31762 - Introduction to energy analytics

Assignment 1: Bidding strategy of a battery system

Deadline: Tuesday, March 1, 2022 at 20.00 hrs.

The goal of Assignment 1 is to become familiar with optimization tools for extracting value out of lots of data.

Our specific goal is to design an optimization program that can help you determine your bidding strategy to the wholesale market in order to maximize your profits.

- Who are you? A battery owner.
- Where are you? Somewhere in Denmark or its neighboring areas: Sweden, Norway, or Germany (we avoid Great Britain for this Assignment, as it has still no direct connection to Denmark).

You will need to use elspot prices, which you can find here: `https://www.energidataservice.dk/tso-electricity/elspotprices`. Prices from 2019 until 2021 can also be found on DTU Learn in Assignment1 as:

- elspotprices_19to21.csv

Once you open the file you will notice that it contains the electricity prices (in DKK/MWh) for every hour of the years 2019 to 2021 **(in UTC)** for various price zones. Work only with UTC time. Using time in UTC means that there are no gaps or extra hours, and you can disregard the issue of summer/winter time.

Logistics for the submission of your report:

1. Maximum length of the report: **4 pages + 1/2 page** for "Lessons Learnt" (see last task) + 1 page for bonus questions (optional; see Task X)
2. Upload one report per group as a .pdf in Assignment 1 at DTU Learn.
3. Please **mention how you shared the workload** either on the frontpage or at the end. This is necessary by the DTU guidelines.
4. You must also **provide running-code**, i.e., the user should be able to press run and obtain answers to all the following questions. The code must be a .py file for Python. Please use short comments in the code to indicate what each part of the code does.
5. You need to upload your report and code on DTU Learn the latest by **Tuesday, March 1, 2022, at 20:00 hrs**.

Problem description

You are the owner of a battery system and wish to use it for profit from trading in the wholesale market. The battery energy storage system (BESS), as such systems are usually called, has a power capacity of 1 MW and an energy capacity of 2 MWh. The battery's state of charge can vary between 10% and 100%. You can neglect any battery degradation costs. For simplicity, assume that you bid in the market shortly before 00.00. Your bid is a set of 'buy' and 'sell' orders for the next 24 hours (one order for each hour), assuming you have perfect knowledge of the spot prices.

Task 1: Decide where you want to install your Battery Energy Storage System (BESS).

1.1 Pick a price zone from the ones you have available in your data: DK1, DK2, SE3, SE4, NO2, or DE.

1.2 Pick the location inside this price zone, i.e. closest city and country.

Task 2: 'Learn' your price zone (so that you can anticipate the level of your profits). Make a statistical analysis of the historical prices between 2019 and 2021 *for the price zone you picked.*

2.1 Find the average price per year.

2.2 Find which time of day has historically had the highest price (i.e. for every day between 2019 and 2021, which hour of day had on average the highest price?).

2.3 Find which time of day has historically had the lowest price.

2.4 Your plan is to profit from the price difference between the different hours of every single day. Note: For this assignment, as you will see in Task 4, you must start and finish each day with the same state of charge. This means that whatever arbitrage you do, you do it during the day, and you do not profit from price differences between different days. Considering this, please calculate *two more statistical indices of your choice* which you think could help you estimate the potential profits of your battery from this daily arbitrage. Please briefly explain your choice.

Task 3: Describe the battery bidding optimization problem. Present the objective function considering a linear cost function with the buy/sell prices, and the battery's constraints. Show the result of your bidding strategy in terms of energy bought/sold per hour for January 14, 2021 (we do not want to pick January 1st, as this is a holiday in Europe; so, we just pick a random 'normal' winter workday). Assume an initial and final state of charge of 50%, no fees/tariffs and no battery losses.

Task 4: It's time to put your strategy into practice!

4.1 Use your strategy to bid in each day of 2021. The state of charge at the first hour and last hour of every day must be equal to 50%. Present and discuss your results.

4.2 Can you find any correlation between each day's profits and any of the metrics on the daily prices you calculated in Task 2?

Task 5: Use the aforementioned strategy with no losses of Task 4 as a benchmark for this step.

5.1 Consider a charging and discharging efficiency of (i) 95% and (ii) 90% and compare the yearly profits for the three cases. (i) Present the changes in your algorithm, and (ii) discuss your results, explaining the effect of losses in your profits.

5.2 What is the charging and discharging efficiency of a Lithium Ion battery system (i.e. not only the battery itself, but including the inverter, etc.)? Please cite the reference which you used as a source for your answer.

5.3 Instead of a battery, we could have had an electrolyzer to produce hydrogen (similar to "charging a battery") and a fuel cell to use this hydrogen to produce electricity (similar to "discharging a battery").

- What is the efficiency of an electrolyzer and of a fuel cell? Please cite the reference which you used as a source for your answer.
- What would you expect to happen with the profits in this case compared to a battery? You do not need to provide a numerical result of the profits. Just explain in a brief, concise way what you expect to observe.

Task X: Food for thought (Bonus questions; you can use an extra page).

X.1 In real life, you would not have the constraint that each day you must start and finish with a 50% state of charge of your battery. Can you think of a strategy to determine what should be the target state of charge at the end of each day? And what would be the effect on the profits? Do you think your strategy will change if you assume different efficiencies (e.g. 95% or 90%)? (Please also take into account that this target value will also affect the next day operation of the battery, as it will be the starting state of charge the next day.)

X.2 Do you think you could apply the same bidding strategy if you had a 200 MW, 400 MWh battery? Yes or no, and why?

X.3 In real-life, would you be able to freely pick where to install the 1 MW, 2 MWh battery? More specifically: assume you have already picked a price zone; would you be able to install the battery at any possible location you wanted within this price zone? If yes, why? If not, what are the additional considerations that one shall make in real life?

X.4 There is currently a lot of discussion in Denmark (and several other countries in the world) that if we install too much wind in the North Sea and the Baltic Sea, then hydrogen can be a good source of energy storage. Considering the efficiencies you found in Task 5 for the electrolyzer and the fuel cell, do you think that the hydrogen storage can be a good option for daily arbitrage? If yes, under which conditions? If not, then what could be other attractive options for hydrogen?

Lessons Learnt: During this assignment there were definitely several issues that came up while trying to answer the questions or until you got your code running correctly. In no more than half a page, please list 2-3 main points that you think you should remember for the next time you code a bidding strategy or you have to design such a strategy. Please list at least one issue that had to do with coding, i.e. what should you remember to do in some specific way, or avoid, next time you code a bidding strategy? And please list at least one main takeaway from the design of the optimal bidding and how it affected the results you obtained.