Energy Portfolio Management for Sustainable Campus

EAEE 4220 Fall 2021 Project 3

1 Introduction

You are a renewable energy manager of a college campus in up-state New York. You are purchasing daily energy supply contracts for tomorrow and your options are below

1. A wind farm near-by offers you at-risk wind generation capacity at $150 per MW capacity for tomorrow, the actual generation depends on the real-time wind power capacity factor. The maximum capacity this wind farm offers is 20 MW. 1
2. A natural gas generator nearby offers three services
   - The first is base load generation service, the generator provides $15/MWh baseload generation for tomorrow, equivalent to $360 per MW. 2
   - The second is peak load generation service, the generator provides peak demand supply from 8 AM to 6 PM at $20/MWh, equivalent to $200 per MW. 3
   - The third is load following service, the generator can provide any supply as requested by the campus up to the contracted capacity. This is an option call contract, the option fee for this service is $50 per MW, and the exercise fee is $18/MWh. 4 - 5

   The capacity of this generator is 10 MW, so the total amount of the three service contracts cannot exceed 10 MW. -> constraint

In addition, the campus has 1 MW capacity of solar panel installed which will provide free solar energy to the campus depending on the actual solar power capacity factor. Also note that all real-time imbalances will be cleared at the real-time electricity price. For example, if the sum of the natural gas, wind farm, and the on-site PV generation is less that the real-time campus demand, you must purchase from the real-time energy market at the real-time price; if you bought and generated more than you need, you must sell them in the real-time market as well. -> market balance.

You do not know what could happen for tomorrow, but your student intern has provided you with five possible scenarios with equal probabilities for tomorrow. Each scenario contains predicted campus demand, real-time price, and the capacity factor for wind and solar. All profiles are generated at a 15-minute resolution.

2 Project Objective

Your boss has requested you to provide the following results so he can make the final trading decision:

- What is the minimum expected cost to serve the campus demand for tomorrow and what is the corresponding contract portfolio?
- How do we minimize the worst case cost scenario for tomorrow, and what is the corresponding contract portfolio?

In addition, the school board would also like to hear your suggestions about the feasibility to power the campus entirely by renewable energy. Based on what you have observed from these five scenarios and your portfolio management results, summarize possible pathways towards a sustainable campus, and the relative costs associated with these pathways. In this discussion, you don't need to limit your options to the trading options listed above, but should focus on the scenario data and the cost numbers of different resource types. You are also encouraged to search for the most up-to-date costs regarding different energy resources.

3 Tips

Here are some tips to get you started

1. The first task is essentially a two-stage stochastic optimization problem, as most of the decisions are made ahead of the operating day. The only decision you need to make during the operating day is to decide how much generation you would like to get from your load following call option. You can assume this natural gas generator is fast enough so it can produce any amount of power you request.

2. It is easier to think backward when trying to solve stochastic optimization problems. First, think about how to formulate the problem during the operating date for each given scenario, in which you can assume you the contract portfolios are already fixed. For example, you can first formulate an optimization problem for each given scenario that calculates the total cost and decides how much on-option natural gas generation to call. This can be formulated in compact form as

$$\min_{x_s} Q_s^\top x_s \text{ subjects to } A_s x_s \le B_s y \tag{1}$$

   where x_s are the decision variables over scenario s, y is the contract portfolio that has already been fixed for the operating day. Q_s should include the exercise price and the real-time price, and the constraint limits how much gas generation you can call based on your option capacity.

   Then you can combine all scenarios together by assigning them equal probabilities ω_s

$$\min_{x_s, y} R^\top y + \omega_s \sum_{s=1}^{N} Q_s^\top x_s \text{ subjects to } A_s x_s \le B_s y \text{ and } Cy \le D \tag{2}$$

   where N is the number of scenarios.

3. The second task is a robust optimization problem in which you are trying to optimize against the worst-case scenario, and be aware, the worst scenario also depends on your generation portfolio. For example, if you weigh more on wind generation capacity, then the scenario with the least wind becomes the worst case scenario.

   One way to solve this robust optimization problem is to use conditional value-at-risk (CVaR) optimization and set the β to 20%, same granularity to the scenario possibilities. Therefore, the CVaR optimization will automatically pick the worst case scenario. The CVaR formulation, followed by the previous stochastic compact form, can be listed as

$$\min_{\alpha, M, x_s, y} \alpha + \frac{1}{N(1-\beta)} \sum_{s=1}^{N} M \tag{3}$$

$$M \ge R^\top y + \omega_s \sum_{s} Q_s^\top x_s - \alpha \tag{4}$$

$$M \ge 0 \tag{5}$$

followed by the same set of constraints are in the earlier formulation. The literature for CVaR optimization can be found in this link. Note that

$$\min_{x \in A} [x]^+ \tag{6}$$

can be equivalently represented as

$$\min_{x \in A} M \text{ subjects to } M \geq 0 \text{ and } M \geq x \tag{7}$$