Analysis of electrical power and energy systems

Assignment: pandapower project 2022

1 Introduction

The goal of this assignment is to help you better understand the concepts seen during the course by illustrating them with a power flow tool and to introduce some applications of power flow calculations for power system operation and planning.

For this assignment, you will use the Python library called pandapower. Documentations about this library can be found here: `https://pandapower.readthedocs.io/en/v2.4.0/`. We also encourage you to check out the pandapower channel on YouTube for video tutorials.

The assignment must be carried out by group of *three students* and submitted as a zip file on eCampus in the Assignments section before **December 8, 23:59**. The zip file must contain a report in pdf format describing your results and analyses as well as the source code in Python you wrote for the assignment.

You will also have to present your project. Information about the presentation will be provided later.

Note that attention will be paid to how you present your results. Careful thoughts in particular - but not limited to - should be given when it comes to plots. For each question, you are given expectations about the format and the length of the answer.

2 Questions

The assignment is divided in two parts. Along the assignment, we consider the slightly modified IEEE 39-bus test system (see Fig. 1), that contains 40 buses, 36 lines, 9 generators and 22 loads [1]. In pandapower, you can load this network with the provided Python function using the following command line:

```
net = import_net()
```

2.1 Part 1

This part should help you better understand the concepts seen during the course. Note that each question here must be solved independently, always starting from the initial power system (run import_net() at the beginning of each question).
Expected: 5 pages, including figures.

1. Use pandapower to run a power flow for this network[1]. Display the results with pf_res_plotly.py. What do you observe? Are all the voltages between the limits? Are the line loadings acceptable?
   Expected: 1 plot with the power flows, 1 bar graph with the voltage magnitudes at the different nodes.

[1] Do not forget to ensure that reactive limits for generators are enforced.

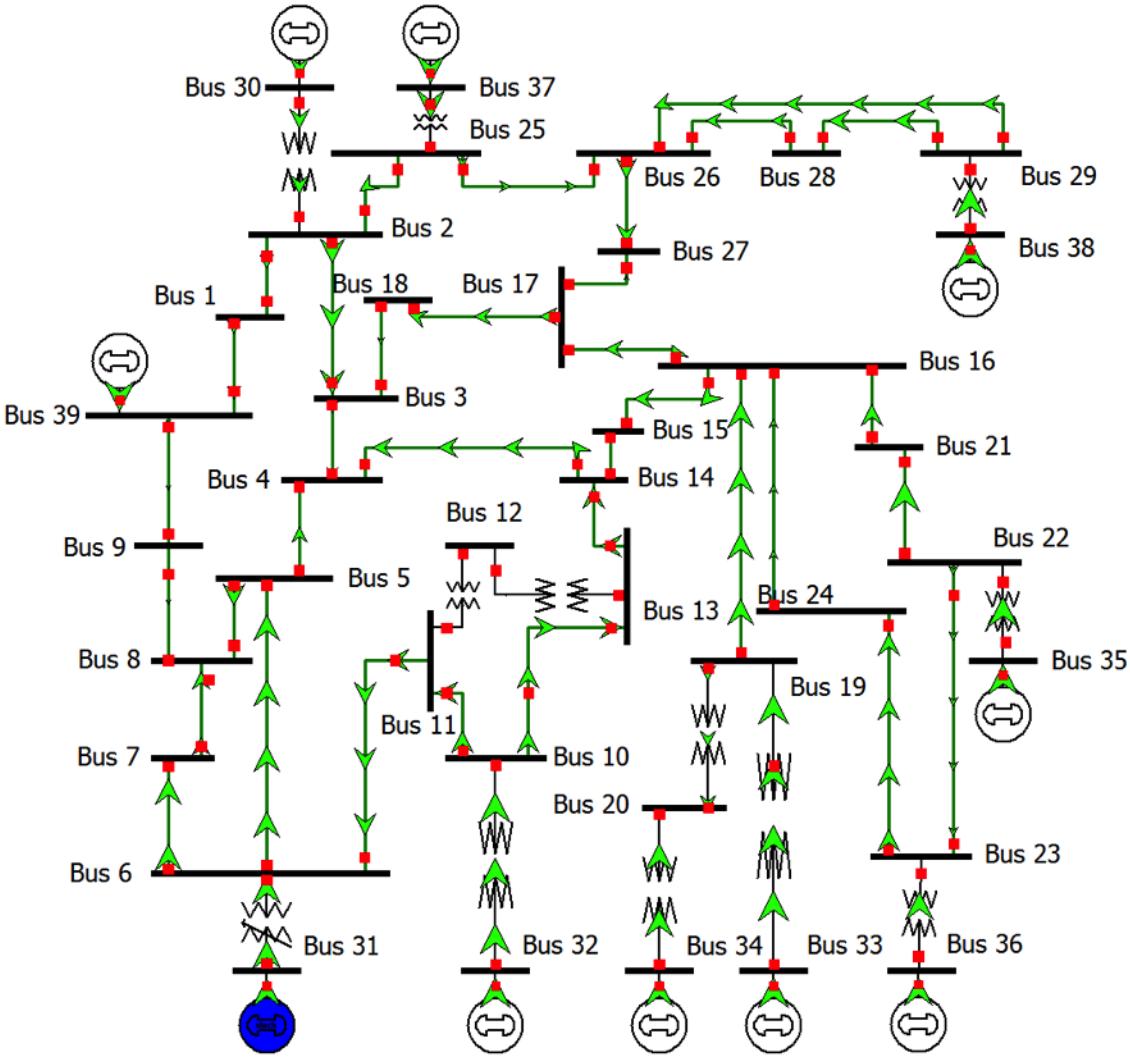

Figure 1: IEEE 39-bus test system.

2. Use the power flow tool to analyse the impact of a progressive increase of consumed power at bus 40[2], while keeping the power factor at this node constant. This bus is not represented in Fig. 1 but it is connected to bus 28 through a long single overhead line. In particular, look at the voltage magnitude of bus 40. At some point, the power flow will no longer converge. Why? For which amount of active power consumed? Plot the voltage magnitude of bus 40 with respect to the active power consumed at that bus. For this question, **do not enforce the reactive power limits of the generators.**
Expected: 1 plot showing the voltage magnitude with respect to the power consumed.

3. Add a capacitor bank to bus 40 such that the power factor becomes 0.9 (leading)[3]. Increase the power consumed at bus 40 and analyse the results. For which amount of active power consumed the power flow does not converge? Plot the voltage magnitude of bus 40 with respect to the active power consumed at that bus. Compare the results you found with those of the previous question. For this question, **do not enforce**

[2]the index corresponding to bus 40 is 39 as the index starts at 0
[3]You can also simply adapt the reactive power consumed at that bus to match the desired power factor

the reactive power limits of the generators.
Expected: 1 plot with the voltage magnitude with respect to the power consumed.

4. Add a phase-shifter[4] to prevent the overloading of the line between bus 6 and 11 (indices 5 and 10, and line index 11). The phase-shifter should not induce overloading in other lines. Plot the loadings of line 11 and 7 with respect to the phase shift imposed by your phase-shifter. The phase-shifter should be placed in series with the line where you consider to add it.
   Expected: 1 plot with the power flows after the addition of the phase-shifter with what you think is the optimal phase shift, 1 plot of the loadings of line 11 and 7 with respect to the phase shift

5. Convert bus 30 which is a PV node into a PQ node. Play with the reactive power Q sent to the grid. What is the impact on the network, regarding power flows and voltages?
   Expected: Figures showing the evolution of the power flows with different reactive power Q.

6. Replace the existing line between bus 24 and bus 16 (line index 23) by a DC line. Consider a lossless DC line and play with the injected power and voltage magnitudes at both sides of the line. What is the impact on the power flows?
   Expected: Figures showing the evolution of the power flows with different injected power and modulated voltages.

2.2 Part 2

In this part, the IEEE 39-bus test system is used but the load and generator data are different for each group. When you have your group, send an email to `antonin.colot@uliege.be` to receive your data, which consist of several csv documents describing the load active and reactive powers and the generator active powers and voltage magnitudes along the 24 hours of one day.
Expected: 5 pages, including figures.

1. Use the pandapower Timeseries module to run a power flow along the 24 time steps. What do you observe?

2. When power system operators operate the network, they usually ensure that the system will continue to operate, even in case of a loss of one of its elements. This is called the N-1 security criterion. Here we consider that the system is N-1 compliant if the voltage magnitudes and line loadings are within limits even in case of a loss of any one line in the system.

   Based on your analysis at the previous question, select an hour of the day where you think problems could arise and check if your network is compliant with the N-1 criterion at that period, i.e. remove one line at a time and use the pandapower Timeseries module with one time step to run the power flow and check if some line or bus voltage constraints are violated when that line is not in service. If the network is not N-1 compliant, which lines are problematic? What are the nature of the problems? Justify the choice of the time step studied.

[4] You can choose as characteristics for this transformer: sn_mva=1000, vk_percent=33.57, vkr_percent=0.92.

3. Let's imagine you have the possibility to realize an investment in the network to ensure that the line and bus voltage constraints are not violated during the hour studied. Consider one of the biggest problems you identified with the N-1 analysis at the previous question. Which element(s), among those seen in the course, would you add to the network and where to resolve the problem ? Describe your choices and justify. Analyse the results and show the impact of your decision on the power flows in the network. In particular, show how your solution improved the aforementioned problem and check that it does not create new problems for the lines that were not problematic in the N-1 analysis.

References

[1] T. Athay, R. Podmore, and S. Virmani, "A practical method for the direct analysis of transient stability," *IEEE Transactions on Power Apparatus and Systems*, no. 2, pp. 573–584, 1979.