Project 1:

Two-stage stochastic market clearing: ADMM and Benders decomposition approaches

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Abstract

This project has four steps:

- Step 1) This step develops and solves a simple deterministic optimization problem.
- Step 2) This step solves the deterministic optimization problem developed in Step 1 in a distributed manner using alternating direction method of multipliers (ADMM).
- Step 3) This step considers a stochastic uncertain parameter (wind power), which is characterized by a set of scenarios. The aim of this step is to develop and solve a two-stage stochastic programming problem (without decomposition).
- Step 4) This step solves the two-stage stochastic programming problem developed in Step 3, but in a decomposed manner using Benders' decomposition.

Hints

- Any relevant programming software, e.g., GAMS and Python, can be used. All codes should be included in the final group's report.
- All optimization models developed in Steps 1-4 are linear and convex. There is no binary variable.

Description

Consider a single-node single-period electricity market with three conventional generators (G1, G2, and G3), a single wind power producer (WP), and a single elastic demand. The following table gives the technical characteristics of conventional generators:

Generator	Capacity [MW]	Production offer [€/MWh]
G1	100	10
G2	80	12
G3	50	16

Demand bids 250 MW at a price of €25/MWh. The installed wind power capacity is 65 MW, and it offers its production at zero price.

Step1) The wind power producer has a deterministic forecast, i.e., 50 MW. Formulate a deterministic linear optimization problem and obtain the market-clearing outcomes (i.e., generators' dispatch, market price, and market's social welfare).

Step 2) Although the deterministic optimization model in Step 1 is small and can be easily solved, the market-clearing optimization problem in real-world markets may contain thousands of variables and constraints. Due to potential computational issues in such large-scale problems as well as concerns about information privacy of market players, implement a decomposition technique based on Augmented Lagrangian Relaxation using ADMM and solve the market-clearing optimization problem in a distributed manner, i.e., one problem per market player.

Step 3) The wind power producer has a probabilistic forecast, and generate five equiprobable scenarios: 20 MW, 28 MW, 35 MW, 55 MW and 65 MW. Develop and solve a two-stage stochastic market-clearing problem, including day-ahead (DA) and real-time (RT) stages. Generators G1 and G2 are inflexible and cannot change their DA schedules in the RT stage. However, generator G3 is fully flexible, and offers upward- and downward-regulation at price of €18/MWh and €14/MWh, respectively. The involuntarily load curtailment cost is €100/MWh. In particular, obtain DA and RT market prices, and then compare DA and expected RT prices.

A useful reference for Step 3:

J. M. Morales, A. J. Conejo, K. Liu, and J. Zhong, "Pricing electricity in pools with wind producers," IEEE Trans. Power Syst., vol. 27, no.3, pp. 1366-1376, Aug. 2012.

Step 4) The DA schedules (as here-and-now decisions) are complicating variables. Solve the two-stage stochastic programing problem developed in Step 3 using Benders' decomposition, yielding a master problem and five subproblems (one subproblem per scenario).