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Tampere University of Technology
Electrical Engineering
Electric Power Systems DEE-24106 7.3. 2014

Sami Repo, Enrique Acha Programmable calculator allowed 5 questions/ á 6 p

Question 1: **(a)** Starting from the complex nodal current injected into bus *k*, shown in Fig. 1, derive expressions for the active and reactive powers injected at node *k* as a function of nodal voltages at nodes *k, n* and *m,* as well as the two branch admittances that connect to node *k*. Express the nodal voltages in either polar or rectangular coordinates (2p).

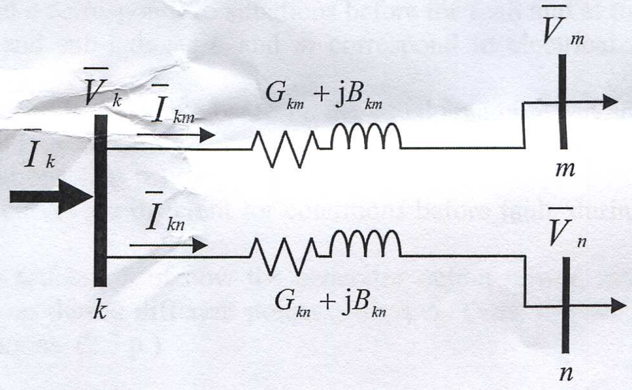

Figure 1

(b) State all the simplifying assumptions that are applied in the polar-coordinates, Newton-Raphson power flow method which lead to the Fast Decoupled power flow method (2p).

(c) Discuss the convergence characteristics of each method and compare these characteristics with each other (2p).

Question 2: The power circuit shown in Fig. 2 undergoes a short-circuit fault involving one-phase-to-ground (conductor in phase A) in bus 4.

A) Calculate the fault current at bus 4 assuming a flat voltage profile of 1.05 p.u. in the four buses just before the fault occurs and zero fault impedance at bus 4, i.e. $Z_f = 0+j0$ p.u. (3p).

B) Determine the currents in <u>phase quantities</u> just after the fault occurs, flowing through the two transmission lines and the transformer (3p).

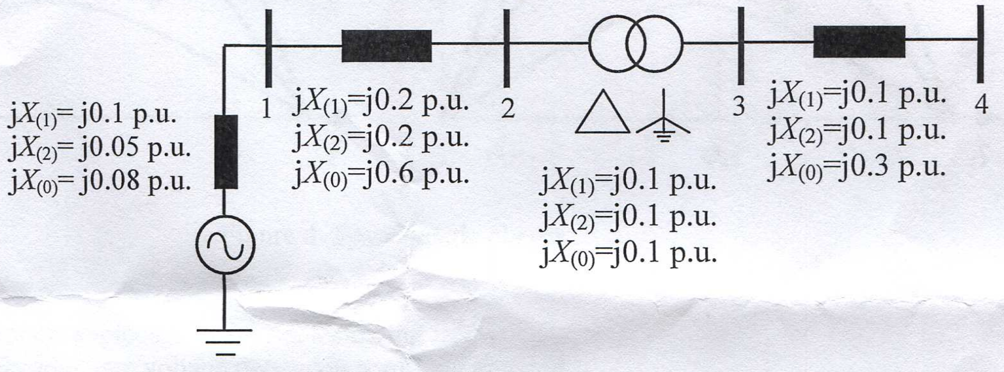

Figure 2

Question 3: **(a)** Describe what the skin effect is in connection with the internal impedance of a power conductor in a transmission line and also describe the so-called long-line effect (2p).

(b) A 350 km, 500 kV three-phase transmission line operating at 50 Hz has the following positive-sequence parameters: $Z_{(1)}$=0.05+j0.25 Ω/km and $Y_{(1)}$=j1.6×10-6 S/km^{-1}. The transmission line feeds into a bulb supply point of 250 MW at unity power factor at the rated voltage of 500 kV - *Notice that this is a long transmission line.* (i) Determine the voltage regulation (3p) and the three-phase power at the sending end of the line (1p).

A = cosh cos sinh sin =
B = Z sinh cos cos sin =
C = $\frac{1}{Z}$ ( ) =
D = A

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Question 4: Figure 4 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.

a) 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. (2.5 p.)
b) Justify why power curves are different for conditions before fault, during fault and after fault. (1 p.)
c) 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. (2.5 p.)

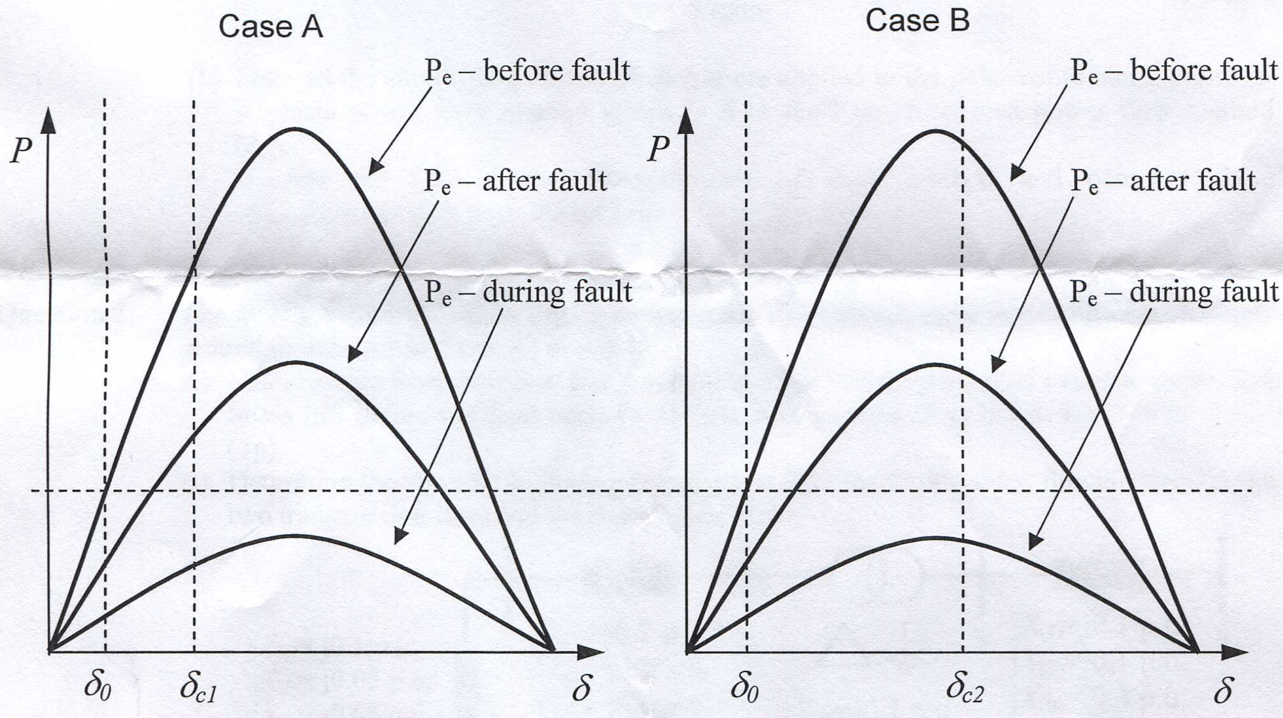

Figure 4. Power-angle curves.

Question 5: Provide short explanations for the following terms:

a) Steady-state voltage dependency of load demand
b) Over-excitation limiter
c) Frequency droop
d) Price area
e) (n-1) criteria
f) Inertia constant