ELEC0447 – Project 1
Low voltage distribution feeder modeling and analysis

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1 Introduction

The goals of this assignment are to

1. get familiar with Python and PandaPower, a power system modeling tool
2. learn to run some first power-flow analyses on a simple network
3. gain some intuition on the impact of high loads and renewable distributed generation
4. compare three-phase balanced and unbalanced operating conditions.

Let's consider a street where a distribution network feeder connects ten houses. A *feeder* is a power line that carries electricity from a substation or distribution transformer, which we will model as our slack bus, to the end-users. The network data is given as an Excel file containing separate sheets describing the buses, lines, and loads.

Remark: I used Google Colab and PandaPower version 2.14.10 to carry out all the experiments below.

2 Your tasks

1. **(Base case)** Write a python code to model a **single-phase equivalent** of the network and run a first power flow analysis[1].

2. Explore the results of the base case. Plot the network schematic and the voltage magnitude and angle evolution along the feeder (from bus 0 to bus 10). Display the line loading coefficients. Briefly discuss the results.

3. Starting from the base case, progressively increase the load (keep the same power factor) at the buses near the end of the feeder (this simulates the addition of electric vehicles or heat pumps). What do you observe? Is there a loading condition where the power flow does not converge? Explain.

4. Starting from the base case, add photovoltaic plants at the buses near the end of the feeder and progressively increase their production (from 1 to 10kW). What do you observe?

5. **(3-phase base case)** Now, you will model the network more accurately using a model of the three phases. Update the model to run a three-phase power flow.

   (a) First, update the cable type to encode the *zero-sequence parameters*[2] of the line

   Listing 1: Updating the cable type.

   ```
   import pandapower as pp
   pp.create_std_type(net, {"r_ohm_per_km": 0.642, "x_ohm_per_km": 0.083,
                   "c_nf_per_km": 210., "max_i_ka": 0.142,
                   "endtemp_degree": 70.0, "r0_ohm_per_km": 1.923,
                   "x0_ohm_per_km": 0.249,
                   "c0_nf_per_km":  70}, name="unsymmetric_NAYY 4x50 SE",element =
                        "line")
   line_type = "unsymmetric_NAYY 4x50 SE" # To be used when creating the lines.
   ```

   and then use this line type to create the lines.

   (b) Using the function `pp.create_asymmetric_load`, load the system so that you are **in the same conditions than in the base case** (with the **single-phase equivalent**). Use star (or wye) connected loads.

   (c) Add the following commands to run the power flow[3]:

   Listing 2: Running a three-phase power flow analysis.

   ```
   net.ext_grid['s_sc_max_mva'] = 1000
   net.ext_grid['rx_max'] = 0.1
   pp.add_zero_impedance_parameters(net)
   pp.pf.runpp_3ph.runpp_3ph(net, algorithm='nr', calculate_voltage_angles=True)
   ```

   (d) If it succeeds, you can now access the results in the `net` object (e.g. `net.res_bus_3ph.vm_a_pu`).

6. Explore the results of the 3-phase base case. Plot the evolution of the magnitudes and angles of the voltage along the feeder (from bus 0 to bus 10). Display the currents in the phases and the neutral along the feeder. Briefly discuss the results.

7. Starting from the 3-phase base case, load the network so that the total load at each bus is equally shared between phase a and phase b. What can you observe?

8. Start from the 3-phase base case. By chance, all house owners connected a photovoltaic inverter of 2kVA on phase a. Model this situation when the inverters all produce the maximum active power. What do you observe? What could you do to improve the situation? Note: a photovoltaic inverter is indivisible.

[1] An example code for a 3-bus network is available as a link in the slides on the power flow analysis. You can use it as a starting point. You should also consult PandaPower's documentation.

[2] This is to model the coupling between the phases. You must not fully understand what is done here, browse internet if you want to know more.

[3] Again, no need to understand everything, it is required to make it work.

3 Submission rules

1. Work by groups of 2.
2. Submit on Ecampus
   - a report in PDF format with an average of half a page per question
   - your Python notebook (a zip if multiple files)
3. Do nice, readable, and interpretable plots $\rightarrow$ Tutorial video.
4. Due date: November 4, 2024, 23:59.