46040 - Introduction to energy analytics

Assignment 1: Bidding strategy of a battery system

Deadline: Tuesday, March 14, 2023 at 20.00 hrs.

The goal of Assignment 1 is to become more familiar with the analysis of electricity spot prices and optimization tools for extracting value out data.

You will use the two datasets we used in the hands on sessions 2 and 3, i.e., the ProsumerData csv and the Elspotprices excel files. We will work with hourly values for PV and load data, as we did by resampling in the previous hands on exercises.

We will use exclusively local time in all tasks.

Logistics for the submission of your report:

1. Maximum length of the report: **6 pages, excluding the frontpage**
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 in your **Main.py** file and obtain answers to all the following questions. Please use short comments in the code to indicate what each part of the code does.
5. Upload all your code files in a single zip file.
6. You need to upload your report and code on DTU Learn the latest by **Tuesday, March 14, 2023, at 20:00 hrs**.

The first task accounts for 20%, the second 30% and the third 40% of the grade. Overall quality and presentation of your work accounts for 10%.

Tasks description

Task 1: Statistical analysis of the historical prices for DK1 and DK2.

1.1 Use the spot price data from years 2019, 2020, 2021 and 2022. Find the average price for each year, but for each of the two areas separately (8 values in total). Present your results in a figure, expressing prices in DKK/MWh, and discuss your findings (evolution of prices and difference between the areas).

Note: you will need to modify the provided *CreatePricesDf.py* function.

1.2 Calculate and plot the average spot price per hour of day over all 4 years, separately for DK1 and DK2 (24x2 values in total). Find which hour of day has historically had the highest price, and which the lowest price. Plot your results, expressing prices in DKK/MWh, and discuss your findings.

1.3 **Focus on DK2 only**. Calculate and plot the average spot price per hour of day for each of the 4 considered years (24x4 values); discuss the results. Which year seems more attractive for using a battery?

Task 2: Battery arbitrage problem.

You are using a battery only to profit from spot price variations with the following considerations:

- You are located in DK2.
- The battery's state of charge can vary between 10% and 100%.
- The battery energy storage system has a power capacity of 6 kW and an energy capacity of 10 kWh.
- Your charging and discharging efficiency is equal to 99%, i.e., $\eta_\mathrm{c} = \eta_\mathrm{d} = 0.99$.
- The battery state of charge at the start and end of your optimization will be set to 50% of the energy capacity.
- Each day you optimize the schedule of the battery between 00:00 and for the next 24 hours, assuming you have perfect knowledge of the prices.
- You buy and sell energy at the spot price.

2.1 Optimize the operation of your battery for each day of the four years (2019, 2020, 2021 and 2022). Present your results on an aggregated yearly basis (4 values to calculate).

Do you see any correlation between **the profits of each day** and **the average electricity price of that day**? Discuss the result and what conclusion you can make. Tip: you can use a scatterplot to visualize correlation.

2.2 Re-calculate your results with $\eta_\mathrm{c} = \eta_\mathrm{d} = 0.95$ and $\eta_\mathrm{c} = \eta_\mathrm{d} = 0.90$. Present the results for each year and for each of the three efficiency cases in a plot (12 values to show). Discuss your findings and explain the effect of efficiency on profits. Does efficiency or the overall price level have a larger impact on profits?

Task 3: Prosumer analytics

We now consider a prosumer, again located in DK2. The PV generation and the consumption of the prosumer are given by the ProsumerData csv file. Consider only years 2020, 2021 and the first 10 months of 2022. The prosumer buys energy with the *Buy* price and sells at the *Sell* price at each hour; your have calculated these prices in a previous hands on. The prosumer is subject to hourly net metering, i.e., at each hour the prosumer pays for the energy import or receives money for the energy export. You will use hourly-averaged PV and load data.

3.1 For this question consider only the consumption part and neglect PV generation. Calculate the total costs of the user between Jan 1st 2020 and Oct 31st 2022 (the customer buys energy at the buying price).

Next, do a rough calculation for comparison. Calculate the total energy that is consumed in each hour of day over the whole period. Multiply these values with the average buying price for each hour of the day. Did you get a similar or very different result from this calculation? What can you conclude on using averaged values in this case? Can you provide a possible explanation?

3.2 Calculate the yearly benefit of the PV system. You can do that by comparing, on a yearly basis, the total costs by neglecting PV generation with the costs of the prosumer under **net metering** when owning the PV.

Present your results on a yearly basis and discuss them. Remember that 2022 is not a full year and that under net metering you need to consider imports and exports.

Do you think this PV is a good investment over a 20-year period? Do you need to make some assumptions on electricity prices? Note that the prosumer's consumption level changes over time. You can look up online for the approximate cost of a 6 kW PV system.

3.3 Our prosumer seems to be trying to match consumption with PV generation. Do you think this affects the benefit you calculated in 3.2, and in which direction?

Tip: consider how the average buying price per hour looks and how the average consumption per hour looks. Plot the two in the same graph and explain how such a *smart* and *cost-conscious* customer would probably behave in the absence of the PV. Would consumption look different and how would that affect the PV benefit? Provide only a qualitative answer on this.

3.4 Now assume that the prosumer owns the battery described in Task 2. Your charging and discharging efficiencies are equal to 95%. Optimize the operation of the battery for every day of 2020, 2021 and the first 10 months of 2022. What is the benefit that the battery brings to the prosumer? You find the benefit by comparing the costs of the prosumer with and without a battery (you calculated those in 3.2).

Do you think that a battery is beneficial for the prosumer that we investigate? Under which conditions a battery would be economically attractive? You can find an indicative battery cost online.

Does the behaviour of the user affect the benefit provided by the battery? In which direction? Provide only a qualitative answer and your justification.

Tip: remember the self-sufficiency you calculated in the Hands-on of Lecture 2 and how the prosumer adjusts demand.