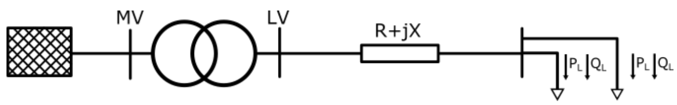
Technical University of Denmark

Course 31778 - Assignment 3 – Distribution grid modelling

- **The assignment is individual and shall be completed by Thursday 07/05 – 12:00**
- **Save both pdf and slx files as: Assignment3_studentnumber_Name_Surname**
- **TO BE UPLOADED**: one Simulink file and a short (approx. 4-5 pages) narrative document
- **Starting conditions**: read (carefully) the instructions below



Main grid:

- Swing generator
- Phase-to-phase voltage: 10000 V; Phase angle of phase a: 0 degrees
- Frequency: 50 Hz
- Impedance: internal, 3-phase short circuit power=50e6 VA, base voltage=10e3 V, X/R ratio=10

Transformer (630 kVA):

- Winding: YgYg; Nominal power: 630e3 VA; Frequency: 50 Hz
- Winding 1: [10000 V; 0.005 pu; 0.0195 pu]
- Winding 2: [400 V; 0.005 pu; 0.0195 pu]
- Magnetization: resistance=500, inductance=500

Line (4x120mm^2 Cu):

- Frequency: 50 Hz
- r_1=0.1556 Ω/km; r_0=0.6224Ω/km
- l_1=0.00023 H/km (equal to X_l=0.072 Ω/km); l_0=0.0009172 H/km (equal to $X_{l,0}$=0.288 Ω/km)
- c_1=0.92 µF/km; c_0=0.485 µF/km
- Length: 500 m

Loads:

- P_1=100 kW and Q_1=50 kVar (inductive)
- P_2=80 kW and Q_2=0 kVAr

OBJECTIVES:

1) Calculate the phase to phase voltage drop ΔV over the line and the transformer, using the complete and the approximated formula. Use both formulas twice; first for the voltage drop across the transformer and secondly for the voltage drop across the cable. Consider in both cases that the overall load is the sum of Load 1 and Load 2 and that Vs is the nominal voltage equal to 400 V.

2) Design the system in SimPowerSystems and run the load flow calculation. Compare the voltage drop including and disregarding the voltage angles and discuss the calculated values from objective (1). Display the values of voltage, current and power of each measurement point with displays and scopes. Notes: Implement a load element for each load.

3) Calculate the joule losses in Watt in both the LV cable and the transformer, based on the current from the Simscape electrical simulation results. Also calculate and compare the losses based on the difference between the active powers (calculated with the power measurements) at the grid side, the LV transformer side, and at the load.

4) Assume that you can change either P_2 *or* Q_2 in order to control the voltage at the end of the line. Calculate (using the simplified formula and considering the voltage drop across transformer and line altogether) the P_2 *and* Q_2 needed to achieve a new voltage drop of $\Delta V=0.05*V_{nom}$ and compare with the results in Simulink (consider the voltage at the main grid terminal equal to 1 pu). Change only either the active or reactive power at the time and keep the other value equal to the initial value: when using P2, keep Q2=0; while when using Q2, keep P2=80 kW. Discuss why the new configuration is not able to completely fulfill the objective. Comment also on any drawback of the solution. Note: there is no need to save the results in Simulink, just use the created model to verify the results.

5) Set P_2 *and* Q_2 back to the initial values. Add a third load at the ending bus, with P_3=0 kW $Q_3(0)$=0 kVar. Assume you can adjust linearly the reactive power between -150 and +150 kVar. Design a Q controller (Q(V) droop control) with the voltage reference equal to 0.95 pu. The voltage controller has an overall measurement delay of 0.5 s and the droop gain has to be chosen to achieve the highest voltage increase without sustained oscillations. Enable the controller only t=3 s and run the simulation for 10 s. Settling time should be within 5 s (tune the controller with the usual Ziegler-Nichols method). Report in the narrative document the derived droop gain, the amount of Q that the unit will deploy and discuss on the consequences on the system. Considering the derived droop, re-analyze the system with a reference voltage for the controller equal to 1.05 pu. Discuss and compare the new results with the ones obtained with a reference voltage equal to 0.95 pu. Note: the Simulink file submitted should include all the elements and values necessary to verify this point.

Note for the Simulink file: the block diagram has to be clearly designed (use tags where convenient).