Chance-Constrained Optimal Power Flow with Uncertain Load Control

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Introduction

Demand response (DR) refers to changing electric load consumption patterns that help the grid operate more reliably and efficiently. With high penetration of renewable resources in power grid, more ancillary services are required to continuously balance the supply and demand due to the generation uncertainty. Previous researches have stated that DR could be potential resources with faster responses, lower costs and less environmental impacts. In this research, we tried to analyze the economic dispatch with both renewable generations and uncertain demand response.

Problem Formulation

In this problem, we want to determine the day-ahead optimal dispatch with uncertain load control and renewable resources by co-optimizing reserves and energy. We use chance-constrained optimization formulation to consider various uncertainties from controllable loads and renewable resources.

To model controllable loads, we use a thermal battery model developed from previous work. A linear charging/discharging mechanism is used to represent the energy change. The baseline power, power capacity and energy capacity are all related to ambient temperature. The aggregated power consumption (set point) are used as design variables.

Methodologies

To reformulate the stochastic problem, we use 2 different methodologies.

1. Probabilistically Robust Design
   Solve a robust optimization problem over a hyper-rectangular set constructed based on the confidence level

2. Analytical Reformulation
   Reformulate constraints deterministically assuming specific uncertainty distribution and correlation
   Convex approximations are performed for nonlinear chance constraints and Cutting-Plane Algorithm is used to solve the problem

Results and Discussion

The idea was evaluated on IEEE 30-bus system with single wind generator for both congested and uncongested cases.

For objective performance, analytical reformulation gives better objective values compared with robust method. This can be seen from effective load shifting, more load reserve and no usage of peak plant.

For reliability, robust methods provide both higher individual and joint reliability than analytical approach.

For computational effort, robust method is resilient to congestion and cutting-plane algorithm works better than standard nonlinear solver.

Conclusions

In this research, we reformulated the chance-constrained problem robustly and analytically. We compared the objective performance, computational effort and reliability between 2 formulations and different solving algorithms for both congested and uncongested case.

Our results demonstrated that analytical approach provides less conservative results with better objective values and more effective responses to peak load and congestion. Cutting-Plane algorithm could lead to faster convergence. Robust method is resilient to congestion and provide better individual and joint reliability.

Acknowledgements

This work was partially supported by Grant #CCF-1442495 from the National Science Foundation, Cyber-Innovation for Sustainability Science and Engineering (CyberSEES) program.

References
