Analysis of electrical power and energy systems

Assignment: pandapower project

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 *two students* and submitted as a zip file on eCampus in the Assignments section before **December 3, 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 on December 7. 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.

2 Questions

The assignment is divided in two parts. Along the assignment, we consider the IEEE-RTS79 network (see Fig. 1), that contains 24 buses, 33 lines, 10 generators and 17 loads [1]. In pandapower, you can load this network with this example code:

```
import pandapower.networks as pn
net = pn.case24_ieee_rts()
```

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 pandapower 'case24_ieee_rts'.

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?

2. Use the power flow tool to analyse the impact of a progressive increase of consumed power at bus 6[2], while keeping the power factor at this node constant. In particular, look at the voltage magnitudes and the line loadings in the system. What do you observe? Can you increase indefinitely the power consumption at bus 6? Why?

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

[2] The indications here correspond to the name of the buses (starting at 1) and not their index.

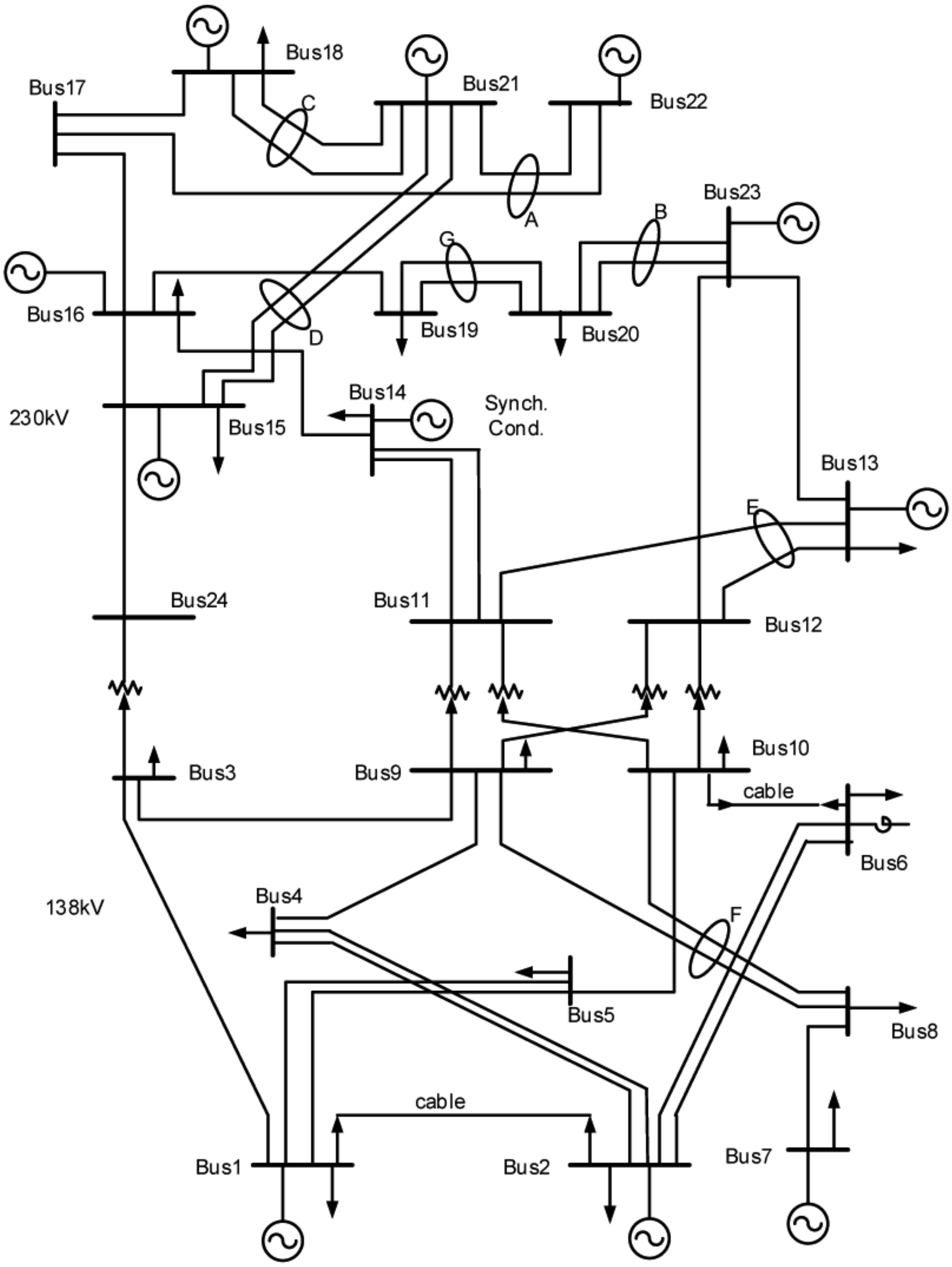

Figure 1: IEEE one area reliability test system.

3. Increase progressively the length of the line between buses 7 and 8. What do you observe? What is the impact on the voltages in the network?

4. Add a tap-changer[3] between bus 7 and bus 8. The transformer is in series with the line connecting the two buses and on the side of bus 7. Display the voltage magnitude at buses 7 and 8 as a function of the tap position. What do you observe? What happens when you do not enforce the reactive power limits of the generators? Is it coherent with the theory?

[3]You can choose as characteristics for this transformer: sn_mva=400, vk_percent=12, vkr_percent=0.25.

5. Add a phase-shifter[4] between bus 11 and bus 14. The transformer is in series with the line connecting the two buses and on the side of bus 14. Which buses and lines are significantly impacted by the phase-shifter? Display their voltage angles and magnitudes, as well as their line loadings, as a function of the tap position. What do you observe? Is it coherent with the theory?

6. Modify the value of the inductor bank (shunt) on bus 6. What is the impact on the power flows? Why ?

7. Convert bus 21 which is a PV node in a PQ node. What reactive power do you choose? What is the effect on the network, regarding power flows and voltages?

8. Add a DC line between bus 20 and bus 24. Play with the power transmitted along this line. What is the impact on the power flows and voltages?

2.2 Part 2

In this part, the IEEE-RTS79 network is used but the load data is different for each group. When you have your group, send an email to `Selim.ElMekki@uliege.be` to receive your data, which consist of several csv documents describing the load and static generator active and reactive powers and the generator active powers and voltage magnitudes along the 24 hours of one day.

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 load 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.

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.

[4] You can choose as characteristics for this transformer: sn_mva=400, vk_percent=33.572608, vkr_percent=0.92.

References

[1] C. Grigg, P. Wong, P. Albrecht, R. Allan, M. Bhavaraju, R. Billinton, Q. Chen, C. Fong, S. Haddad, S. Kuruganty, *et al.*, "The ieee reliability test system-1996. a report prepared by the reliability test system task force of the application of probability methods subcommittee," *IEEE Transactions on power systems*, vol. 14, no. 3, pp. 1010–1020, 1999.