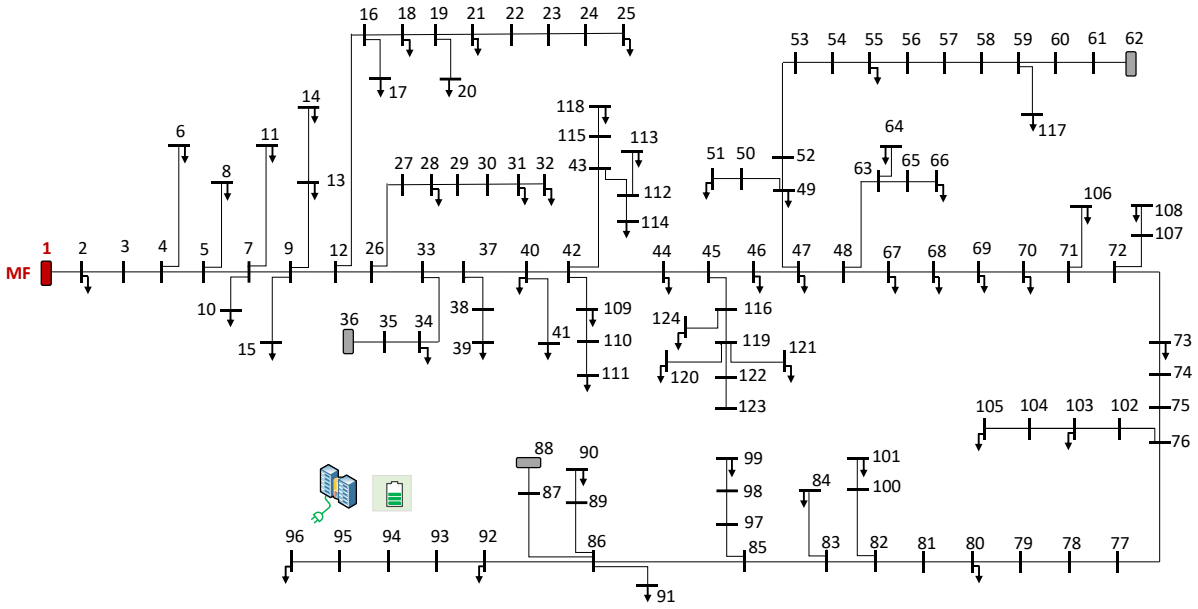
Exercise 0 ("warm-up exercise"): A battery in the grid

The CINELDI reference system is extended with a large customer at bus 95 (at the end of a long radial), which triggers voltage problems in the grid. A battery in the grid (at bus 94, for instance) is considered to mitigate voltage problems.



Learning outcomes:

- Hands-on experience with using the CINELDI reference system (introduced in the first double lecture)
- Building intuition on the relationship between voltage problems and the load in the grid

Data and code inputs:

- Data set: https://doi.org/10.5281/zenodo.7703070
- Intro script (code for getting started): https://github.com/SINTEF-Power-system-asset-management/CINELDI_MV_reference_system/blob/flexibility_course_NTNU_public/exercise_0_battery_in_the_reference_system.py

Other references:

- Data article describing the CINELDI reference system:
  - I. B. Sperstad, O. B. Fosso, S. H. Jakobsen, A. O. Eggen, J. H. Evenstuen, and G. Kjølle, 'Reference data set for a Norwegian medium voltage power distribution system', *Data in Brief*, 109025, 2023, doi: 10.1016/j.dib.2023.109025.
- Documentation of pandapower (Python package for grid modelling and power flow analysis):
  - https://pandapower.readthedocs.io/en/latest/

Getting started:

- Find code for using data set:
  - https://github.com/SINTEF-Power-system-asset-management/CINELDI_MV_reference_system
  - Download the code (all the files) from the flexibility_course_NTNU_public branch
  - (NB: The repository also contains code files that are not directly relevant to the exercises; these are part of the general code base for using and documenting the CINELDI reference data set and are also included with the branch prepared for this course module.)
- Download data set:
  - https://doi.org/10.5281/zenodo.7703070
  - The entire data set is can be downloaded as a .zip file: CINELDI_MV_reference_system_v_2023-03-06.zip
  - Unzip the .zip file to some folder on your local hard drive and make note of the path
- Install pandapower
  - http://www.pandapower.org/start/#install
- Open your copy of the Python script exercise_0_battery_in_the_reference_system.py in the folder where you downloaded the code files from GitHub
- Set the value of path_data_set in the script to your local folder with the data set
- Run the script and extend it as described in the tasks below

Tasks:

1. Use existing code (intro script) to load the CINELDI reference system as a pandapower grid model object.
2. Plot the voltage profile in the grid from the main feeder (bus 0) to the bus at the end of the radial where we will connect the customer (bus 96). What is the lowest voltage value in the grid?
   - (This is also to be redone for the tasks below.)
3. Add a 1 MW load with power factor 0.95 at bus 95 with and replot the voltage profile.
   - (See https://pandapower.readthedocs.io/en/latest/elements/load.html. Remember to specify reactive as well as active power.)
4. Add a load representing a battery at bus 94.

    - (Alternatively, it could also be represented as a pandapower storage element or generator element. If represented by a load element, the power consumption value (p_mw) needs to be set to be negative to represent power injection from the battery to the grid.)

5. Check how large power capacity the battery needs to have to mitigate voltage problems in the grid, assuming that the minimum allowed voltage in the MV grid is 0.95 p.u and that the battery can absorb or inject active power only.
6. Let the battery be able to inject 0.2 Mvar reactive power as well as absorbing active power. How does this change the battery's operational benefits in terms of mitigating voltage problems?

Frequently encountered problems:

- For problems with importing python-igraph, you can try the following steps until until the problem is (hopefully) resolved:
    - Run from the terminal: pip install pandapower
    - Run from the terminal: pip install pandapower["all"]
        - (This will install all the dependencies of pandapower, including python-igraph, which is required for plotting.)
    - Add pandapower and python-igraph to your python interpreter or working project environment
    - Uninstall igraph and install igraph version 0.10.2 (in case it is the newest version 0.11.6 that is not working)
    - Uncomment the code for plotting ("pp_plotting.pf_res_plotly(net)")
        - (Plotting is not strictly necessary, so a quick workaround is to add some code of your own to extract, print and/or visualize the results some other way.)