Tampere University
Electrical Engineering

EE.EES.430 ELECTRIC POWER SYSTEMS

Ari Nikander

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Attempt ALL questions

The numbers in square brackets after the assignments indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

An electronic calculator may be used provided that it does not have a facility for either textual storage or display, or for graphical display. If a calculator is used, intermediate steps in the calculation should be indicated.

Q1 Find the sending-end voltage of a 250 km, three phase, 50 Hz transmission line delivering 25 MVA at 0.8 lagging power factor ($\cos\varphi = 0.8_{ind}$) to a balanced load at 132 kV. This load is located at the receiving end. Apply nominal - π representation. The conductor resistance R = 0.11 Ω/km, line inductance L = 1.24 mH/km and line capacitance C = 0.0094 μF/km. Leakage resistance representing the line conductance is neglected. Determine the percentage voltage rise of the line with no load (voltage regulation). [6]

Q2 (a) State the three types of buses used in conventional AC power flow solutions and their specified and calculated variables. [2]

(b) For the circuit shown in Figure 1 determine the nodal voltage solution using one iteration round of the power flow Newton-Raphson method. Select Bus 1 to be the slack bus, with a voltage magnitude of 1.0 p.u. and 0 phase angle. The voltage magnitude at bus 2 is also kept at 1 p.u. To start the iterative solution, assume 0 phase angle at Bus 2. Notice that synchronous generator at bus 2, is injecting 0.5 p.u. of active power at Bus 2. [4]

Tip: Nodal active (P_l) and reactive (Q_l) power equations in a generic node l, have the following form:

$$P_l = V_l \sum_{m=1}^{n} V_m \left(G_{lm} \cos(\theta_l - \theta_m) + B_{lm} \sin(\theta_l - \theta_m) \right)$$

$$Q_l = V_l \sum_{m=1}^{n} V_m \left(G_{lm} \sin(\theta_l - \theta_m) - B_{lm} \cos(\theta_l - \theta_m) \right)$$

where V_l and V_m are the nodal voltage magnitudes at nodes l and m, θ_l and θ_m are their corresponding phase angles, and G_{lm} and B_{lm} are the conductance and susceptance of a transmission line linking nodes l and m.

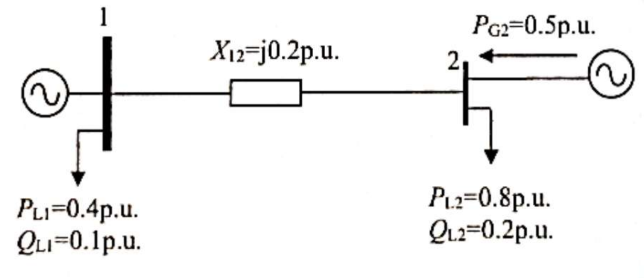

Figure 1.

Q3 The power circuit shown in Figure 2 undergoes a single-phase-to-ground fault in Bus 4.

(a) Calculate the fault current assuming a flat voltage profile of 1 p.u. in all buses just before the fault occurs and the following fault impedance value $Z_f = 0.1 + j0.1$ p.u. [2]

(b) Determine the nodal voltages during a fault in all buses, in sequence quantities. Express briefly, how the nodal phase voltages could be determined according to the nodal sequence voltages. [2]

(c) Determine the current flows in all sections between nodes during a fault, in sequence quantities. [2]

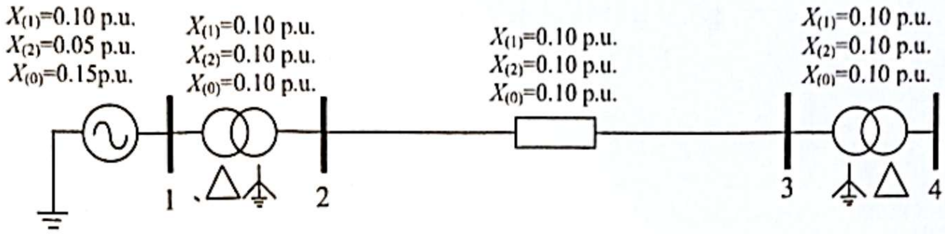

Figure 2.

Q4 The generator of Figure 3 is delivering 1.0 p.u. power to the infinite bus ($V = 1.0\angle 0°$ p.u.), with the generator terminal voltage of $V_t = 1.0\angle 20.5°$ p.u. The voltage and impedance values of the lines, transformer and generator presented in Figure 3 are also in p.u.

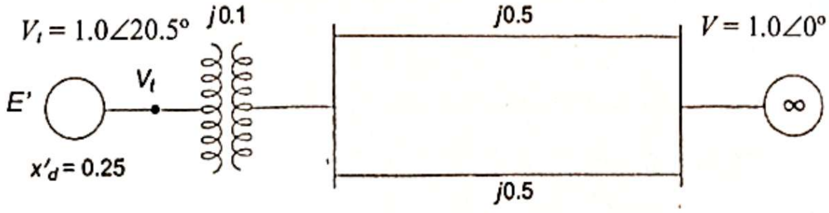

Figure 3.

a) Calculate generator's electromotive force (emf) E' behind the transient reactance x'_d. [2]

b) Find the maximum power that can be transferred under the following conditions:

i) System is in healthy normal state.

ii) One of the parallel lines is open (disconnected). [2]

c) The generator of Figure 3 has an inertia constant of 4 MJ/MVA. Write the swing equation immediately after the disconnection of one line (corresponding situation as in section b), ii). What is the initial angular acceleration? If this acceleration can be assumed to remain constant for $\Delta t = 0.05$ s, find the rotor angle at the end of this time interval.

Q5 Provide a brief explanation and/or calculation model for the following terms:

(a) Characteristic impedance Z_c of transmission line [1]
(b) Earth fault factor [1]
(c) V-P characteristics of the system (VP-curve) [1]
(d) Ferranti effect [1]
(e) Speed droop with a frequency control [1]
(f) List three factors, how to improve transient stability [1]