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N-SIDE
OPTIMIZING YOUR DECISIONS

SmartNet
Smart TSO-DSO interactions schemes, market architectures and ICT solutions for the integration of ancillary services from demand side management and distributed generation

Modelling real-time markets : market design for provision of ancillary services from DER for different TSO-DSO coordination schemes

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N-SIDE

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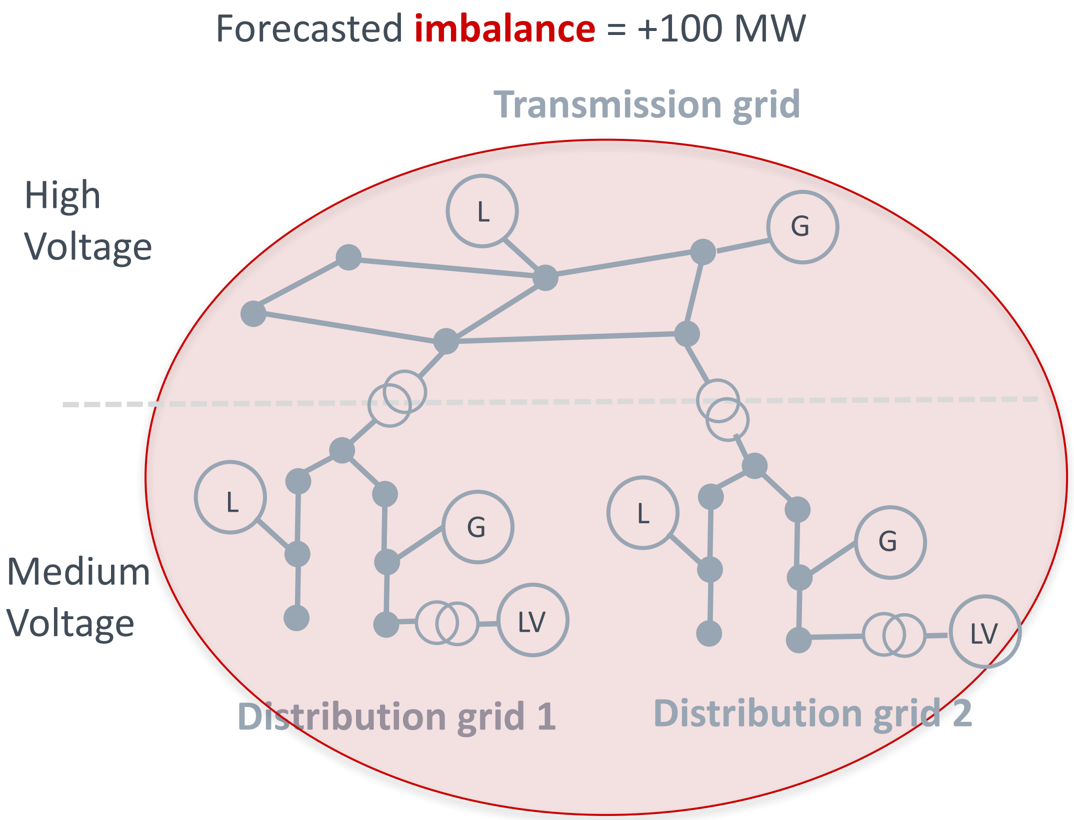
For the market simulation, the following **services** procured by the **TSO/DSOs** are considered and are **procured together**

- **Balancing** services



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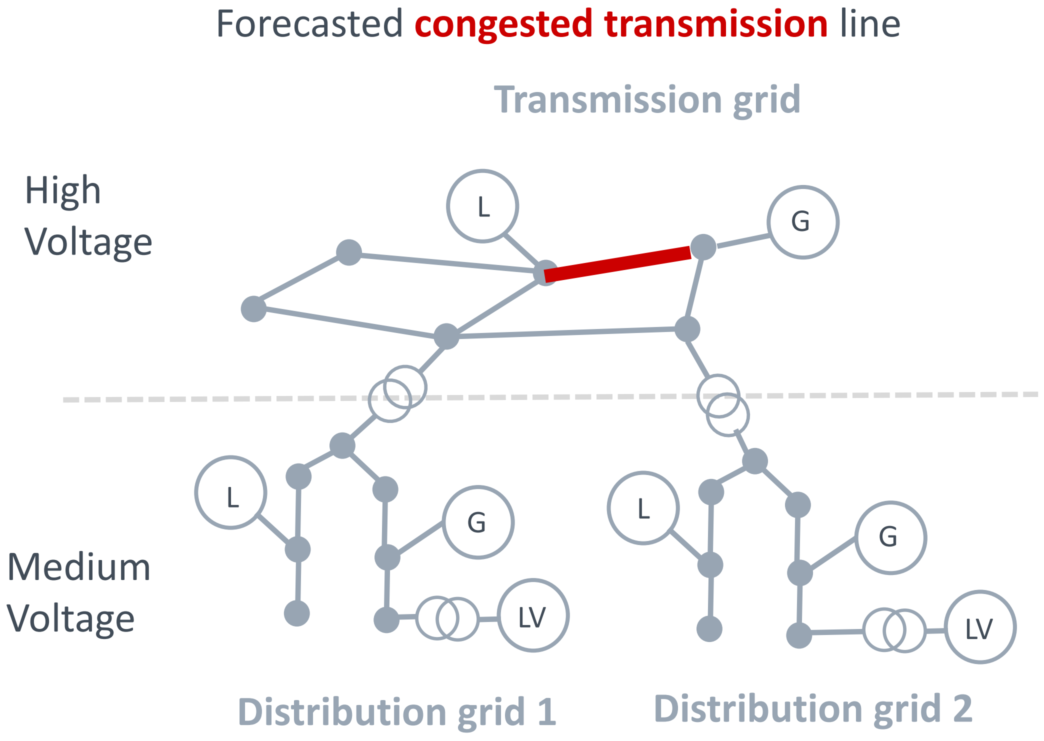
- **Balancing** services
- **Congestion** management
  - At the **transmission** grid level



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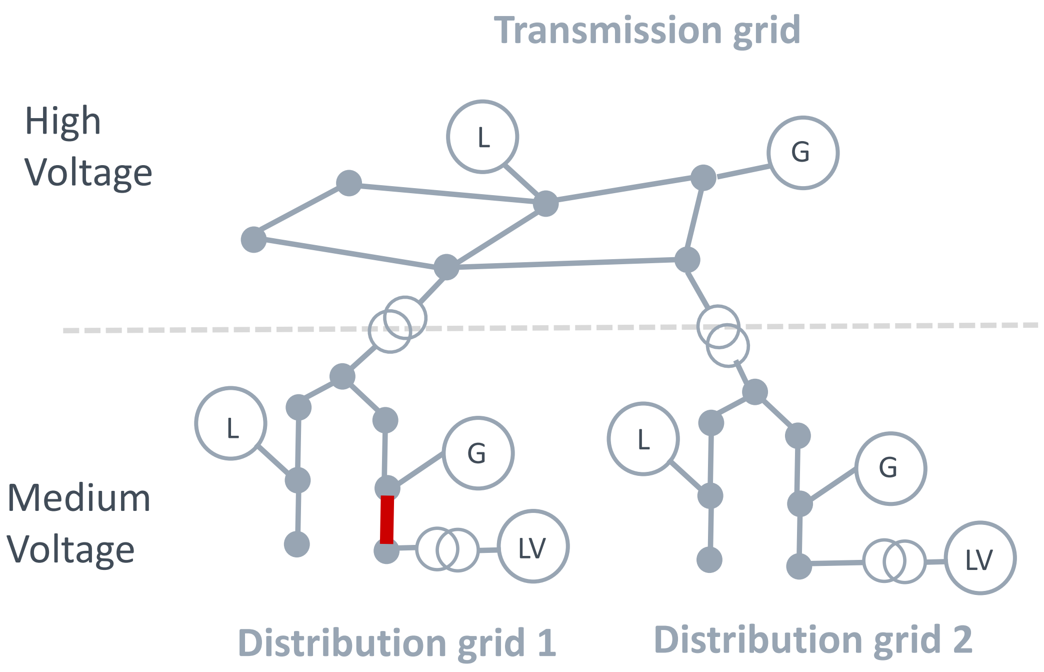
  - At the **transmission** grid level
  - At the **distribution** grid level (medium voltage)

Forecasted **congested distribution** line



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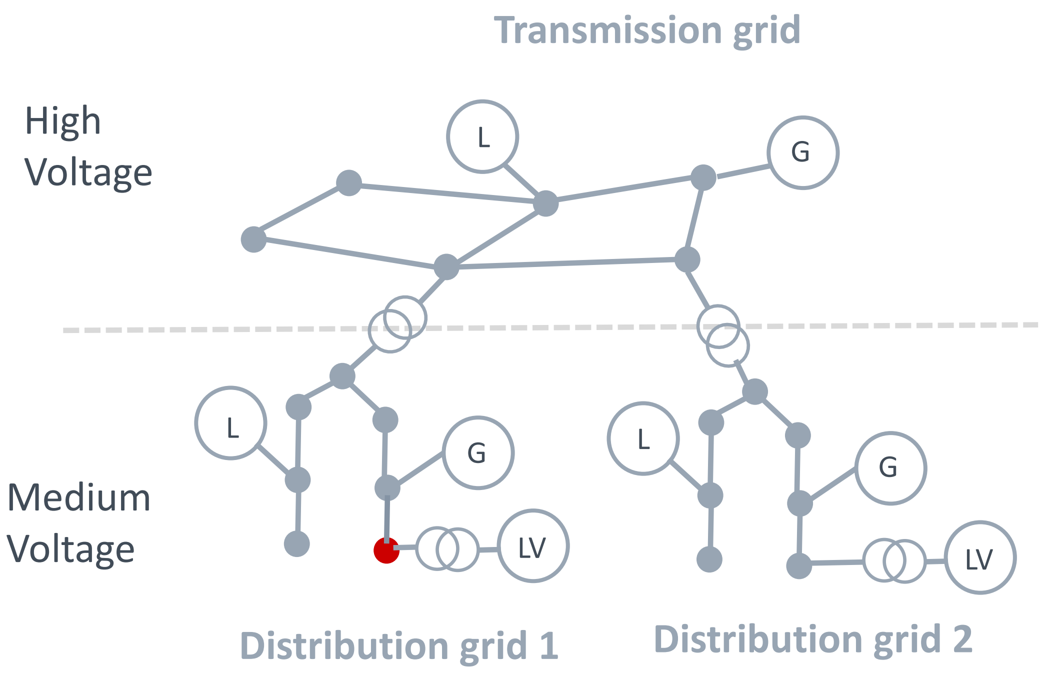
- **Balancing** services
- **Congestion** management
  - At the **transmission** grid level
  - At the **distribution** grid level (medium voltage)

- In addition, the goal is also to **avoid creating voltage problems** in the distribution grid (medium voltage)

➔ Requirement for **transmission** and **distribution grid** models in the **market clearing algorithm**

Avoid **under** or **overvoltages** when providing the services



Market design specificities for different **TSO-DSO coordination schemes**

TSO-DSO Coordination Schemes

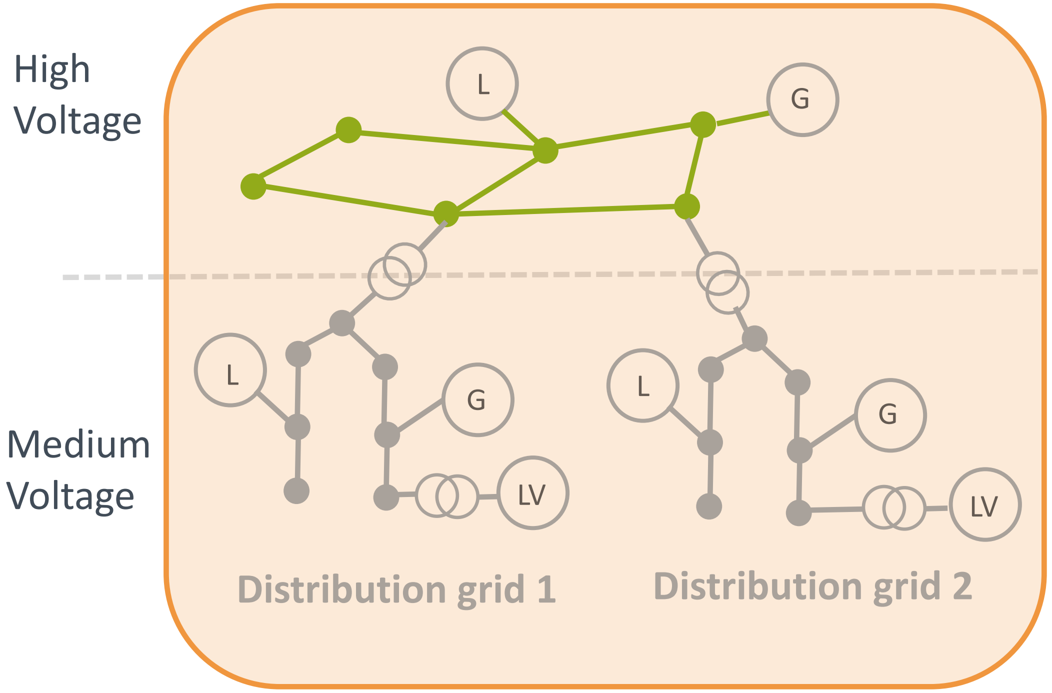
Centralized

- **Centralized AS market**

Decentralized

- **Transmission grid** model only
- **Congestion** management DSO level is tackled outside market

Centralized AS market



Market design specificities for different TSO-DSO coordination schemes

TSO-DSO Coordination Schemes

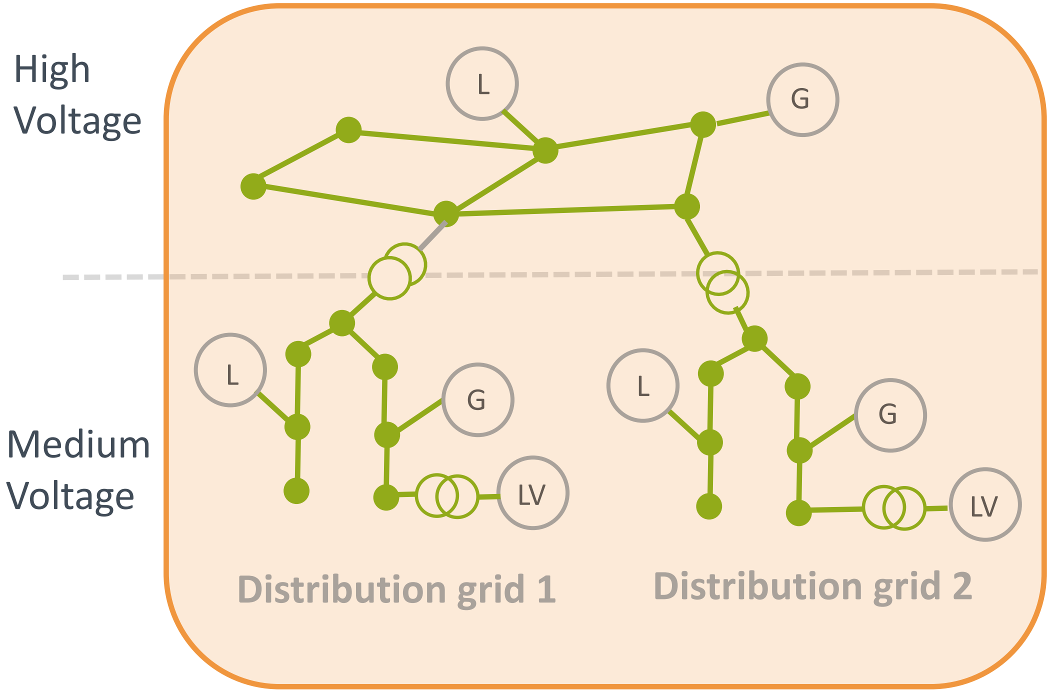
Centralized

- Centralized AS market
- **Common TSO-DSO AS market (centralized)**

Decentralized

- **Transmission + distribution grid** models
- **Minimize total activation costs** for TSO and DSOs

Common TSO-DSO AS market (centralized)



Market design specificities for different **TSO-DSO coordination schemes**

TSO-DSO Coordination Schemes

Centralized

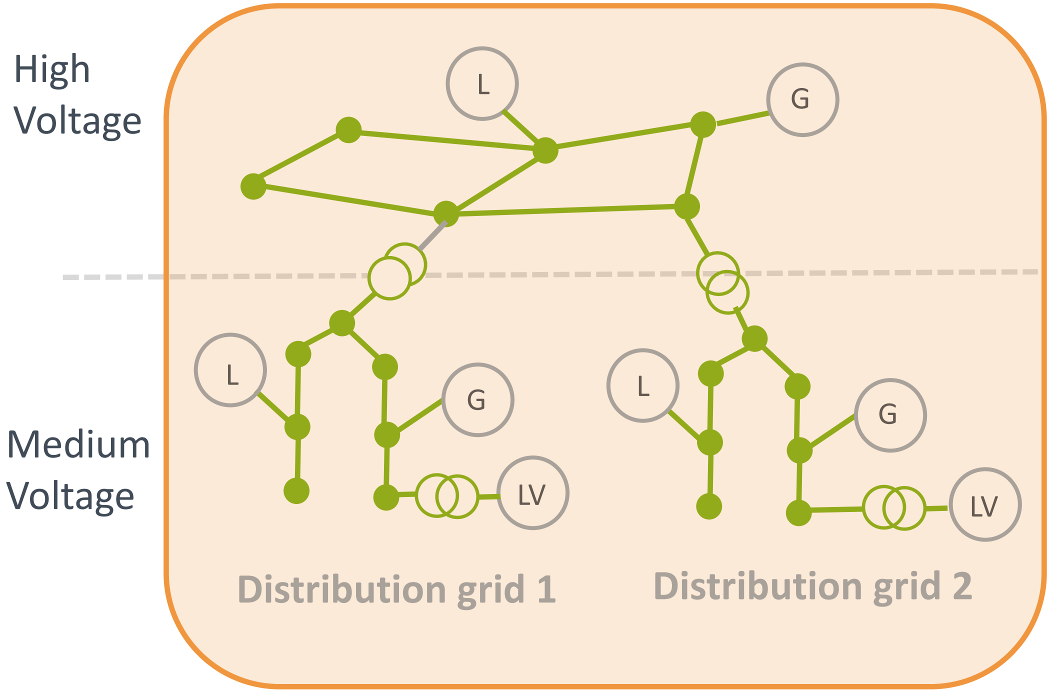
- Centralized AS market
- Common TSO-DSO AS market (centralized)
- **Integrated flexibility market**

Decentralized

- **Transmission + distribution grid** models
- Maximize **welfare**
- **CMPs** (e.g. BRP) allowed **to purchase flexibility** offers on the market, in competition with SO

➔ TSOs, DSOs need to **explicitly bid** on the AS market

Integrated flexibility market



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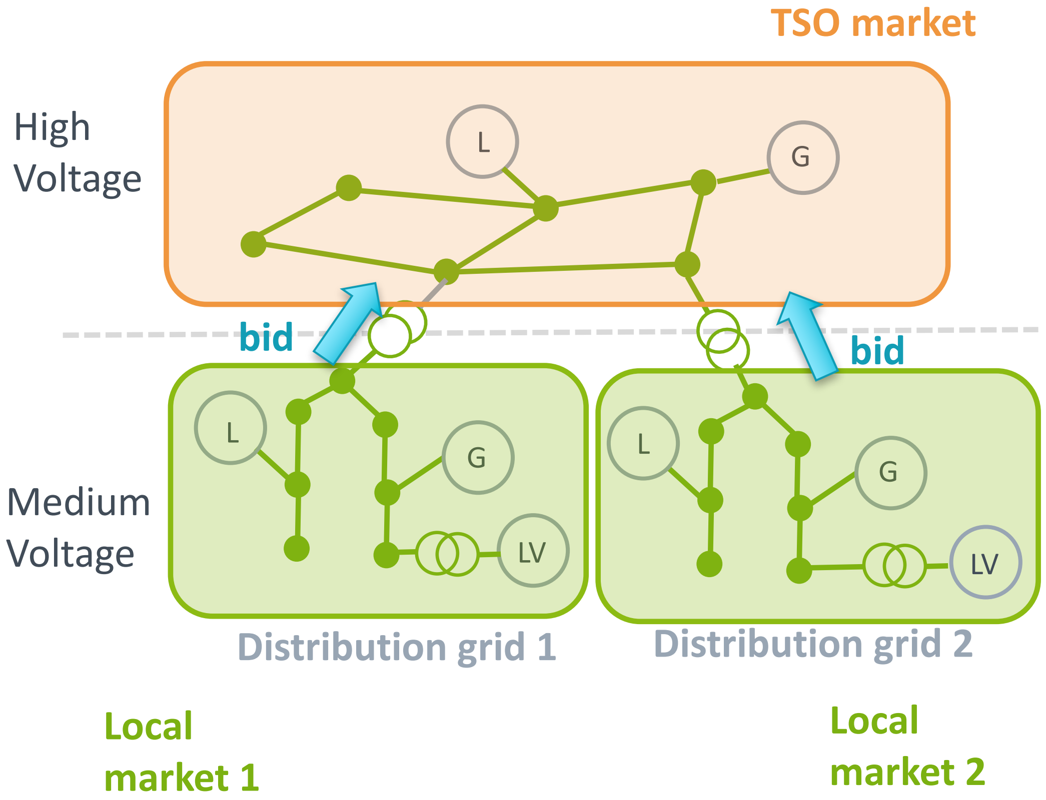
Decentralized

- **Local AS market**

Local AS market



- **DSO** uses **local market** as a priority to solve local problems **(congestion)**
- Then **remaining flexibility** is (smartly) **aggregated** and sent to the **TSO AS market**

Market design specificities for different **TSO-DSO coordination schemes**

TSO-DSO Coordination Schemes

Centralized

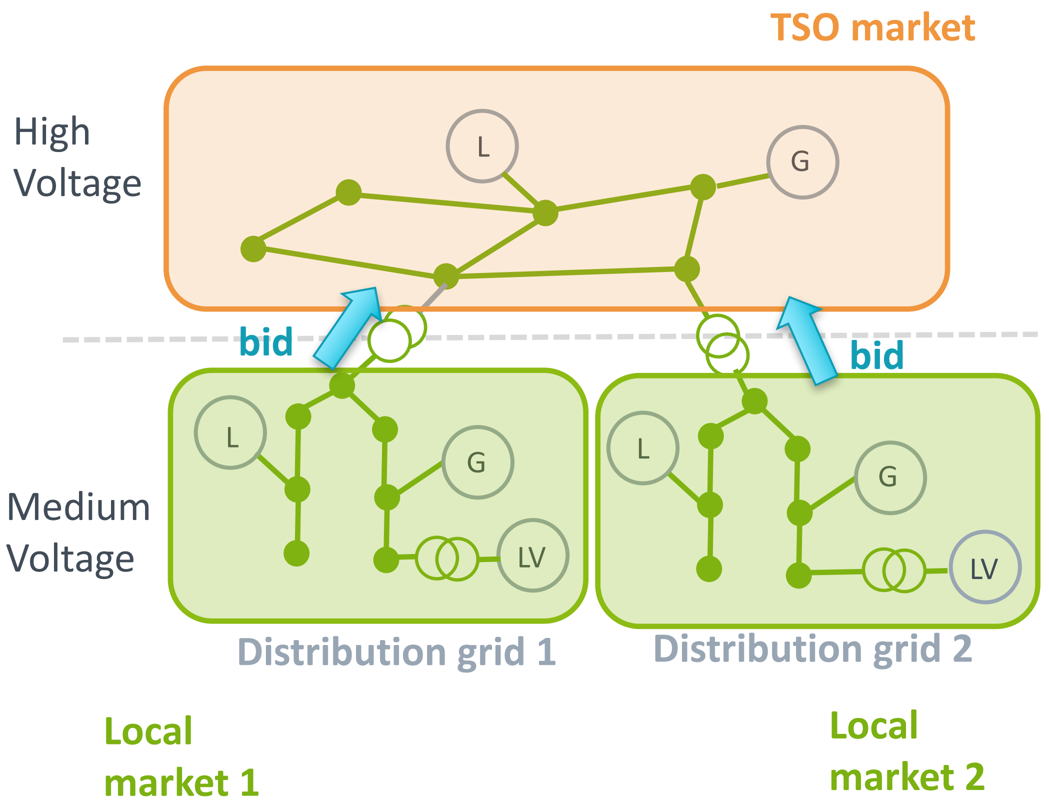
- Centralized AS market
- Common TSO-DSO AS market (centralized)
- Integrated flexibility market

Decentralized

- Local AS market
- **Common TSO-DSO AS market (decentralized)**

- **DSO** is responsible to collect bids from DER on a local market and to **(smartly) aggregate** them and send them on TSO market
- **Smart aggregation**
  - Take **distribution grid** constraints into account
  - Solve **DSO problems** (congestion) for any quantity proposed in the bid

Common TSO-DSO AS market (decentralized)



Market design specificities for different **TSO-DSO coordination schemes**

TSO-DSO Coordination Schemes

Centralized

- Centralized AS market
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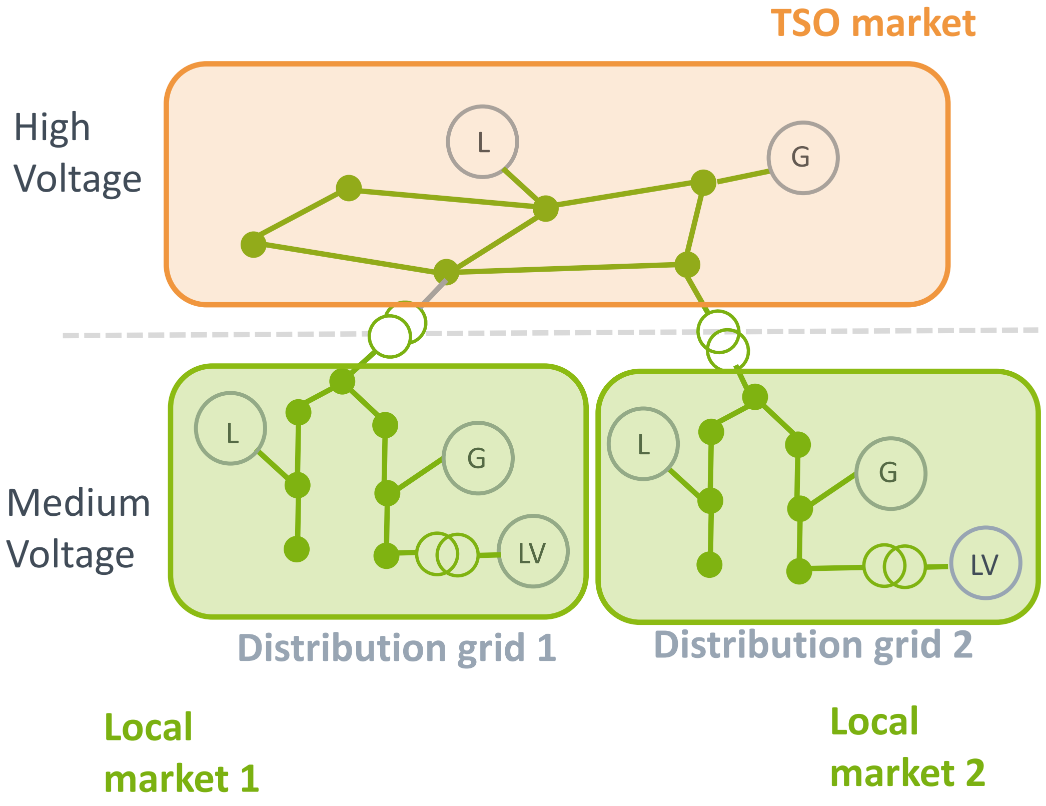
- Integrated flexibility market

Decentralized

- Local AS market
- Common TSO-DSO AS market (decentralized)
- **Shared balancing responsibility model**

Local AS market



- **DSO** and **TSO** **agree** in advance on a **power profile exchange** at the HV-MV substation
- Each **market** solves its balancing and congestion problems using its own resources

Key **market design ingredients**

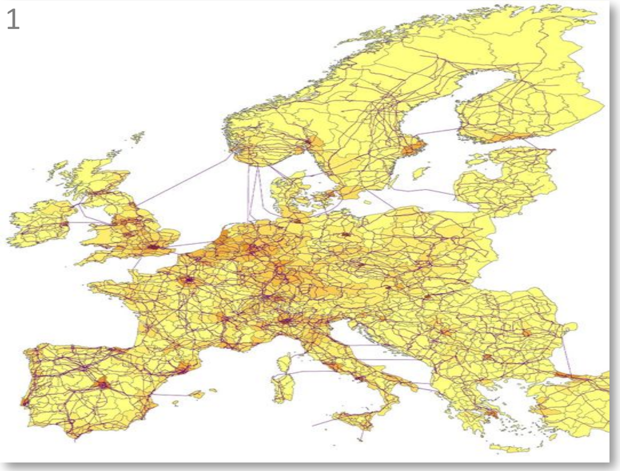
Network Dimension	Which **mathematical models** for the distribution and transmission grids in the market clearing algorithm ?
Timing Dimension	What are the the market clearing **frequency**, time **granularity** and **horizon** ?
Bidding Dimension	How market actors can bid ? What market products are proposed?
Clearing Dimension	What are the objectives of the market clearing ?
Pricing Dimension	What price is paid to the activated bids ?

Network Dimension

Use of **different models** for the **transmission** and **distribution** grids

Transmission grid

[1]

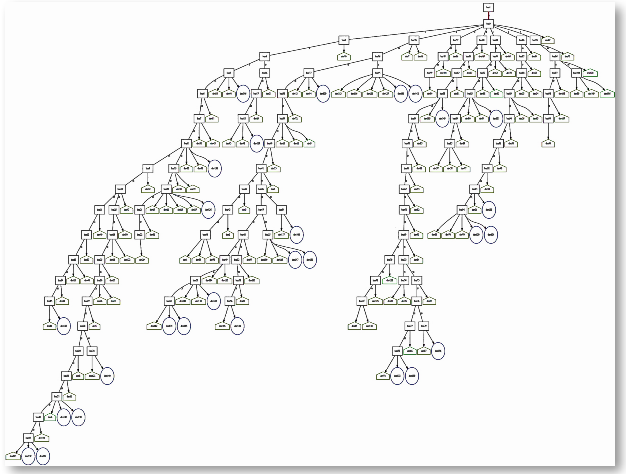


+ Accuracy

+ Numerical Complexity

Copper plate — **LP** — AC (NLP)

MV distribution grid



+ Accuracy

+ Numerical Complexity

Copper plate — LP — **SOCP** — AC (NLP)

SOCP Problem (Convex **optimization** problem)

[1] Photo source: Technical University of Munich (*http://ens.ei.tum.de*)

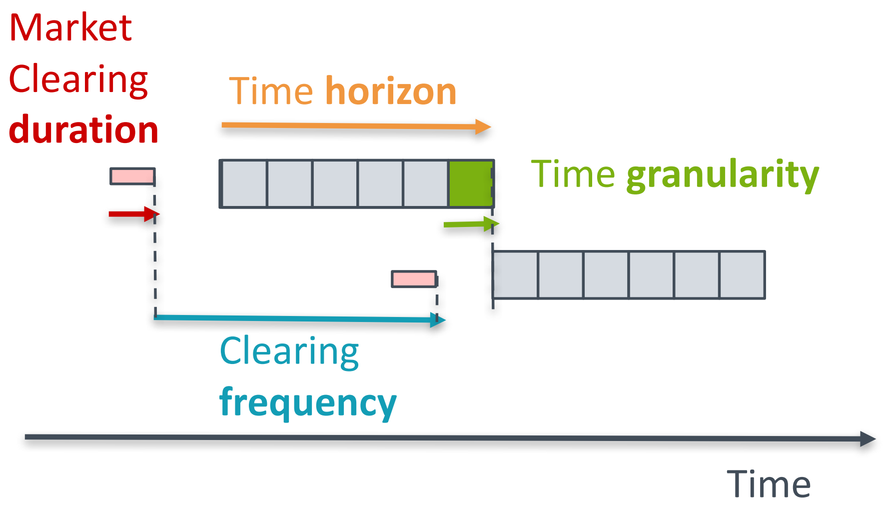
Timing Dimension

Generic approach to test **combinations** of important **timing parameters**

The market is a **closed-gate auction**.

- **Time horizon** of the market (optimisation window, delivery period): e.g. 30 min
- **Time granularity** of the market horizon: e.g. 5 min
- **Market clearing frequency**: e.g. 30 min

  → The shorter, the better, but limited by optimization problem complexity (market clearing duration)



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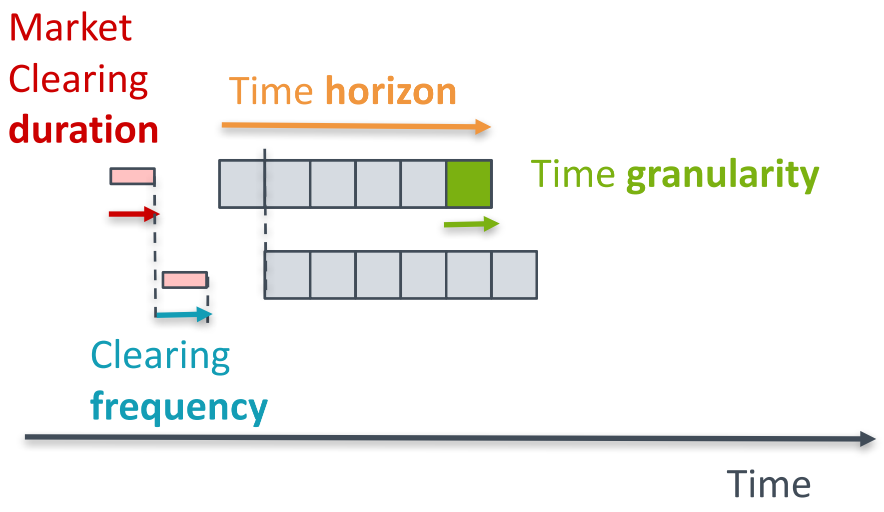
- **Rolling optimisation concept** when time horizon larger than market clearing frequency AND time granularity:
  - e.g. **horizon** = 30 min, **frequency** = 5 min, **granularity** = 5 min



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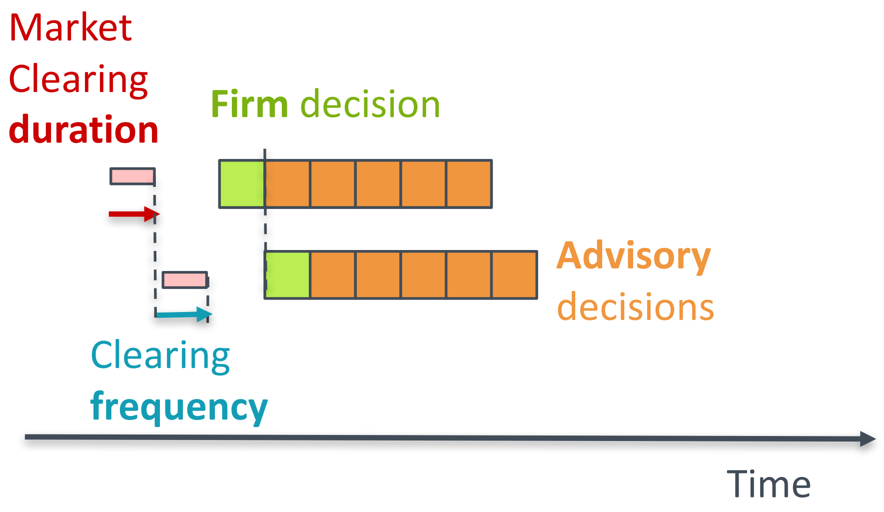
  → The shorter, the better, but limited by optimization problem complexity (market clearing duration)
- **Rolling optimisation concept** when time horizon larger than market clearing frequency AND time granularity:
  - e.g. horizon = 30 min, frequency = 5 min, granularity = 5 min
  - Results for the **first** time step are a **firm** decision. It contains the actual activation of flexible assets and has to be followed by the aggregators/owners
  - Results for the **next** time steps are (mostly) **advisory** decisions. They will assist the aggregators and the TSO to anticipate the availability of flexibility in the upcoming time steps.

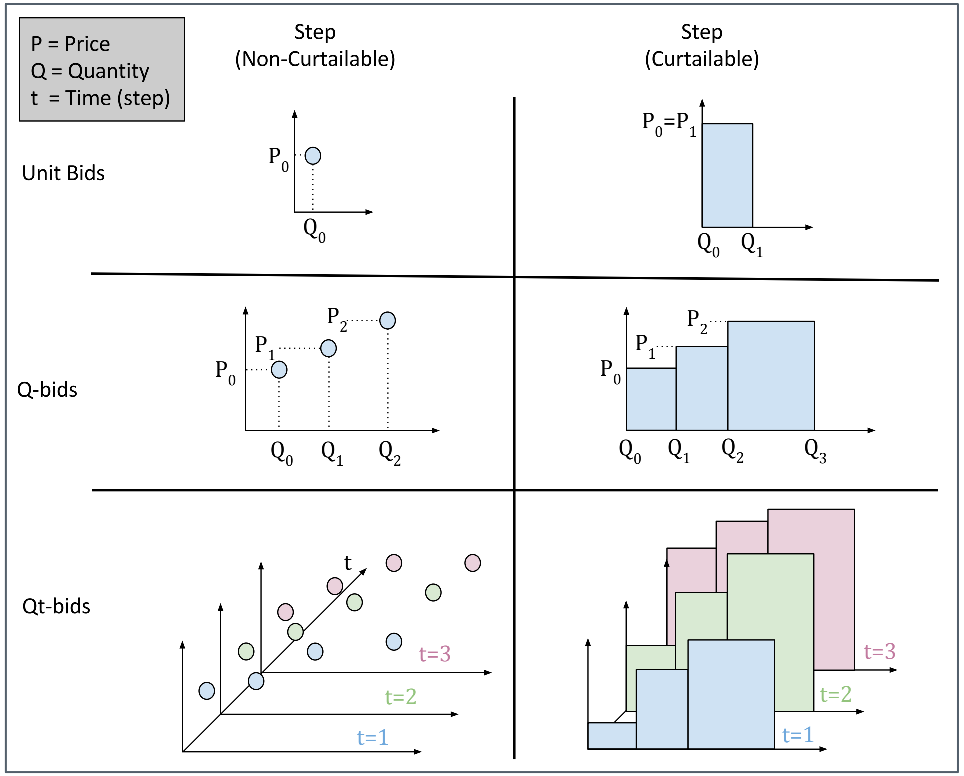


Bidding Dimension

A **catalogue** of **market products** is proposed, to allow all flexibility providers to be on a **level playing field**

- **Bids** are energy offers/asks, defined by **quantity/price** pairs in their simplest form
- **Curtailable** or non-curtailable
- Extension to **multi-period bids** when time horizon is larger than the time granularity
- **Complex** contraints
  - **Temporal** constraints
  - **Logical** constraints
- **Binary variables** are needed to express some of these constraints (e.g. a simple non-curtailable bid requires a binary variable)

➔ **MISOCP Optimisation** problem



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Temporal constraints (Intra-bid)

- **Accept-All-Time-Steps-or-None**: → Profile tracking
- **Ramping**: → Turbines
- **Max. number of activations**: → Avoiding wear & tear
- **Max. duration of activation**: → Air conditioning
- **Min. duration of activation**: → Plant efficiency
- **Min. delay between activations**: → Avoiding wear & tear; cool-down and warm-up
- **Integral**: → Electric storage

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Logical constraints (Inter-bid)

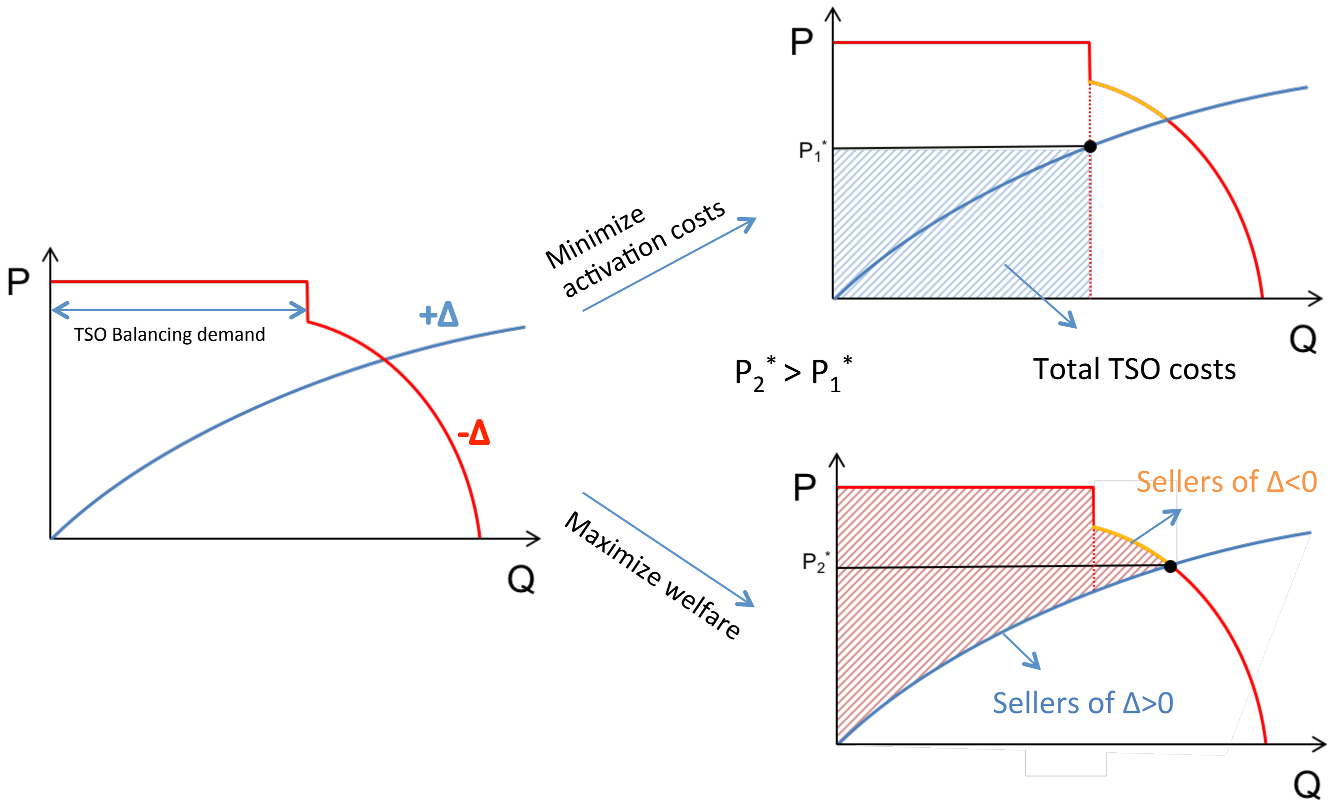
- **Implication**: → Series factory lines
- **Exclusive Choice**: → Parallel factory lines
- **Deferability**: → Wet appliances

Optimization **objective** under **network** and **bid constraints**

- **Minimize activation costs** and **maximizing welfare** may return different results

- Objective is to **minimize the activation costs** in all coord. Schemes, **except** for the *integrated flexibility market* TSO-DSO CS

- Maximizing social welfare for the latest, since regulated and non-regulated entities are in competition for the same flexibility resources

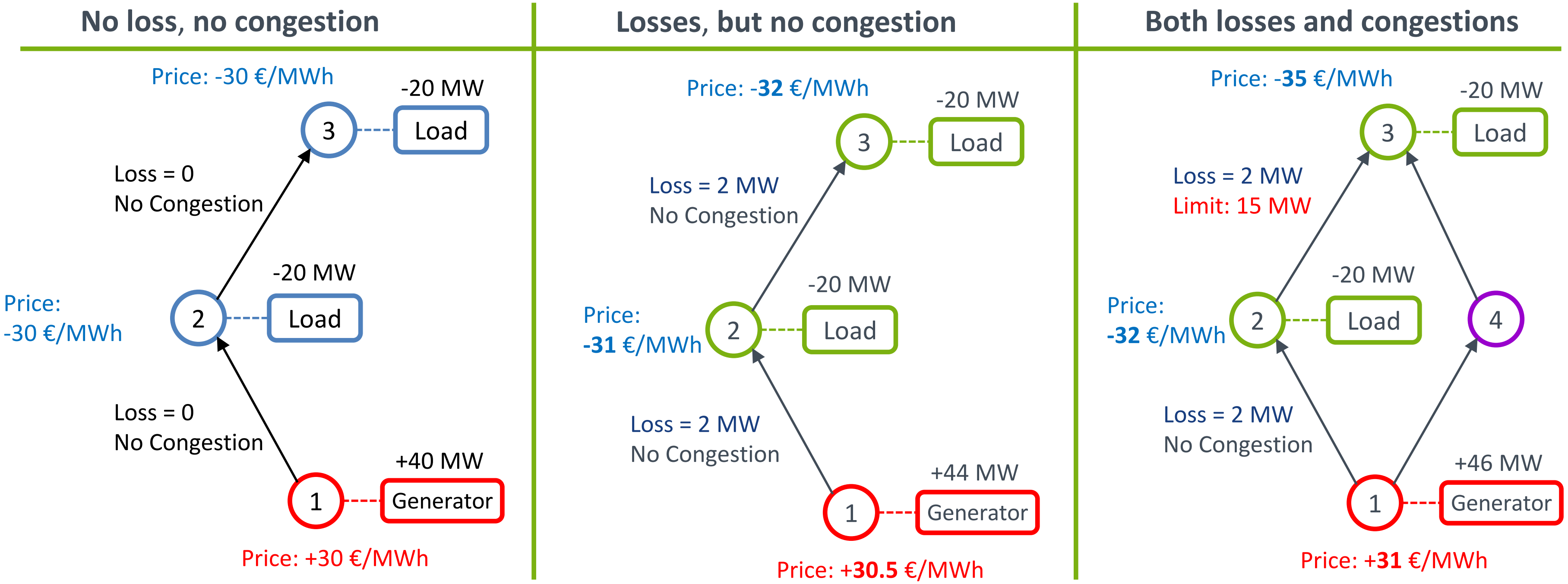


Pricing Dimension

Locational marginal price (LMP) chosen to remunerate **bidders**

- Potentially **different prices** for each network **node** (in the model), due to:
  - **Losses**
  - **Congestions**

- **Pros**: Projects real value of flexibility at each node
- **Cons**: Complex pricing mechanism and intuitiveness



A part of the **computational tractability** of the **market clearing algorithm** **depends on** the **design choices…**

- **SOCP** network model for **distribution** grid
  - ➔ more accurate model BUT **computationally** more **challenging** than linear model
  - ➔ **Tractability** also depends on the **size of network** to handle

- Introducing **binary variables** **complicates a lot** the optimisation problem (**MISOCP**), but needed for many market products (e.g. a simple non-curtailable bid)
  - ➔ Need to limit and/or make sure not too many binary variables are introduced (i.e. make sure it is worth to have them)

- A time horizon with **multiple time steps** may be advantageous but **also introduces further computational complexity** (e.g. bids with inter-temporal constraints)

… **another** part of the **computational tractability** **depends on** the **TSO-DSO coordination scheme**

Centralized AS market	Common TSO-DSO AS market (centralized)	Integrated flexibility market	Local AS market	Common TSO-DSO AS market (decentralized)	Shared balancing responsibility model
The **easiest** since only transmission grid	The **most difficult** since full transmission AND distribution grids in a single problem		Optimizations in parallel BUT with smart aggregation using some complexity		Many optimizations in parallel

Computational tractability linked to TSO-DSO coordination scheme mainly **depends on** whether they are **centralized** or **decentralized**

➔ direct impact on the **network dimension** to tackle in the **optimisation** problem

➔ Quite challenging to solve the coord. schemes with full networks included (**transmission grid + multiple distribution grids**)

➔ Ongoing work on **spatial (network) decomposition methods** to efficiently solve such problems

Challenges and next steps

- Your **feedback** is **welcome** : preliminary report on market design and algorithm (Deliverable D2.4) available on SmartNet website

http://smartnet-project.eu/

- **Run the algorithms** on real data instances form simulated **scenarios** (Denmark, Italy, Spain) to compare the different TSO-DSO coordination schemes
- **Computational Tractability** issues: solving a MISOCP (market clearing) in a few minutes is challenging ➔ investigation of efficients methods to tackle this issue
- **Data availability**: e.g. prediction of injection/offtake at network nodes, scheduled TSO-DSO exchange profiles

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Thank You

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