Motivation

- Aggregations of electric loads can provide reserves but their capacities are usually uncertain and affected by usage patterns and ambient conditions.
- To manage uncertainties from renewables, loads and load-based reserves, stochastic optimal power flow problems have been formulated and solved, e.g., [2].
- Contribution: We develop a two-stage distributionally robust optimal power flow (DR-OPF) model to optimize energy and reserve dispatch under these uncertainties and derive a quadratic program using the method in [1]. We further compare the performance of this model with a distributionally robust chance constrained optimal power flow model (DR-CC-OPF) [2].

Results

1. Energy and reserve dispatch differences

2. Comparison of cost and reliability (high reliability cases)

3. Comparison of cost and reliability (equivalent cost)

- Under high reliability (close to 100%), out of sample tests show that DR-OPF yields slightly better reliability and lower cost than DR CC-OPF. When reliability requirement is low, DR-OPF could perform worse than DR CC-OPF.
- Enhanced linear decision rule is justified through empirical tests.
- Inclusion of auxiliary variables strengthens its explanatory power.
- Future work will focus on developing a multi-stage distributionally robust optimal power flow formulation using similar techniques.

Formulation

1. Distributional Ambiguity Set and Lifting Transformation

\[ \mathcal{P} = \{ P \in \mathcal{P}(R^{I_1}) : \frac{E_P[Z] - \mu_i}{\sigma_i} \leq 1, \forall i \in [I_1] \} \]

\[ \mathcal{Q} = \{ Q \in \mathcal{P}(R^{I_1} \times R^{I_2}) : \frac{E_Q[Z] - \mu_i}{\sigma_i} \leq 1, \forall i \in [I_1] \} \]

2. Two-stage Formulation

Objective:

First Stage (deterministic)

\[ Q(x, \tilde{z}) = \min_{y \in Y} c^T y \]

Second Stage (Stochastic)

Some example constraints

\[ \bar{E}_G \leq P_G + R_G + y_{11} \]

\[ \bar{E}_L \leq R_L + y_{11} \]

\[ \bar{P}_L + y_{11} \leq \bar{P}_L \]

3. Enhanced Linear Decision Rule

\[ Q(x, \tilde{z}) = \min_{y \in Y} c^T y : A(\tilde{z}) x + B y \geq b(\tilde{z}) \]

\[ y_{11}^{\min} \]  

\[ y_{11}^{\max} \]

\[ y_{11}^{\bar{Q}} \]

4. Combining 1 to 3, we derive a quadratic program, following the steps in [1].

References
