Convex Relaxations of Chance Constrained AC Optimal Power Flow

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Why Consider Uncertainty?

Development of redispatch measures in German transmission grid (2016: 31.5 % RES)

Source: Bundesnetzagentur

⇒ New tools necessary for power system operation of AC grids under uncertainty which are able to:
  • anticipate forecast errors to maintain a secure system operation
  • define a-priori suitable corrective control policies

Source: AWEA
Why Convex Relaxations?

- AC optimal power flow problem non-linear & non-convex
  - No guarantee obtained solution is global optimum
  - Distance to global optimum cannot be specified (cost)
- Semidefinite relaxation transforms AC-OPF to convex semi-definite program (SDP)

⇒ Under certain conditions, obtained solution is the global optimum to the original AC-OPF (Zero relaxation gap in work by Lavaei and Low$^1$)

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What this paper is about?

• First formulation of a chance-constrained OPF with convex relaxations for meshed transmission grids
  – Convex optimization (SDP) is more robust → OPF based on SDP can solve systems with more than 10,000 buses where AC-OPF fails².
  – Finds the global optimum or, at least, provides a distance measure to the global optimum

• We consider two uncertainty sets
  – Rectangular Uncertainty Set (Randomized and Robust Optimization)
  – Gaussian Uncertainty Set

Randomized and Robust Optimization

- We use a piecewise affine policy which interpolates system state between forecasted system state $W_0$ and vertices of the uncertainty set $W_{1-4}$.

- That is, we compute the exact AC-OPF solution at each of the vertices and at the forecasted system state.

- As result of piecewise affine approximation, chance constraints are convex.

- Using robust optimization, it is sufficient to enforce chance constraints at the vertices of the uncertainty set.
• Piecewise affine policy which interpolates system state between forecasted system state $W_0$ and end-point of the ellipsoid axes of the uncertainty set $W_{1-4}$
• Consider correlation of the uncertain variables
• Analytical reformulation of the linear chance constraints as SOC constraints
Investigating Relaxation Gap

... for a IEEE 24 bus test system with 2 wind farms and rectangular uncertainty set.

⇒ Near-global optimality guarantee of 99.74%.
Conclusions

• First formulation of a tractable chance constrained AC-OPF using the semidefinite relaxation

• Testing our algorithms to larger case studies and using realistic forecast data

• Current work includes