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

Market Architectures Integrating Ancillary Services from Distributed Energy Resources

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Market architecture for TSO-DSO coordination schemes

Defining a new ancillary service (AS) market for TSO-DSO coordination schemes

What is required?

- Ensure a safe AS **procurement** at the **lowest cost** for system operators
- Extract flexibility of **distributed energy resources** (DERs) in an efficient way
- Allow a **level playing field** for competition between different sources of flexibility
- Valorize flexibility at its **real value** for the power system

What has to be avoided?

- Discouraging participation of DERs by not taking into account their **constraints**
- Creating **congestion** and/or **voltage problem** by activation at a wrong location
- Making **myopic** real-time decisions that compromise an efficient balancing management for future time steps
- Doing **unnecessary activations** that increase cost and/or risk for system operators

Key market design ingredients

Timing Dimension	What are the the market clearing frequency, time step and horizon ?
Bidding Dimension	How market actors can bid ? What market products are proposed?
Network Dimension	How network constraints are taken in the market clearing ?
Clearing Dimension	What are the objectives of the market clearing ?
Pricing Dimension	What price is paid to the activated bids ?

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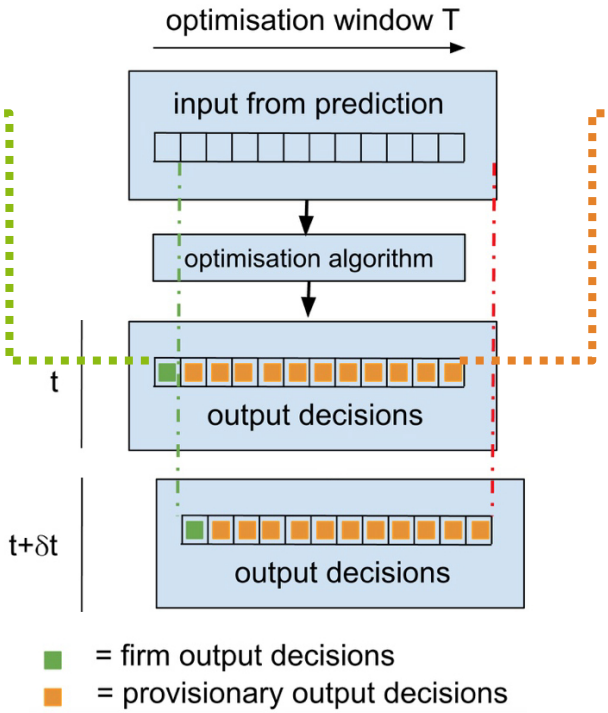
Market Design: Timing

The market is a **closed-gate auction**. The clearing frequency is chosen close to real-time (e.g. **5 minutes**).

The market uses a **rolling optimization**. The optimization window (or horizon) contains several time steps (e.g. **1 hour**)

Output of the first time step is a firm decision. It contains the actual activation of flexible assets and has to be followed by the aggregators/owners.



Output of the next time steps are advisory decisions. They will assist the aggregators and the TSO to anticipate the availability of flexibility in the upcoming time steps.

Key market design ingredients

Timing Dimension	What are the the market clearing frequency, time step and horizon ?
Bidding Dimension	**How market actors can bid ? What market products are proposed?**
Network Dimension	How network constraints are taken in the market clearing ?
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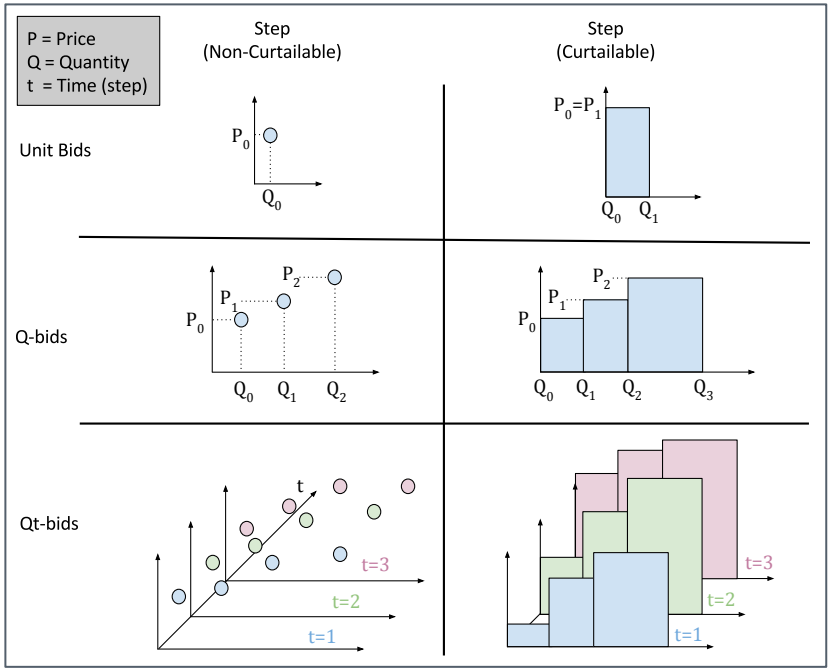
Market Design: Products

Market allows various bid format, accompanied by temporal and logical constraints:



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

Logical constraints (Inter-bid)

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

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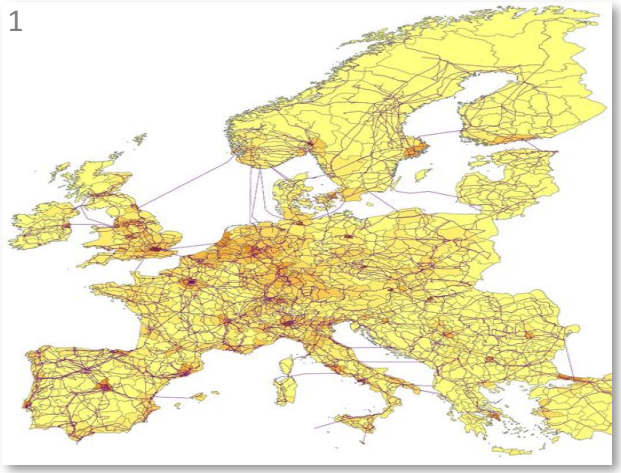
Market Design: Network

Transmission grid

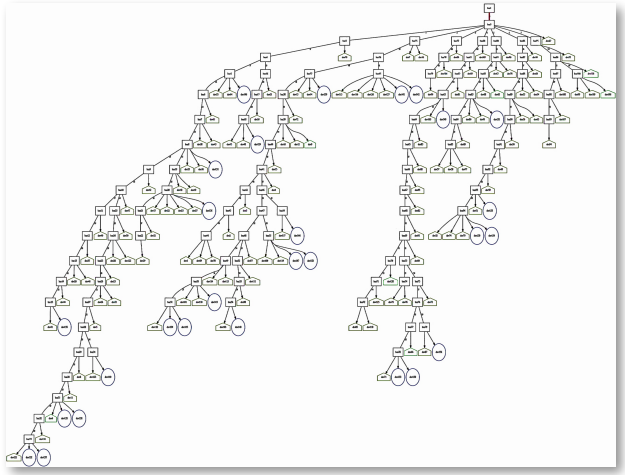


+ Accuracy

+ Numerical Complexity

Copper plate — LP — AC (NLP)

MV distribution grid



+ Accuracy

+ Numerical Complexity

Copper plate — LP — SOCP — AC (NLP)

SOCP Problem (Convex)

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

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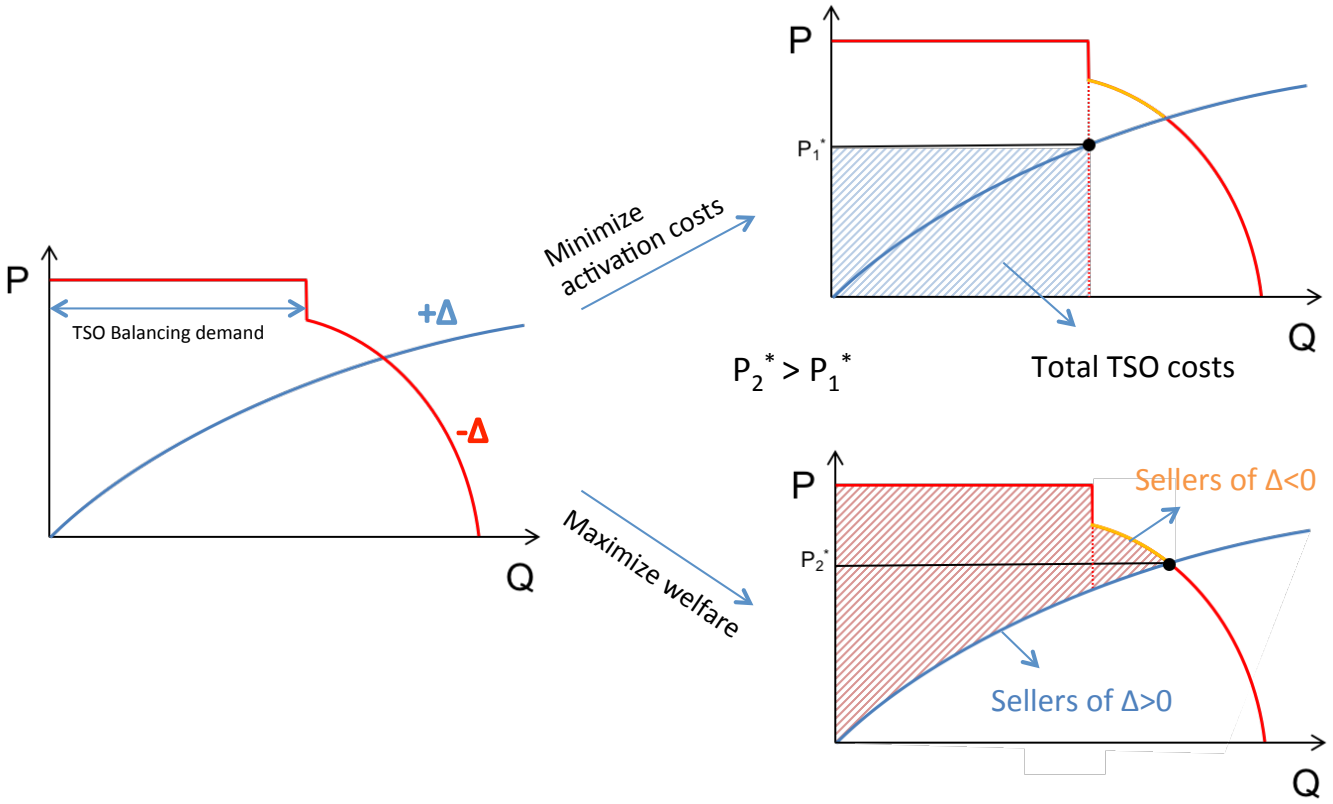
Market Design: Objective

- Maximization of Welfare versus Minimization of Activation Costs
- Should we only activate what is necessary, or favor extra welfare by allowing additional exchanges?



Market Design: Objective

$$SW^c(t) = \sum_{\beta \in \Pi_{p<0,q>0}} f(p_{\beta,0}, p_{\beta,0}, q_\beta, x_\beta) - \sum_{\beta \in \Pi_{p<0,q<0}} f(p_{\beta,0}, p_{\beta,0}, q_\beta, x_\beta) + \sum_{\beta \in \Pi_{p>0,q<0}} f(p_{\beta,0}, p_{\beta,0}, q_\beta, x_\beta) - \sum_{\beta \in \Pi_{p>0,q>0}} f(p_{\beta,0}, p_{\beta,0}, q_\beta, x_\beta)$$

Summation over bids with positive/negative values for *q* and *p*

Objective: **Maximization of Social Welfare** **&** **Avoiding Unnecessary Activations**

Adaptation of prices for bids with wrong direction

$$p_\beta^{new} = \psi + \epsilon + \epsilon^2 \cdot |p_\beta^{old}|$$

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Options to define the price received by activated bids:

A. Pay as Bid: The same price that was provided during the bidding.

Pros: Simplifies the pricing mechanism. **Cons**: It does not encourage to bid at real marginal cost of flexibility. Reduces welfare. Reduces transparency.

B. Zonal Marginal Price: One price per region/zone/area.

Pros: Projects value of flexibility at each zone. Less complex than nodal pricing. **Cons**: How to define the zone sizes? One price for each distribution network? Does not reflect real local needs in pricing

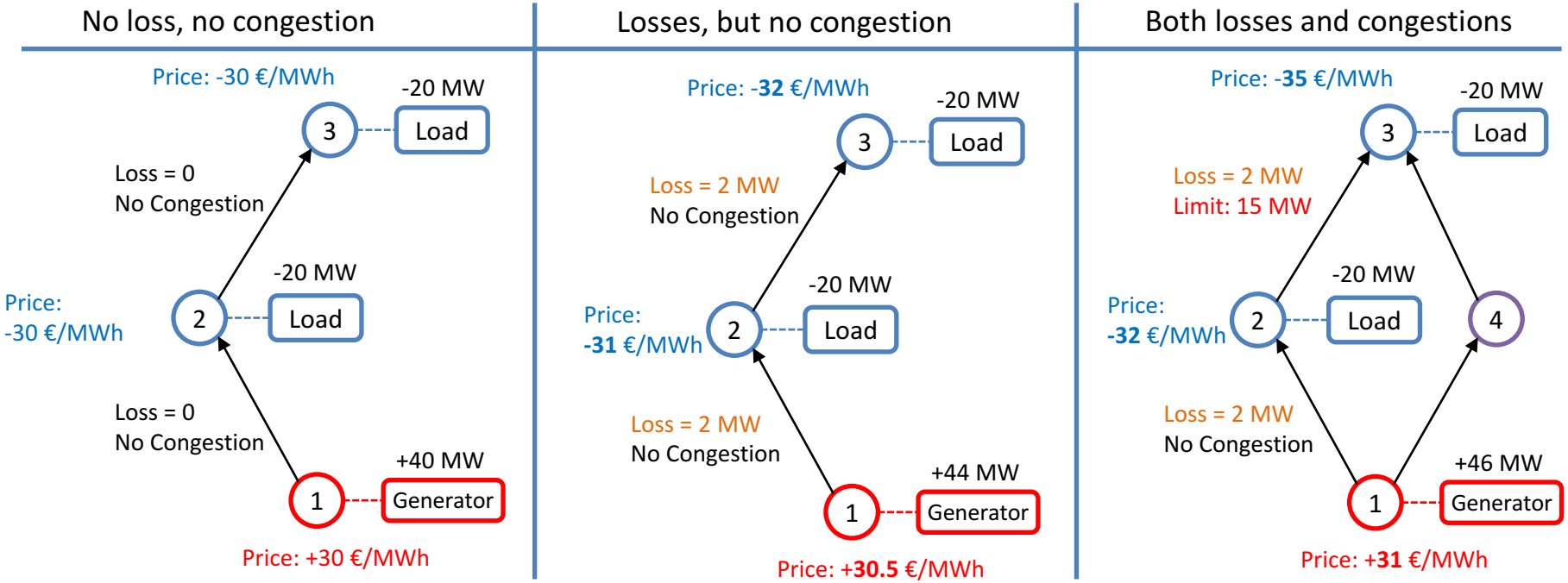
C. Locational Marginal Price: A single price at each node of the transmission and distribution(s) networks.

Pros: Projects real value of flexibility at each node. **Cons**: Complex pricing mechanism. Intuitiveness.

Locational Marginal Pricing as the preferred option

Market Design: Pricing

- Calculating Distributed Locational Marginal Prices (DLMP) in which the clearing algorithm assigns individual prices for each node of the grid.
- A difference between DLMPs is a result of two phenomena in the lines:
  - Energy losses (as a result of non-zero impedance)
  - Network constraints (line capacity limits and congestions)



Summary

Defining a new ancillary service (AS) market for TSO-DSO coordination schemes:

What is required?

- AS **procurement** at the **lowest cost** → Mathematical optimization
- Extract flexibility of **DERs** → Open for aggregated/non-aggregated bids
- Allow a **level playing field** for competition → Variety of market products
- Valorize flexibility at its **real value** → Nodal pricing

What has to be avoided?

- Not taking into account DERs' **constraints** → Complex products
- Creating **congestion** and **voltage problem** → Integrated detailed network model
- Making **myopic** decisions → Rolling optimization
- Doing **unnecessary activations** → Smart objective function

Challenges and next steps

- Next steps:
  - **Implementation** of the different market designs for the different TSO-DSO coordination schemes
  - **Test** the different TSO-DSO market architectures with different parameters
  - **Report** on speed vs accuracy tradeoff

- Challenges
  - **Tractability** issues: solving a MIP (market clearing) in a few minutes, while considering: transmission and distribution grid constraints, a receding time horizon and complex market products (integer variables)
  - **Data** availability: e.g. prediction of injection/offtake at network nodes, scheduled TSO-DSO exchange profile.

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