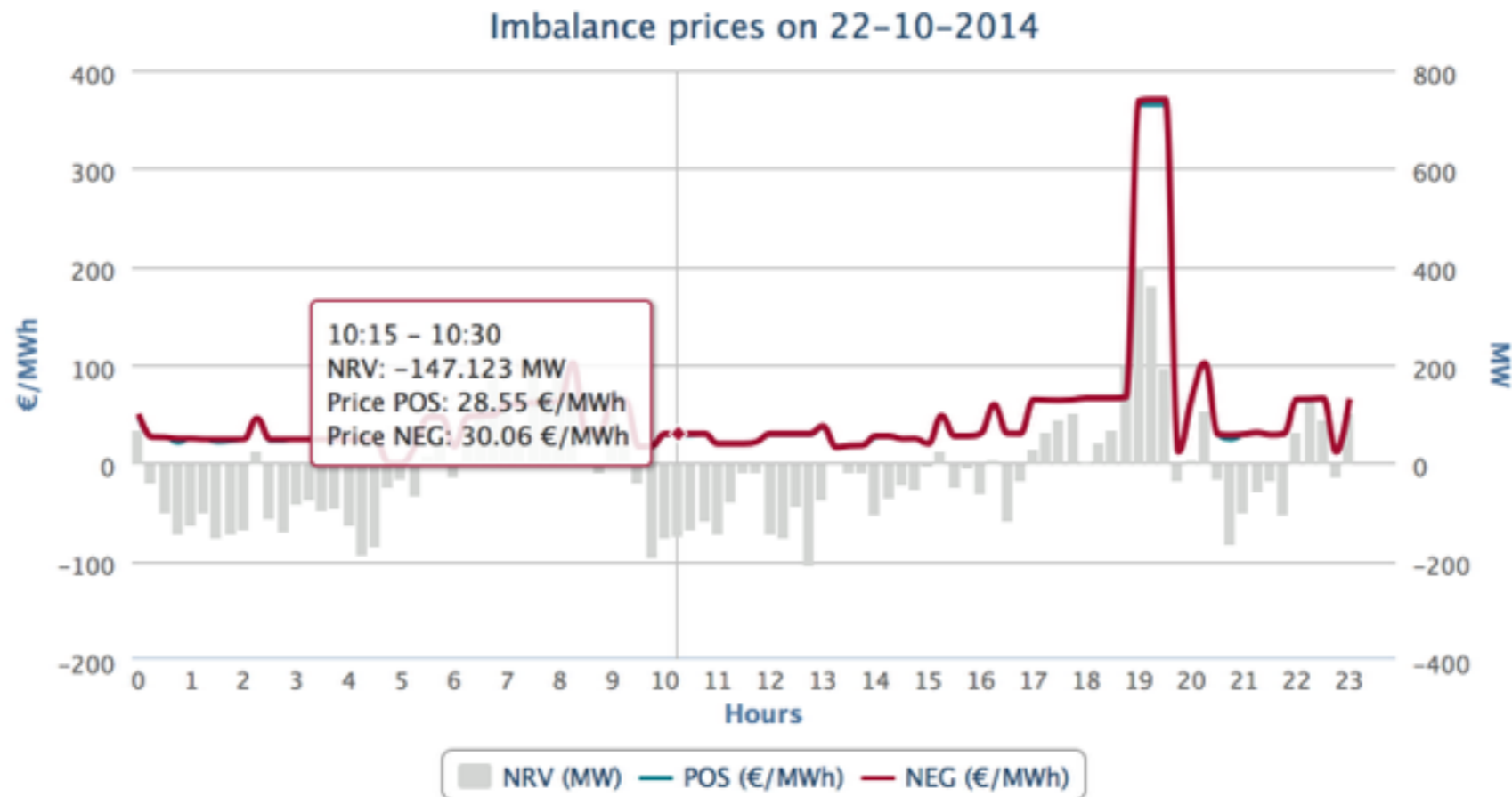- q indexes quarters
- System imbalance: SI = ACE - NRV

Source: ELIA, "Tariff for maintaining and restoring the individual balance of access responsible parties"

Who pays what to who?

Prices for Positive Imbalance can either be positive or negative. A positive price for Positive Imbalance (injection exceeds off take) means a payment from Elia to the BRP and a negative price for Positive Imbalance means a payment from the BRP to Elia. (Similarly for negative imbalance.)

Features of the mechanism are (1) it is designed to incentivise BRPs to be in balance (obviously) or to deviate in the right direction to help the system naturally; (2) designed so that BRPs provide the required services when asked by the TSO (through correction of the perimeter), (3) designed so that imbalance fees (over) compensate activation fees, and (4) the prices and volume activated are published, it is thus a transparent system.

Illustration of net regulation volume and imbalance price (from Elia's website)

Imbalance prices on 22–10–2014

10:15 – 10:30
NRV: –147.123 MW
Price POS: 28.55 €/MWh
Price NEG: 30.06 €/MWh

NRV (MW) — POS (€/MWh) — NEG (€/MWh)

Quarter	NRV (MW)	SI (MW)	a (€/MWh)	MIP (€/MWh)	MDP (€/MWh)	POS (€/MWh)	NEG (€/MWh)
00:00 > 00:15	67,858	-179,559	4,83	**45,41**	27,16	**45,41**	50,23
00:15 > 00:30	-41,119	116,009	0,00	46,83	**26,59**	26,59	26,59
00:30 > 00:45	-98,663	118,506	0,00	46,36	**26,12**	26,12	26,12

Question: What is the meaning of the columns?

Challenges

Main challenges

The recourse to FRR and tertiary reserve is more and more frequent (meaning amplitude is increasing), because the share of steerable generation decreases and the share of RES increases. In the past, generation was following the load. Now more and more the load has to follow the generation. The RES are geographically dispersed and there is more wind in northern Europe, more sun in southern Europe. Local imbalances are thus naturally more likely. They can be cancelled out by integrating the balancing markets at a European scale.

Solution 1

Use **demand flexibility** for balancing. It is difficult because (1) of the stochastic nature of the load (at least from the perspective of a BRP or ELIA), causing metering and verification issues, (2) of the distributed nature of load, causing an overhead of communication, and (3) of the one-sided nature of the load: it is easier to ask for a decrease of consumption than to force an increase (although theoretically possible). The use of storage for ancillary services purpose is also a topic of active discussion. The main questions there are about the economic efficiency of storage, the technology to use, etc.

Example of demand flexibility

If you have some flexibility on the temperature of a room,
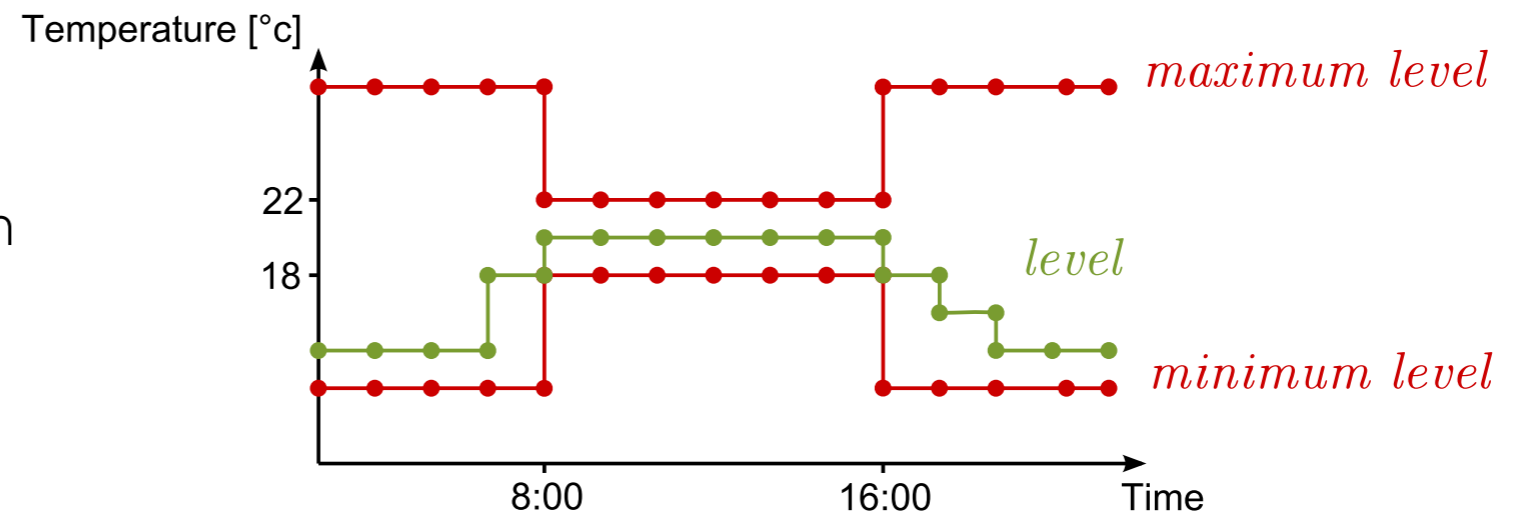
You can sell your capacity to decrease or increase momentarily your consumption.
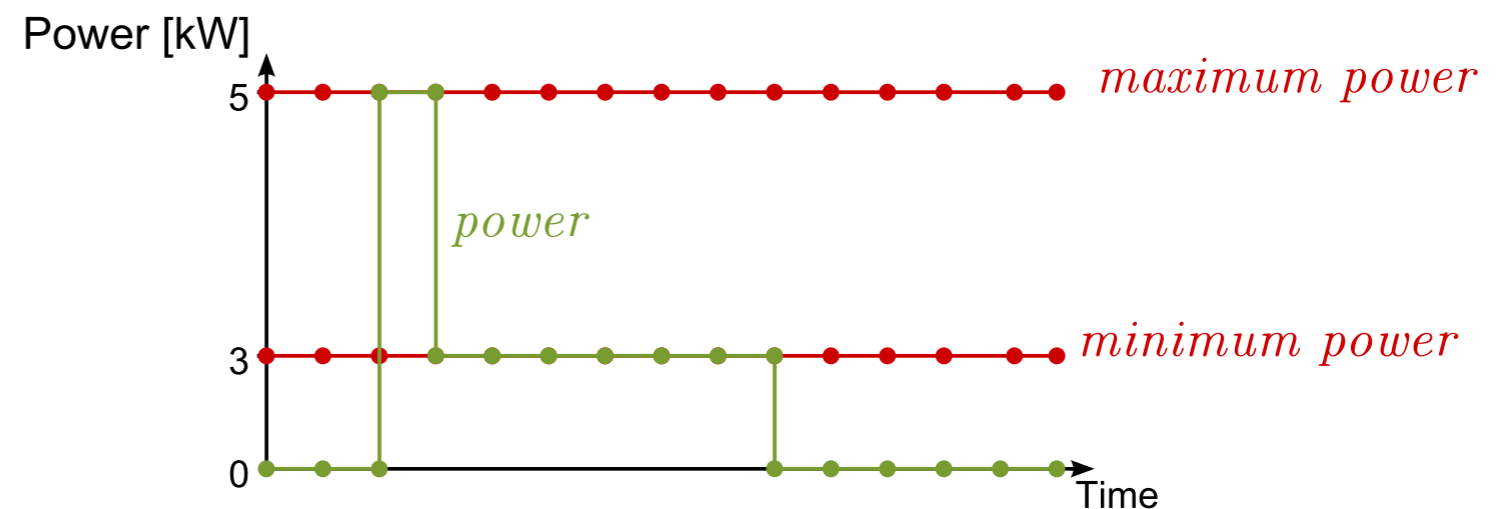
Using demand flexibility

- ❑ **Technical constraints linked to industrial GUs**   Source: slides from ELIA.
  - • Availability (through year and or after one activation)
  - • Smaller available volumes

- ❑ **Product Design**

  The effectively activated energy is defined as the difference between the real profile and what would have been that profile if there was no activation ⇒ use of a reference curve

  - ⇒ Use of a nomination but limited to transmission grid
  - ⇒ Other (compiled) reference:
    - • last 15' metering
    - • an average ?
    - • another day curve?
    - • Miror consumer? ….
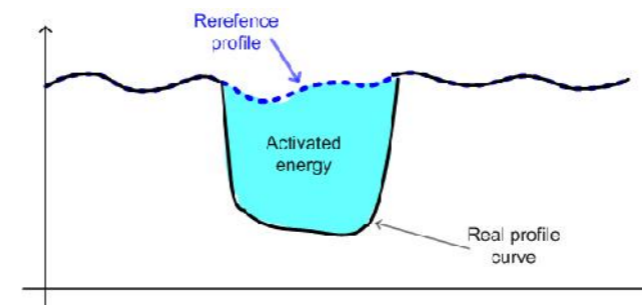
- ❑ **Impact on grid security (congestion)**
  - • Participation of Demand to energy markets will modify the "statistical consumption profile" of grid users ➔ impact on security

    - • Grid security
    - • Ex ante prequalification
    - • Dynamic grid management

    - • Availability of product ~100%
    - • BSP need to know where they are allowed to use flexibility
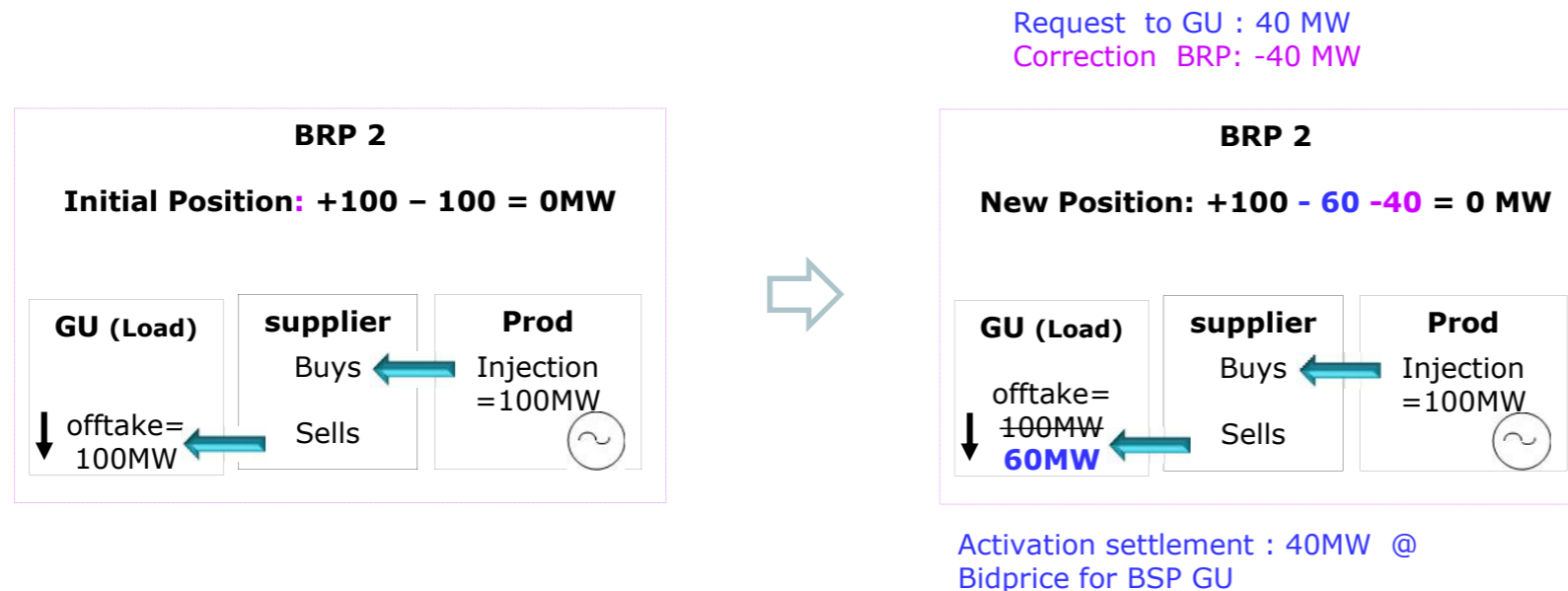   - • Non discriminatory acces to balancing market

- ❑ **Market design and impact on BRP & Supplier**   Issue of "stolen energy".

Zoom:

Implications when BSP is not BRP (1)

Elia investigated how to create a product that allows new players to bid energy as independently as possible from the ARP. Therefore the impact that an energy bid coming from a GU could have on the BRP and on the supplier was analysed.

Request to GU : 40 MW
Correction BRP: -40 MW

BRP 2

Initial Position: +100 – 100 = 0MW

GU (Load)	supplier		Prod
	Buys	←	Injection =100MW
↓ offtake= 100MW	← Sells		∼

BRP 2

New Position: +100 - 60 -40 = 0 MW

GU (Load)	supplier		Prod
	Buys	←	Injection =100MW
↓ offtake= ~~100MW~~ **60MW**	← Sells		∼

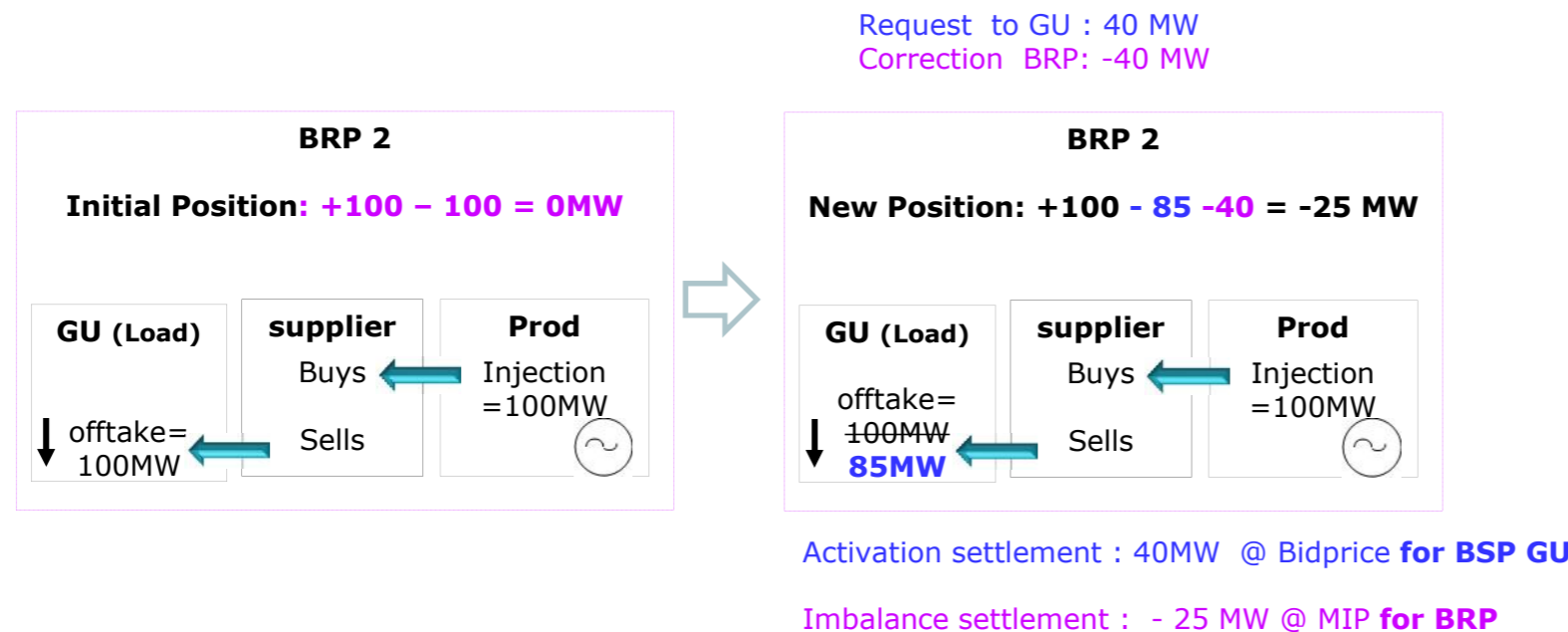Activation settlement : 40MW @
Bidprice for BSP GU

- **Issue n° 1:**
  ⇨ GU sells the (40 MW of) activated energy to Elia but does not buy that energy as he reduces his consumption
  ⇨ Supplier (buys 100MW, sells 60) has to be remunerated for the activated energy

Zoom:

Implications when BSP is not BRP (2)

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What if the GU activates less energy than requested (15 instead of 40)?

Request to GU : 40 MW
Correction BRP: -40 MW

BRP 2

Initial Position: +100 – 100 = 0MW

GU (Load)	supplier	Prod
	Buys ←	Injection =100MW
↓ offtake= 100MW ←	Sells	∿

BRP 2

New Position: +100 - 85 -40 = -25 MW

GU (Load)	supplier	Prod
	Buys ←	Injection =100MW
↓ offtake= ~~100MW~~ **85MW** ←	Sells	∿

Activation settlement : 40MW @ Bidprice **for BSP GU**

Imbalance settlement : - 25 MW @ MIP **for BRP**
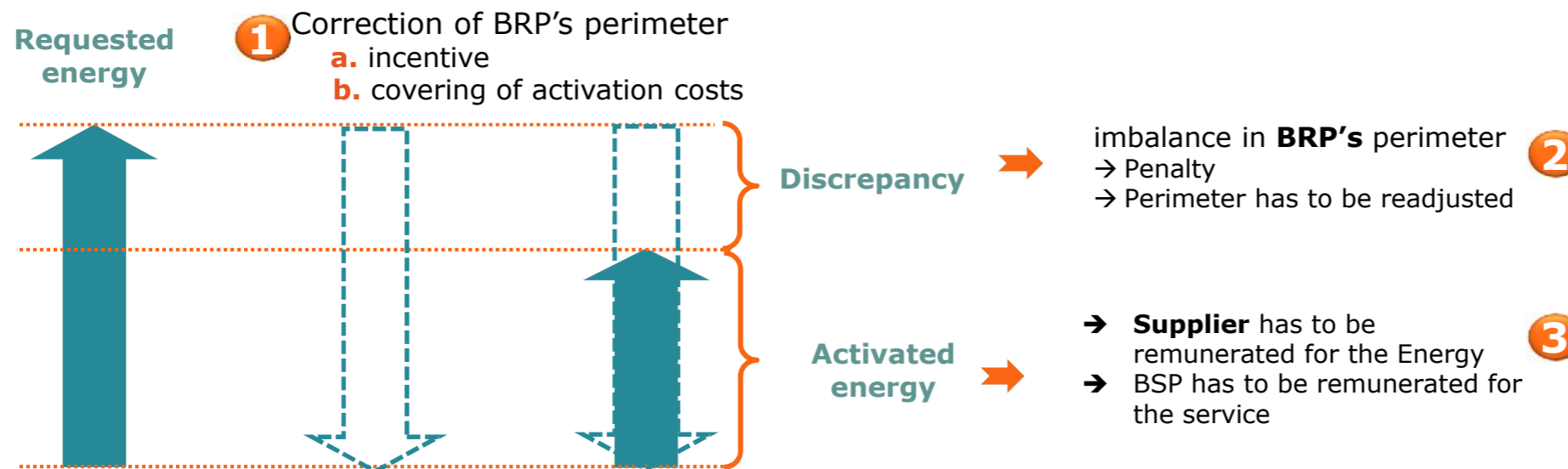
- **Issue n° 2:**
    - BRP's perimeter is adjusted with the quantity of energy requested (40MW)
    - **the BRP is penalized for the discrepancy between the requested and effectively activated energy (40-15)** → BRP will be invoiced for the resulting imbalance at MIP
    - Remark: When the BSP is also BRP there is no need to control and penalize discrepancy as this is automatically done trough the tariffs

Challenges: (2)

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❑ **Market design and impact on BRP & Supplier**

- Solutions aiming at independency of BSP towards BRP should keep main principles (1.a & 1.b) but mitigate any damage to BRP nor Supplier (2 & 3)

Requested energy

① Correction of BRP's perimeter
  a. incentive
  b. covering of activation costs

Discrepancy

imbalance in **BRP's** perimeter ②
→ Penalty
→ Perimeter has to be readjusted

Activated energy

➔ **Supplier** has to be remunerated for the Energy ③
➔ BSP has to be remunerated for the service

- Several explored models with pro's and con's

⇒ Related issues are analyzed in depth in collaboration with stakeholders (BSPs, BRPs (Ah TF balancing & Expert WG AS by DER)

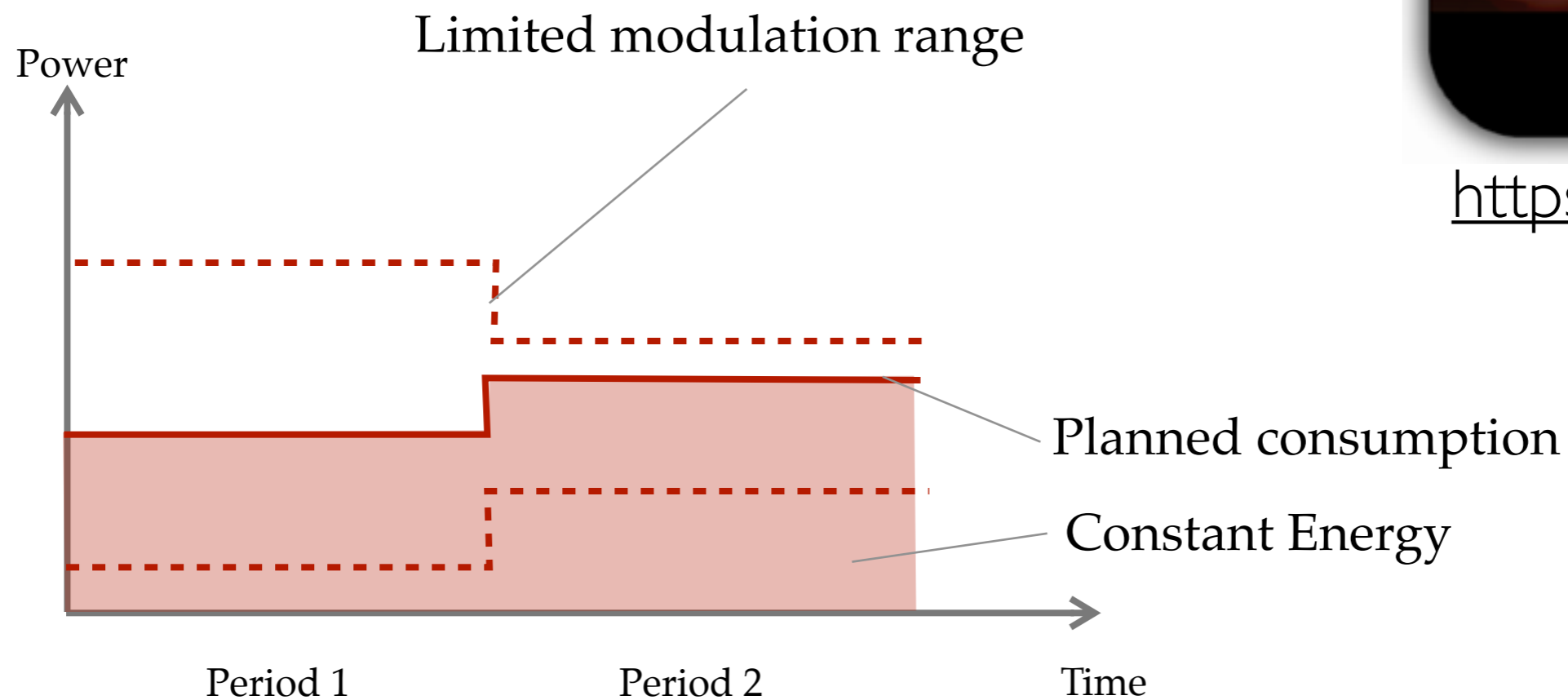# There are many ways to define ancillary services from demand side (…)

- ELIA introduced services called "R3 Dynamic Profiles"

- 50 MW contracted for 2014, from large consumers in distribution networks aggregated (notion of aggregator or balance service provider).

There are many ways to define ancillary services from demand side

Here is **an example** we have used in a research project @ ULg, accounting explicitly for the rebound effect.

https://gredor.be

Limited modulation range

Power

Planned consumption

Constant Energy

Period 1   Period 2   Time

Pricing:
Availability price
Modulation price = 0 (<< generation or load curtailment price)

Solution 2

Integrate markets, i.e. balancing, intraday and day-ahead markets, couple and harmonise them geographically. Exploit at best cross-border capacity. Do not generate redundant markets, and maybe more importantly opportunities of gaming between markets.

As we learned in the last lecture, day-ahead markets are now mature and almost coupled throughout all Europe, although markets are not fully harmonised. Intraday markets are on the way, although a lot of work still needs to be done. For balancing markets, the question is yet more sensitive.