DEE-24106 ELECTRIC POWER SYSTEMS

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Attempt ALL questions

The numbers in square brackets in the right-hand margin 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 (a) Discuss the convergence characteristics of the Newton-Raphson power flow method emphasizing it quadratic rate of convergence. [2 points]

(b) For the circuit shown in Fig. 1 determine the nodal voltage solution using two iterations of the power flow Newton-Raphson method. Select bus 1 to be the slack bus, with a voltage magnitude of 1.05 p.u. and 0 phase angle. The voltage magnitudes at buses 2 and 3 are kept at 1 p.u. each. To start the iterative solution, assume 0 phase angles in buses 2 and 3. [4 points]

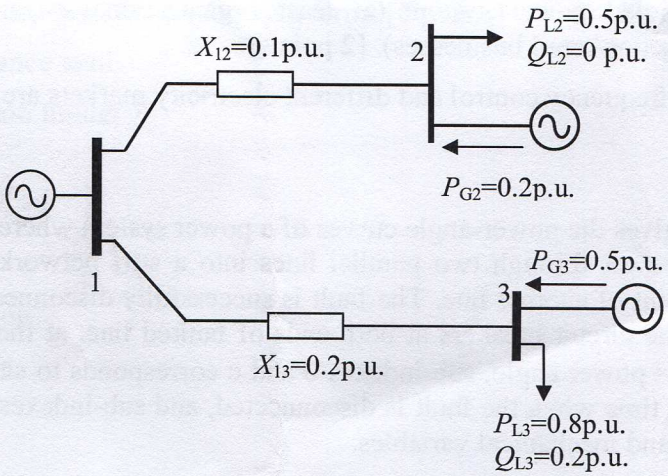

Fig. Q1

Q2 The power circuit shown in Fig. 2 undergoes a single-phase-to-ground short-circuit fault in bus 3.

(a) Calculate the short-circuit fault currents (positive, negative and zero sequence) assuming a flat voltage profile of 1 p.u. in all buses just before the fault occurs and zero fault impedance, i.e. Zf = 0+j0. [4 points]

(b) Determine the faulted nodal voltages in all buses, in sequence quantities. [2 points]

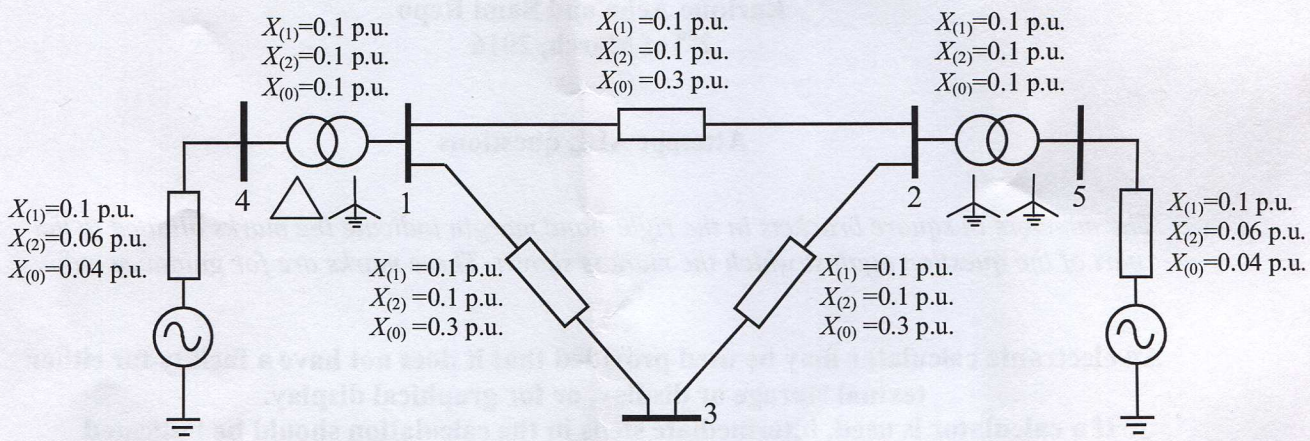

Fig. Q2

Q3 Describe with your own words how the frequency control of large interconnected power system like Nordic power system functions. Maximum one page well-structured answer is allowed.

a) Explain the key mechanisms to keep constant frequency during normal and disturbance conditions. [3 points]

b) Explain the roles and responsibilities of producers and TSO in liberalized and unbundled power system (at least organizational separation of network and production/retail businesses). [2 points]

c) How frequency control and different electricity markets are related? [1 point]

Q4 Figure 3 gives the power-angle curves of a power system where synchronous generator supplies power through two parallel lines into a stiff network. A fault occurs in the middle point of another line. The fault is successfully disconnected after some time by opening the circuit breakers at both ends of faulted line, at the same time. P = active power, δ = power angle, sub-indexes 0 and c corresponds to situations before the fault and at the time when the fault is disconnected, and sub-indexes e and m correspond to electrical and mechanical variables.

d) Estimate if cases A and B are stable based on the equal area criterion and figures. Draw the accelerating and decelerating areas and the maximum angle into both figures. Explain your estimations. [3 points]

e) Justify why power curves are different for conditions before fault, during fault and after fault. [1 point]

f) Determine a rough estimation of how the generator output power, rotating speed and power angle functions during different points of case A. Draw the necessary figures to explain your estimations. [2 points]

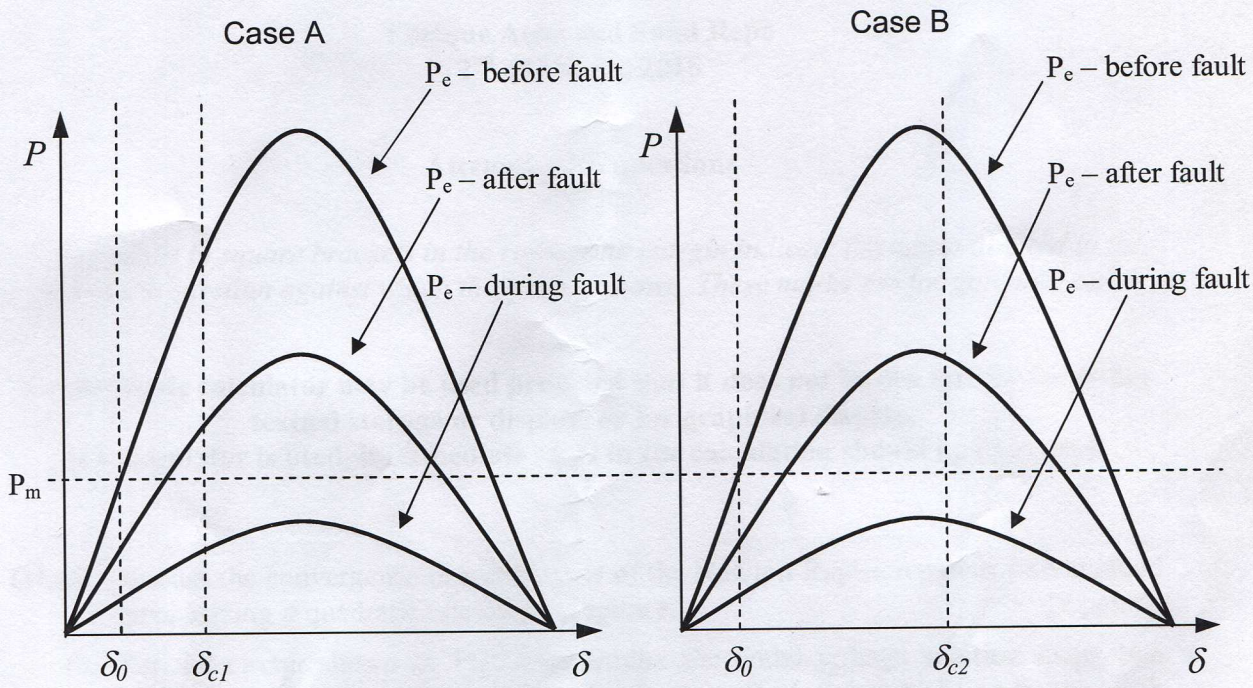

Figure 3. Power-angle curves.

Q5 Provide short explanations for the following terms [6 points]

a) Surge impedance load

b) Over-excitation limiter

c) PV-curve

d) Speed-droop

e) (n-1) criteria

f) Swing equation