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Enhanced Flexibility Aggregation for LinDistFlow[1]

Application in TSO-DSO Coordination

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Background & Motivation[2]

Integration of renewables

- Data privacy and limited info exchange between TSO & DSO
- Growing DERs increase computational complexity

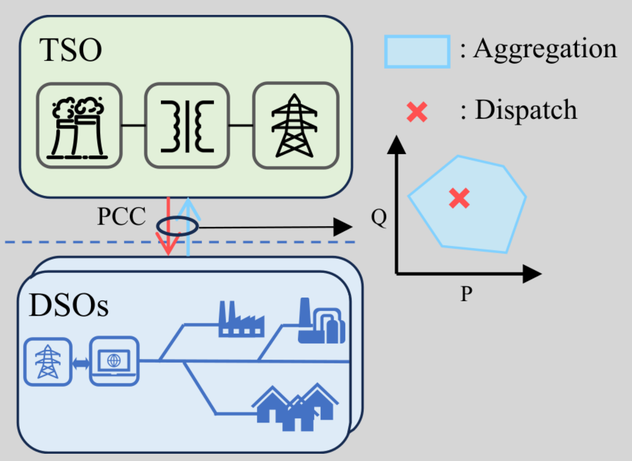
Limitations of LinDistFlow

- Assumption of negligible power loss and voltage drop
- Inaccurate flexibility aggregation and potential operation risks

Compensation method

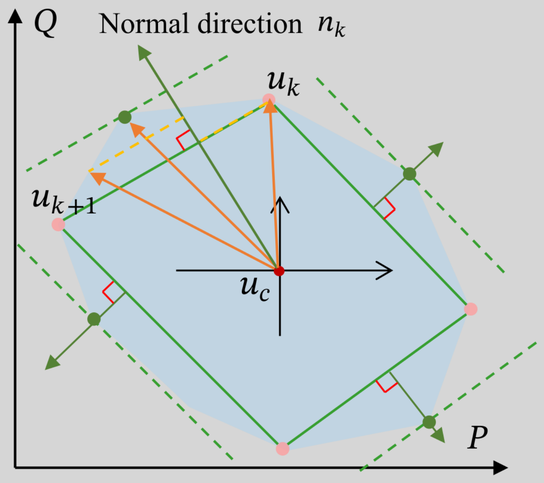
- Compensation for power losses and refining aggregated flexibility
- Simulations confirm better integrated TSO-DSO coordination

1. Coordination with Flexibility



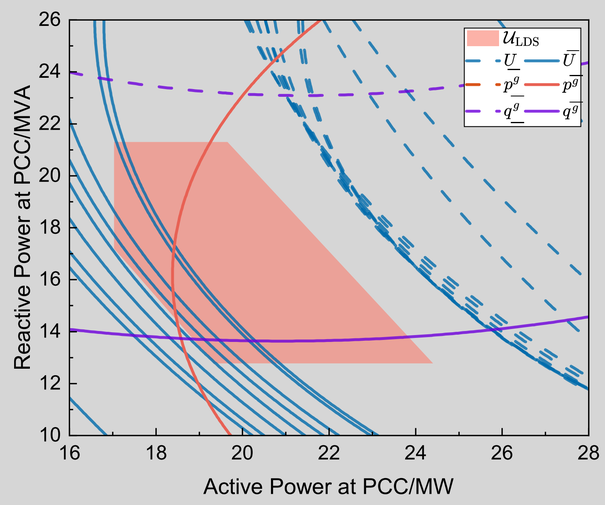
- Projection onto $P^{pcc} - Q^{pcc}$ domain to help TSO make dispatching decision

2. Linear model Aggregation



- Properties: convex but inexact compared with the AC power flow model

3. LinDistFlow Aggregation



- LinDistFlow model (red) vs. Reference, formed with solid and dashed lines.

Improving Flexibility Aggregation with Loss Compensation in LinDistFlow

Problem: What results in the mismatches between LinDistFlow and the reference? How to improve the flexibility of the LinDistFlow model?
Contribution: We propose a compensation method to correct LinDistFlow-based flexibility by approximating power loss on boundary points.

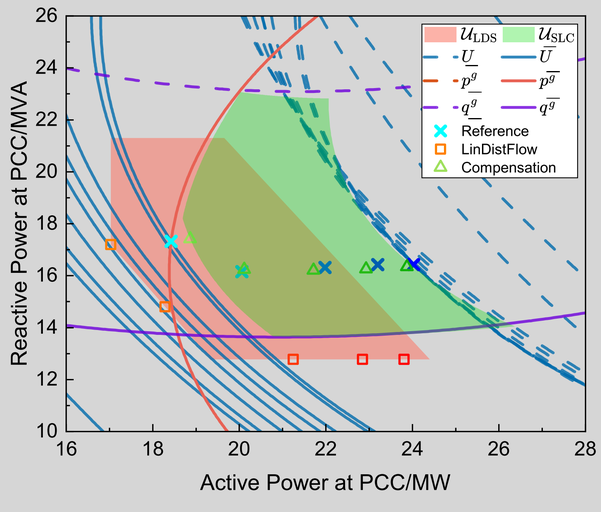
4. Loss Compensation

$$p^{\mathrm{loss}}(u) = R^\top \hat{\mathbf{U}}^{-1} \left(\mathbf{P}^2(u) + \mathbf{Q}^2(u)\right) \mathbb{1},$$
$$q^{\mathrm{loss}}(u) = X^\top \hat{\mathbf{U}}^{-1} \left(\mathbf{P}^2(u) + \mathbf{Q}^2(u)\right) \mathbb{1},$$

- R: Branch resistance, X: Branch reactance
- $\mathbf{P}$: Active branch flow, $\mathbf{Q}$: Reactive branch flow
- $\hat{\mathbf{U}}$: voltage differences across branch
- $\mathbb{1} \in \mathbb{R}^{N^{\mathrm{line}}}$ denotes the vector of all ones

- $u = [P^{\mathrm{pcc}}, Q^{\mathrm{pcc}}]$ denotes the decision variable. The active and reactive power losses are approximated and incorporated at the boundary points of the LinDistFlow model to correct the aggregated flexibility.

5. Our method



- LinDistFlow (red) vs. Compensation (green)
- Dispatch simulations(markers)

6. Future Work

- Extend the flexibility aggregation to meshed distribution networks.
- Achieve multiperiod flexibility aggregation for scheduling problem.
- Leverage higher-order implicit function to improve the approximation

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[1] Y. Jiang, X. Dai, F. Zahn, and V. Hagenmeyer, “Enhanced Flexibility Aggregation Using LinDistFlow Model with Loss Compensation”.
[2] X. Dai, Y. Guo, Y. Jiang, C. N. Jones, G. Hug, and V. Hagenmeyer, “Real-time coordination of integrated transmission and distribution systems: Flexibility modeling and distributed NMPC scheduling”

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