Operational planning assignment

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You will have to devise a strategy for charging a pool of electrical vehicles (EVs) in an industrial-like microgrid. The electricity can come from the grid (at a price π_{grid}^{imp}) or from the photo-voltaic (PV) panels (or both). There is a limit $\bar{P}_{grid}$ on the power that can be imported from or exported to the grid. The energy exported to the grid is not valorized, and there is no net-metering. We assume every EV has access to a charging station when it arrives in the parking, and is characterized by

- an arrival time T_e^a (time step)
- a departure time T_e^d (time step)
- an arrival state of charge S_e^a (%)
- a desired departure state of charge S_e^d (%)
- a battery capacity $\bar{C}_e$ (kWh)
- a max charging power $\bar{P}_e$ (kW) (we assume an EV can charge at any value between 0 and $\bar{P}_e$, but cannot discharge in the grid)
- a charging efficiency function of the charge power (that you will determine from Figure 1)
- the price the owner is willing to pay for the energy charged π_e^{cha} (i.e. the penalty incurred if S_e^d is not met) .

The arrival and departure times are uncertain. At every time-step (of 60 minutes), you receive a forecast of arrivals for the current day. A forecast of PV generation is also available.

If technically possible, all the EVs must receive some power, i.e. you can assume the price EVs are willing to pay is higher than the grid import price (otherwise they do not plug in). However, the charging strategy should allocate power among EVs using the following priority index (higher index means higher priority)

$$\frac{\Delta_t (T_e^d - T_e^a)}{\bar{C}_e} \pi_e^{cha}$$

to weight the excess or lack of percents of state of charge they reach at departure time compared to S_e^d. This priority index tends to favor EVs that will stay for long and have a little capacity, unless the EV owner is ready to pay for a fast charge. Overall you have to minimize

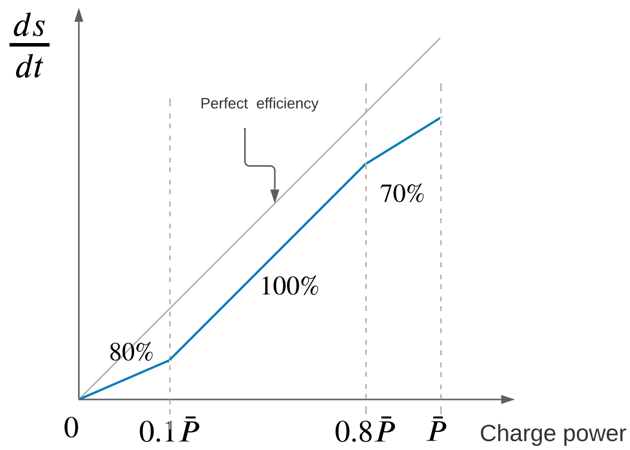

Figure 1: Variation of the state of charge of an EV per unit of time as a function of the charge power (index e omitted).

a trade-off between the costs of the electricity purchased and the penalty (using the priority index) incurred to EV owners if their desired S_e^d is not met. Use a trade-off coefficient to express all terms of the objective function in euros.

Note: the desired state of charge S_e^d should ideally not be exceeded. However, it may happen that $S_e^a > S_e^d$. You cannot do anything to it, just be sure your model is robust to this.

Your tasks:

1. From Figure 1, determine the expression of the charge efficiency $\eta(p)$ as a function of the charge power. Plot $\eta(p)$.

2. Write down a model of the optimization problem to be solved at each time step, as a MILP.

3. Code the model in Python with the Pyomo modeling library and use CBC as solver (there is a code template here).

4. Test your controller on your own, i.e. test with a few arbitrary inputs and check your results make sense. Report one attempt that shows your controller takes meaningful actions.

5. Submit on Gradescope, where a simulator of the microgrid will call your controller every time step and apply the first action. You will see how your controller performs on the Leaderboard of GradeScope. Play with the objective trade-off coefficient.

We expect a readable[1] report with maximum 6 pages of content. You can send

[1] A4 paper, 11 pt font, one column, decent margins.