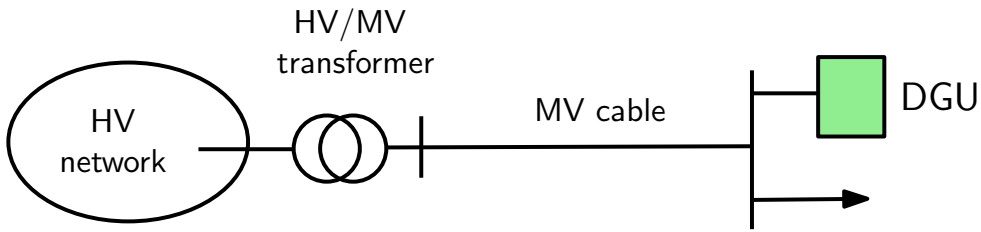
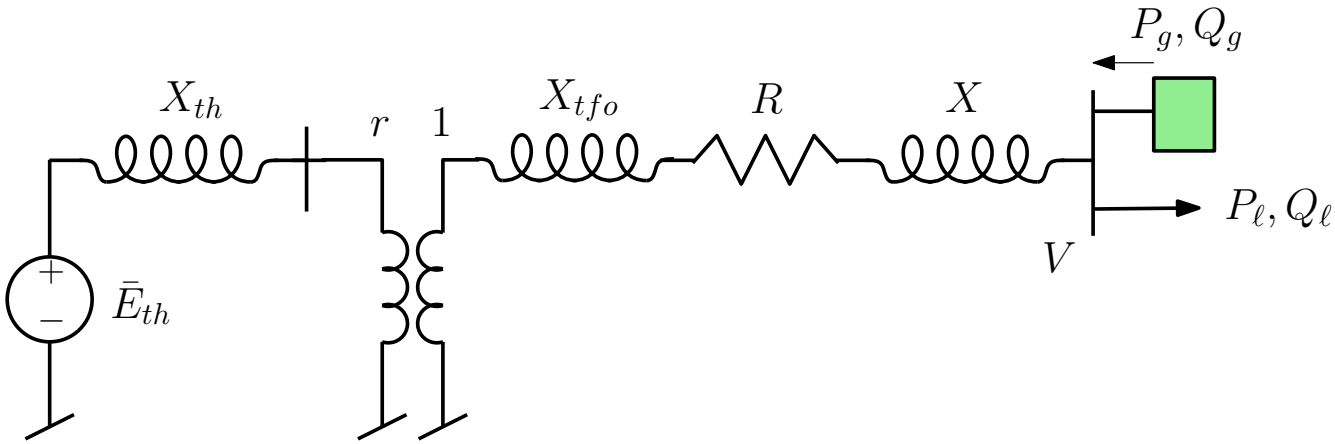
The following exercise illustrates, in a simplified manner, a concern due to the connection of Distributed Generation Units (DGUs) to distribution grids. In situations of low load and high DGU production, the active power flow reverts from distribution to transmission, and the voltage rises in the medium-voltage and low-voltage distribution grids. In case of overvoltage, customer appliances may be damaged and DGUs may be disconnected by the protections of their power electronics.

Consider the following system:



modeled as follows:



Data:

- HV network: nominal voltage: 150 kV; short-circuit capacity: 5000 MVA
- magnitude of Thévenin e.m.f. $E_{th} = 1$ pu
- transformer nominal apparent power: 10 MVA
- transformer: reactance $X_{tfo} = 0.14$ pu on the 10-MVA base; ratio $r = 138/11$ kV/kV
- cable: nominal voltage: 11 kV; $R = 1.0\ \Omega$; $X = 1.2\ \Omega$
- load power factor: 0.95 (inductive)
- DGU: nominal voltage = 11 kV; nominal apparent power = 5 MVA.

Questions:

1. Consider a "high" load $P_\ell = 5$ MW with the DGU not in operation. Compute the load voltage V. Comment on the effect of the transformer ratio r.
2. Consider a "low" load $P_\ell = 1$ MW and a "high" production $P_g = 4.5$ MW with $Q_g = 0$ (unity power factor). Show that the voltage V takes a high value.
3. Consider the same P_ℓ and P_g values, but a consumption of 2 Mvar by the DGU. Show that the voltage V is brought back to a normal value.
4. Is the current in the DGU acceptable ?
5. Which reactive power must be consumed by the DGU to bring the voltage V to 11.44 kV ?

- Derive the expressions of the active and reactive power losses in the $R + jX$ impedance (slide 2, Fig. 1 of lecture notes) as a function of $V_1, V_2, \theta_1 - \theta_2$.

The following exercises relate to the one-generator one-load system

- In the (P, Q) plane (slide 19, Fig. 9 of lecture notes), determine the locus of operating points corresponding to a given current in the reactance X.
  Hint: consider the apparent produced by the generator.
- For a given power factor $\cos\phi$, compute the maximum active and reactive powers transmissible to the load as well as the corresponding critical voltage.
- Same question when a capacitor of susceptance B is installed in parallel with the load.
  Hint: determine the Thévenin equivalent seen by the load.
- Starting from the results of the previous exercise, compute the maximum active power that can be transmitted to the load if the susceptance B (in parallel with the load) is adjusted so that the load voltage V remains equal to the generator voltage V_g. It is assumed that operation on the lower part of the PV curves is not possible.