POLITECNICO
MILANO 1863

DIPARTIMENTO DI ENERGIA

Electric Power Systems Project 2025-2026
Power Flow Analysis on Medium Sized Systems

Assume that you are an operation engineer working for EPSTSO. Your job is to provide engineering support for the real-time operations of your 14 bus power system which supplies PoliMi (represented in Figure 1). The green bus represents the slack bus, while the blue ones represent the generator (PV) buses.

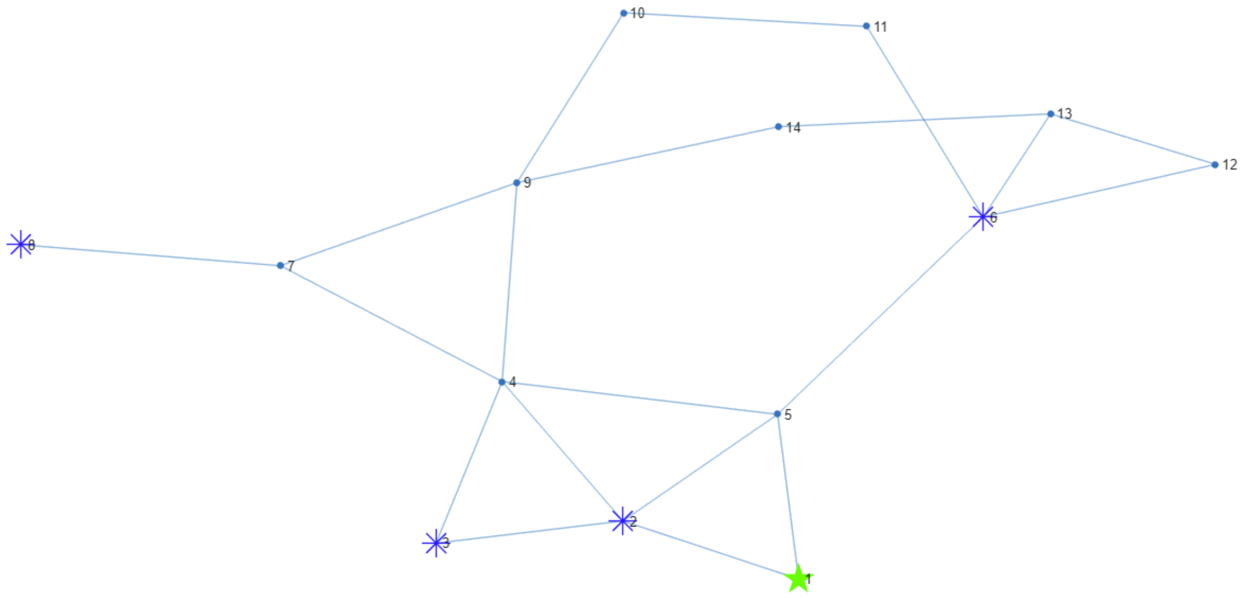

Figure 1: 22 bus PPL system.

Implement the 14 bus system in PowerWorld considering all the lines closed. You can find all the necessary data in the attached Excel file. Remember also, when you draw a transformer, to select at first the HV bus (PowerWorld puts the tap changer on HV bus). To set the controller of the transformers:

a) Open the transformer dialog window
b) Go to the "Transformer" tab
c) Select "change automatic control options" and modify them according to the Excel file.

Transformer controllers can be added in draw tab → field → transformer field. Leave the "Automatic Control" not enabled.

This will be your "Configuration 0".

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You know your boss is a stickler for following procedures. So, you know you must read through the entire procedure before you start. You also know you'll need to prepare a report on what you've done, so you need to keep a log of what you do.

1. Starting from Configuration 0, your boss is asking you why there are no changes in voltage magnitude and currents if you change the slack bus voltage angle from 0° to 60°.
2. You notice that several overloads are present in the network, among which the highest one is on branch 2-3 (approx. 193%) .
3. You remember that EPSTSO has recently installed three phase shifting transformers (PST). Starting from Configuration 0, experimentally calculate the MW line/transformer flow (this data can be found in the Model Explorer → Branches State → MW From) sensitivities on branch 2-3 for a change in the phase shift across these transformers . Go in 2-degree increments (use the increment/decrement option added from the transformer field tab) and investigate the degree of linearity in this calculation (when you evaluate one PST, put the others at 0 degrees). Of course, all values are recorded in your report. The range on the phase shifters can be found in the Excel file.
4. Try to fix all the overloads. To do it you can move the phase shifters as much as you want (up to their limits and avoiding any other line/transformer overloads). If necessary you can modify the real power of the generators installed in buses 3-6-8 (follow the limits from the Excel file, each step is 5 MW; the control of the generators can be added in the diagram in the same way you added the transformer one), but remember that your boss asked you to prepare a plan that require less change in total generation (you do not need to consider changes to the slack bus generation). While usually you would want your system to be N-1 reliable, now you just need to get the loading on all the lines and transformers back to 100% or less. Note that in PowerWorld an overload is indicated with a red circle; if the circle is orange, then the overload is not present (this is due to the graphical approximations).
5. Implement your plan in the power flow. Save the case for your report, but in doing so be sure to use **SAVE CASE AS** to avoid overwriting the existing case. Then make a copy of the oneline diagram with the changes implemented. To save an online image, right-click on a blank portion of the oneline. This will display a local menu. Select Export Image to File and save it in one of your directories. You'll need to include this in your report. This will be your "Configuration 1".
6. Once that you did all the calculations, your boss sent you a document that defines the monetary cost in €/MW necessary to modify the real power outputs of the generators, which is expressed as:
$$Cost_g(P_g)[€] = \alpha_g P_g^2 + \beta_g P_g + \gamma_g X_g$$
where P_g is the real power produced by generator g, $\alpha_g, \beta_g, and\ \gamma_g$ are the cost coefficients that can be found in the Excel file, and X_g is a binary variable that is equal to 1 if $P_g \neq 0$, 0 elsewhere (hence, if generator g produces/absorbs reactive power only, then $X_g = 0$. How do you modify the plan implemented at Point 5? Again, save everything as previously explained. This will be your "Configuration 2".
7. Your boss then asks you, based on your engineering judgement, which configuration is better and why (of course if any differences appear).

Somebody appears to have switched out all the capacitor banks, and the tap on the LTC transformer (between buses 7-8) is in its nominal position.

8. Starting from the configuration defined at Point 7, for each capacitor record sequentially how the MW losses would change if that capacitor (and only that capacitor) was energized. Be sure to re-open each capacitor as you move to the next. (to see the MW losses, edit mode → draw tab → field → area field → single click on white space → MW losses). Suggestion: close without saving and re-open the project after each calculation to avoid numerical issues.
9. Pick one capacitor and close it (choose it according to your judgment). Then repeat Step 8 for the other capacitors. in che senso close it Comment on whether you think this is a linear relationship. That is, does superposition hold?
10. Using your engineering judgement coupled with experimentation, come up as closes as you can get to the optimal values for the LTC transformer tap ratio, and the capacitors switch positions. Save an image of the oneline with your changes; this should be included in your report. This will be your "Configuration 3". Save also the file related to this configuration.
11. Now your boss asks you to study the system security: with reference to Configuration 3, determine if there is any critical contingency according to the Italian TSO N-1 security criterion. List in a Table the worst 5 contingencies and why you consider them as critical. Determine, for the two first-ranked contingencies, the control actions needed to bring the system back to an alert or normal state. **Is the system N-1 secure? (an answer to this question is needed!)**
12. With reference to Configuration 3 and considering a convergence tolerance of 0.01 MW/Mvar, carry out 50 iterations and discuss the power flow results with reference to the following methods: Gauss-Seidel, Newton Raphson, Fast Decoupled, DC. In order to investigate the convergence properties, before?? consider also running a single iteration of the afore-mentioned methods: compare and discuss the solution with the output of a single iteration. To be sure that the correct method is running, after each evaluation close the file (without saving) and open it again. All the options are available in Run mode →Tool → Simulator Options.
13. Implement in the Matlab environment the Fast-Decoupled power flow based on the Input data provided (everything that you derive from them must be put in the code). You are free to handle the inputs as you wish, but the code must be complete and parameterizable (We will try the code with other networks to see if it works). To check the code, do the comparison with PowerWorld results (Suggestion: PowerWorld uses a weird transformer equivalent model, therefore the comparison should be done by putting the PST angle equal to 0 and the off-nominal tap ratio equal to 1). If necessary put any comments you think are useful.

Report:

Provide a step-by-step account of the procedure you followed and of the results you obtained. Your report should answer all the questions raised in the procedure. In accordance with engineering practice, document your recommended specific course of action and justify it with the data you collected. Be sure to include images of the systems and keep in mind that the executives reading your report will want it well written. Include also the Matlab code you implemented. Some groups may be asked to present the work done.

The report must not exceed 30 pages. (excluded the Matlab code).

Evaluation criteria:

- Length limit
- Completeness
- Correctness
- Clarity

The deadlines are as follows:

- Exam in **January/February 2026**: the report of the project must be uploaded in **PDF** before **November 23rd, 2025** in Assignments>Project 1 - Power Flow Analysis (report delivery).
- Exam in **June/July 2026**: the report of the project must be delivered in **PDF** before **May 31th, 2026** sending an email to **riccardo.nebuloni@polimi.it**;
- Exam in **September 2026**: the report of the project must be delivered in **PDF** before **July 26th, 2026** sending an email to **riccardo.nebuloni@polimi.it**.