Densys in Liège

Operational planning and sizing

March 21, 2024

Operational planning
In this first part, your task consists of implementing a controller to manage a complete microgrid that represents a typical home setup. The electric system of this home is designed as a grid-connected microgrid.

The home is therefore connected to the main power grid and includes solar panels, a backup generator, a battery energy storage system (BESS), and some loads (see Figure 1). You are given standard household data in Belgium, like consumption and maximum PV production. Your role is to ensure the balance between consumption and production at all times while minimizing operational costs over the whole year.

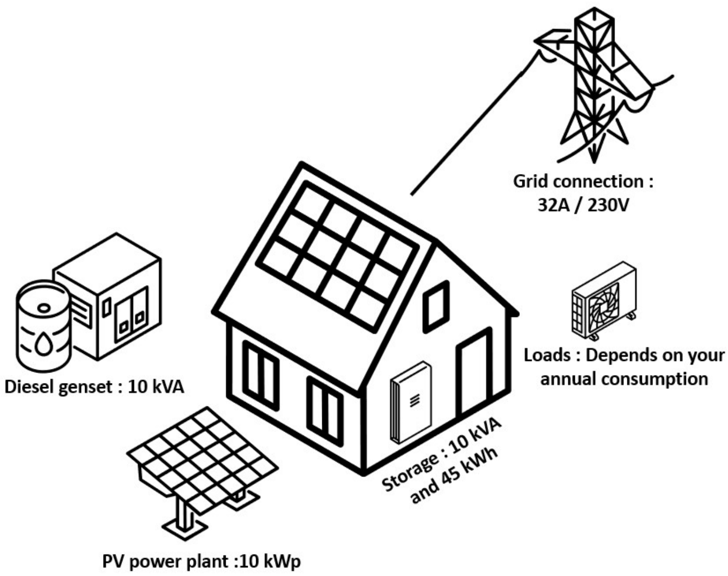

Figure 1: Schematic representation of the microgrid representing a home

The role of the controller will be to manage the energy production in your system by using its flexibility (*e.g.* PV curtailment, usage of a diesel Genset, and the BESS). The activation of this flexibility should be done coherently regarding your energy usage objectives. This should be fully described and justified in the report.

The controller's primary function is to regulate energy production within your system, leveraging its flexibility. This includes actions such as adjusting solar power output, using a diesel generator when needed, and managing the BESS. The activation of these flexible measures should align with your energy usage objectives, which should be fully detailed and justified in the report.
Among the key objectives of your controller, you should:

- minimize load shedding;
- reduce PV curtailment;

- use of the genset only when necessary;
- ensure reliable use of the main BESS.

Questions:

1. Import the normalized load and power profile from `profile.csv` using your own yearly energy consumption.
2. Solve the operational planning problem (in `OP_opt.py`) using a linear programming formulation. Here, the sizes of the devices are known, you just want to optimize the usage of each device to minimize OPEX.
3. Compute the **yearly** system costs and compare you results for three different tariffs (net-metering, selling to the grid, or giving it away)
4. What are the main decision variables in this problem?
5. What are the key parameters? How could they totally change the optimal results?
6. What are the strong assumptions made when solving this problem? Discuss.

   Hints:

   - Start by specifying all the constraints (names are already provided in the code to help you).
   - Specify the objective introducing only real costs
   - **Selling to the grid**: Use the import and export prices
   - **Giving it away**: The export price should be set to 0
   - **Net metering**: This involves calculating the net electricity imports over a specified period. If the net imports are positive (indicating more electricity consumed than produced), you pay the import price multiplied by the net imports. Conversely, if the net imports are negative (indicating excess electricity production), your electricity bill is zero.

Sizing

In the second part of this assignment, you are asked to size a household microgrid that could potentially be installed in your home. Initially, you will design it as a grid-connected system and then as a standalone (isolated) microgrid. To do so, you need to build an optimization model taking into account both OPEX (operational expenditure) and CAPEX (capital expenditures). This will allow you to:

- determine the appropriate grid connection capacity.;
- size the BESS, with the inverter power and the system capacity considered independently;
- size the Photovoltaic (PV) installation, where the PV capacity can be chosen independently of the PV inverter power;
- decide whether to invest in a genset or not and its nominal capacity. (This could be needed especially for achieving a fully islanded scenario).

All in all, you will have to adjust your energy system design to optimize asset sizes across various scenarios (grid-connected or islanded) and multiple tariffs. You should include personal data from your house (annual consumption, number of kilometers traveled per year, maximum PV capacity).

Questions:

1. Reformulate the optimization problem of the previous section as a sizing problem. Additional constraints are required and the objective function must be adapted to include scaled CAPEX.
2. Compute the optimal sizing considering only January.
3. Apply the same procedure for June instead of January and finally for the whole year. Compare the results you obtain in each case.
4. Size the microgrid over the entire year considering the three export tariffs explained previously (giving it away, selling to the grid and net metering). How do these influence your results? Explain.
5. What are the main decision variables in this problem?
6. What are the key parameters? Describe their impact on the results. How would a change in these parameters affect the results?
7. Discuss the results and show how the asset sizes are linked. Also show the usage and price of each investment. Discuss the savings they create.
8. Solve the same problem after removing the grid connection to isolate your house from the grid.
9. For the previous cases, compute the yearly CO_2 emissions. Discuss your findings.
10. How would you implement such an algorithm considering uncertain forecasts instead of perfect predictions? How would it affect the results? Discuss.

Bonus

1. Add the electric vehicle to the optimization problem and compare the results with those obtained in the previous questions. What has changed and why do you think this is the case?

Few advice and hints

- Since your role is now to size the microgrid, **you should set the device sizes as variables**.
- The objective must be changed to **take into account both CAPEX and OPEX**.
- To avoid losing too much time waiting for the solver, you should start by simulating one month before solving the whole year problem when you are sure that your code works.

- When connected to the grid, try to use some metrics such as self-consumption or self-sufficiency. These measures will help you assess your system's performance and efficiency.
- In the sizing part, don't forget to compare the installed capacities and the energy produced by the different units. Try to interpret the results.
- Generally speaking, you should always keep an eye on the prices obtained and try to interpret them.
- Pay attention to the way you present your results. Try to be as clear as possible when using graphs and tables. Do not hesitate to change the given plot function or to add some more. Do try to
- Questions are given as a guideline for the report. You are encouraged to go outside of this and to discuss further your models and results if they are of interest.

The assignment should again be carried out by groups of three students and submitted as a zip file by email before the 26th of April 23:59. The zip should contain a report describing your process, results, and analyses (maximum **8** pages) and your modified Python files. You will also be asked to present in an oral session. This will be organized on Teams probably during the week of the 6th May. Each groups will present separately for maximum 10 minutes with some slides, then we will ask questions during 10 more minutes.

For questions and remarks, please contact:

- tstegen@uliege.be