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A Framework for the Coordination of Flexibility in Multi-Area Power Systems

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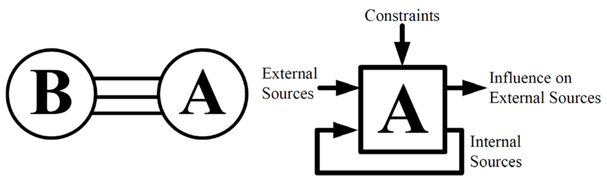
Motivation
- Decreasing reserve availability
- Increasing grid congestions
- Better coordination and sharing of operational flexibility between TSOs needed

Goal
Improve inter-TSO coordination of flexibility in a decentralized way incorporating *transmission constraints* by expressing possible deviations of *tie-line power flows* and related *costs*.

Requirements
- Data privacy
- Minimal information
- No centralized coordination entity
- Considering transmission constraints

Modeling

Two area system split in two areas results in two MIMO-systems:



→ *internal* sources (index i): generators, loads
→ *external* sources (index e): tie-lines, HVDC,…

Shareable flexibility: feasible deviations of external sources, i.e. tie-line flow changes.

Power flow deviations due to deviations of internal/external sources (Δ_i,Δ_e) :

$$P_L^{actual} - P_L^{scheduled} = H_i\Delta_i + H_e\Delta_e$$

Constraints on $\Delta_{i/e}$:
- allowed redispatch of units
- ramping limitations («reaction time»)
- (linearized) grid constraints (H: PTDF)
- N-1 security constraints

Method

Operational Limits

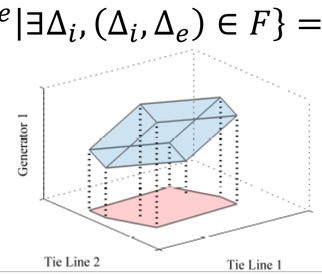
Goal: Find allowed deviations of external sources Δ_e.

Flexibility Set: All constraints are stacked to a linear matrix inequality.

$$F = \{(\Delta_i, \Delta_e) \in R^{ni \times ne} | C_i\Delta_i + C_e\Delta_e \leq b\}$$

Explicit limits on Δ_e: Projection of *F* (blue) on the axes of Δ_e (red).

$$F_d = \{\Delta_e \in R^{ne} | \exists \Delta_i, (\Delta_i, \Delta_e) \in F\} = \{\Delta_e | G\Delta_e \leq g\}$$



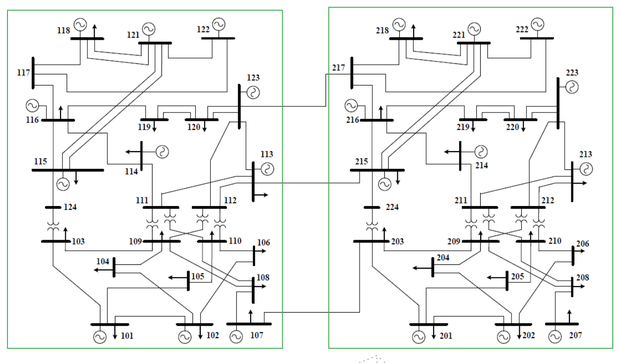
Costs for shared flexibility

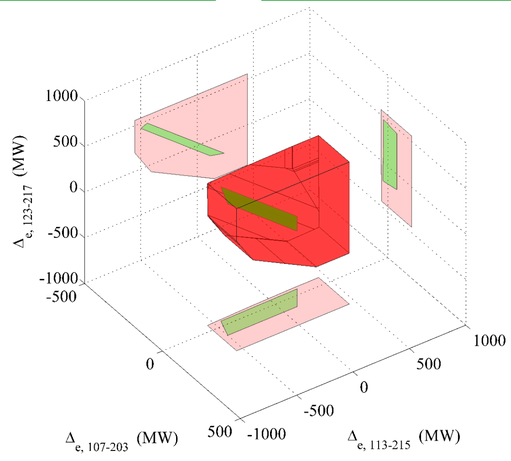
Goal: Construct lower bound for redispatch costs of generators for neighboring TSO using linear cuts.

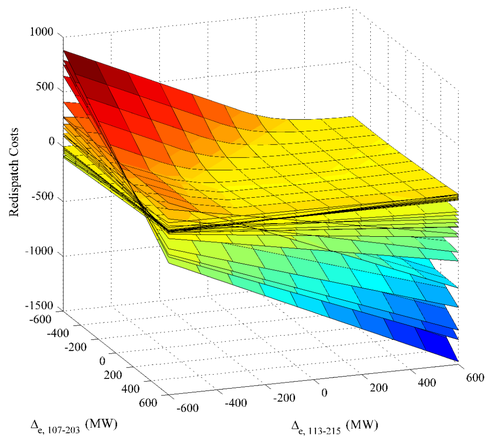
Construction: Calculate redispatching costs q_0^k for a number of selected Δ_e^k. Using dual variables λ, improve bound by adding cuts:

$$q \geq q_o^k + \lambda^k (\Delta_e - \Delta_e^k)$$

Application RTS-96 2-area system





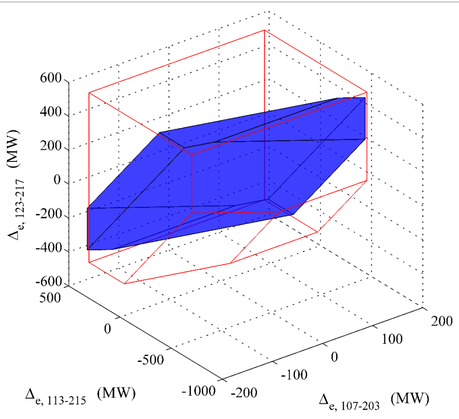


Coordination

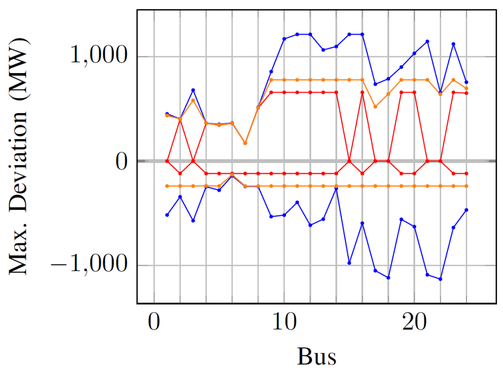
Every TSO prepares information on shareable flexibility and corresponding costs → Data exchange (interval-/event-based) → Incorporation of information, e.g. in redispatch optimization → Communication of remedial procedure to neighboring TSOs and initiation

Comparison with ATC

Methods considering the ATC (available transfer capacity) for sharing flexibility result in a less flexible system (blue) compared to the method presented above (red), i.e. deviations need to be smaller.



The figure shows the maximal possible deviations of bus injections in the neighboring area that can be balanced. In orange, a method considering the ATC is applied; blue: method above. The method can deal with larger deviations, e.g. from intermittent energy sources.



Conclusion

→ Decentralized coordination of flexibility between different control areas
→ lower bound for costs can be determined using a cutting-plane approach
→ Allows to share more operational flexibility compared to methods respecting ATC

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