ENVIRON/ENERGY 590.05 - Economics of Modern Power Systems
Fall 2022

Instructor	**TA**
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Assignment #3
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The same residential customer from A#1 decided to upgrade his behind the meter PV system with battery storage. Please refer to the file "*Pdata.csv*" for information on hourly PV production, costumer hourly demand and electricity rates to answer the questions bellow.

1. **Original model**

   (a) Implement the energy management optimization model we developed together in class using Python. You can use the file "A3_EnergyManagementSystem.ipynb" as a starting point but make sure you understand all pre-existing parts of the code. After you add constraints and objective function to the notebook, run the code and report the optimal solution, i.e., what is the customer daily cost with electricity and values for decision variables (you may use charts or tables to illustrate your decision variables schedule).

   (b) Generate plots based on values for the decision variables found in part 1 showing the schedule for charging and discharging the battery (use Python or Excel to generate the plots). Note that it may seem like something is wrong because if you look at hour 9 am, you will see that P_{slack} is greater than zero ($P_{slack}[9] = 2.68997$) which means the system is throwing electricity away, but the battery state of charge is still 0.2. Why is that excess power being curtailed when it could be used to charge the battery?

   (c) Add a constraint to the model that fixes $P_{ch}[9] = 2.68997$. Note that the value is below the maximum of 3 MW, so it should lead to a feasible solution. Report the new optimal solution, i.e., objective function value and compare its value and decision variables plots with results from part (a). What happened? Is the optimal solution still the same? What about the objective function value? Could a LP have more than one solution leading to the same objective function value?

2. **Impact of utility rates policy**

   Imagine the utility implemented two-tiered time of use rate such that from hours 15-20 (peak hours) the rate will be 2 x 0.099963724 which will continue to be the rate for off-peak hours. You can change this policy manually on you data set file "*Pdata.csv*", or implement this change directly in your code. The later is the easiest way to do because you can simply comment that section of the code whenever you need to go back to the original problem.

   (a) Report the solution and compare with your results from part (1a). Did the SOC curve changed? What about P_{ch} and P_{disch}?

   (b) Remove the constraint that says you can only charge the battery with electricity from the PV system. Compare the results with those from part (a).

   (c) Now let's assume customer experience a cloudy day and it's PV production was only one-third of the values in "*Pdata.csv*" and re-run the model from part (b). What happened now? Is the customer using electricity from the grid to charge the battery in this scenario? Why?

3. **Sizing storage system**

   Consider the original model and data from part (1). Run your code for different values of storage capacity in kWh. Recall that our original capacity is 4 kWh. Start by running the model at 1 kWh and increase the capacity by 1 kWh until you reach 12 kWh (12 runs). Store objective function values for all simulations. Don't worry about charge and discharge capacity per hour for now.

   (a) Using R or Excel generate a line plot with total electricity cost from objective function values in the y axis and storage capacity in the x axis. What are the takeaways from this graph? Can you make a statement about the optimal storage capacity from the plot?

   (b) Now consider an approximate cost of 176 $/kWh for the storage system. Would you change your answer to part (a) based on that new information? Recall that this model gives you daily cost of electricity, you should look at a longer horizon and maybe revisit you financial model from A#1 to answer this question.

4. **Impact of net metering policy**

   Consider the original model with flat electricity rates throughout the day. Assume that there was a change of policy and this customer is now entitled to net metering.

   (a) How could you change the model to accommodate that? How this changes your results from part (1). *Hint: Look at* P_{slack} *values for the original model. Think about what they represent when net metering is allowed.*