S. Karaki AMERICAN UNIVERSITY OF BEIRUT FALL 2009/ 2010

FACULTY OF ENGINEERING AND ARCHITECTURE

FINAL EXAM

FUNDAMENTALS OF POWER SYSTEMS ANALYSIS (EECE 471)

CLOSED BOOK (2.5 HOURS) August 10, 2010

PROGRAMMABLE CALCULATORS ARE NOT ALLOWED.

THIS QUESTION SHEET MUST BE RETURNED WITH THE ANSWER BOOKLET.

BRIEFLY EXPLAIN CALCULATIONS BY SHOWING FORMULAE USED.

NAME: ________________________ **ID#:** ________________________

1. It is required to perform an economic load dispatch study on a system of two generators supplying a load of P_D= 200 MW and connected by a transmission line, and the system losses are approximated by: $P_L = 8\times 10^{-4}\times (P_D - P_{G2})^2$. The maximum and minimum active power limits of the units are given as: $40 \le P_{G1} \le 160$ and $25 \le P_{G2} \le 100$. The units have the following fuel-cost curves:

$$C_1(P_{G1}) = 375 + 45\,P_{G1} + 0.008\,P_{G1}^2 \ \text{\$/h}$$
$$C_2(P_{G2}) = 150 + 42\,P_{G2} + 0.024\,P_{G2}^2 \ \text{\$/h}$$

a) Write the objective function and the constraints of the economic dispatch of the system with losses and use the method of Lagrange to write the necessary optimality conditions defining the saddle point (i.e. the optimum point).

b) Describe an iterative procedure based on penalty factors to solve the optimality conditions developed above and determine the active powers provided by each units (P_{G1}, P_{G2}), the incremental cost (λ) and the total cost of operation at the given system demand. Carry out an iteration of this procedure starting at the lossless ELD solution and determine the incremental cost at nodes 1 and 2 and the power supplied by each generator at the end of the iteration.

2. In this problem it is required to examine the solution of the load flow problem of the system of Fig. 1 using the fast-decoupled load flow (FDLF).

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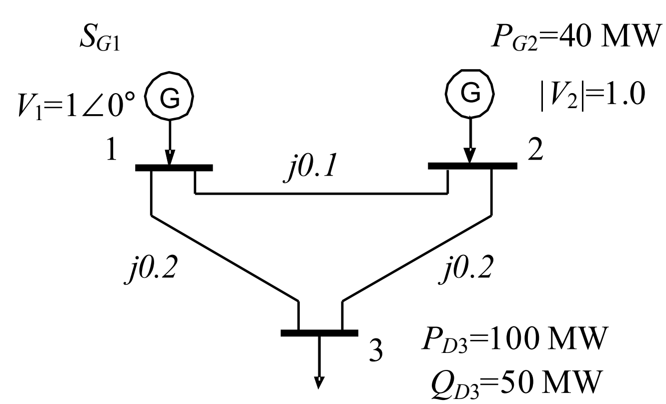

Fig. 1: Transmission system for FDLF analysis.

a) Form the nodal admittance matrix of the system shown in Fig. 1.

b) Identify the type of busbars and the unknown variables that we are solving for in the system shown in Figure 1. Write the active and reactive mismatch equations to be solved in order to determine these variables.

c) Briefly describe the main characteristics of the FDLF method and how it can be derived from the Newton-Raphson method. Write the iterative FDLF equations showing the elements of the approximate Jacobian matrices for the problem being solved.

d) Carry out an iteration of the FDLF method for the equations in Part c from a set of appropriate starting values.

3. In this problem it is required to carry out a fault level analysis of the system presented in Fig. 2. The fault calculation is to be carried out at about 5 cycles following fault occurrence. System data is as follows:

Generator G_1: 250 MVA, PF= 0.85, 20 kV, X'_d= 32%.
Generator G_2: 120 MVA, PF= 0.85, 15.5 kV, X'_d = 20%.
Transformers T_1 and T_2: 250 MVA, $X_{T1}= X_{T2}$= 12%
Transformers T_3: 125 MVA, X_{T3}= 12%
Transmission line: voltage 220 kV, X_{T1}= 60Ω per circuit,
Load: 66 kV of 10 feeders each with a load of 30+j12 MVA

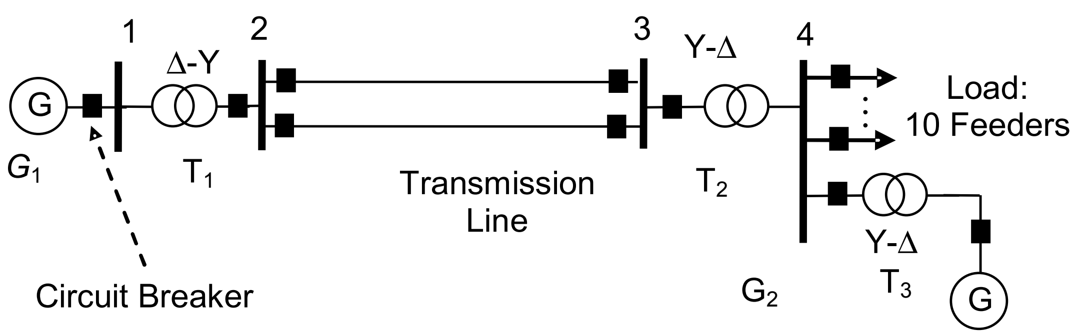

Fig. 2: Transmission system under analysis.

a) Calculate all reactance values in per unit on 100 MVA base. Show the details of calculation of the per-unit calculations for one generator reactance, a transformer reactance, and the transmission line, and form the nodal admittance matrix for fault calculations.

b) The nodal impedance matrix, which is the inverse of the nodal admittance matrix is given below. Explain what is the significance of a diagonal element Z_{kk} where k is a particular node in the system? Calculate the fault current in per unit and in kA for a solid three-phase short circuit at about 5 cycles after fault occurrence at each of the nodes.

$$\mathbf{Z} = \begin{bmatrix} j0.1036 & j0.0944 & j0.0803 & j0.0679 \\ j0.0944 & j0.1298 & j0.1105 & j0.0934 \\ j0.0803 & j0.1105 & j0.1467 & j0.1241 \\ j0.0679 & j0.0934 & j0.1241 & j0.1455 \end{bmatrix}$$

c) For a fault on one of the transmission line near node 2, calculate the fault current contributed from each generator. Which breaker(s) should "see" the fault first and clear it? Explain.

d) Using given system data, the results of Part b above, and Tables I and II of circuit breaker properties given below, select appropriate circuit breakers for the transmission line, transformers, generators, and load feeders with justification for your choice.

Table I: High Current Generator Circuit Breakers

Type	Nominal Voltage (kV)	Maximum Voltage (kV) [1]	Crest Voltage (kV)	Rated Current (kA)	Breaking Current (kA)	Making Current (kA)	Cycles
GB1	7.2-12	35	75	1.2-3.5	17-87	40-200	5
GB2	12-24	55	125	1.2-10.9	12-100	30-250	5
GB3	20-36	75	170	1.2-4.2	10-64	25-160	5

(1) Rated power frequency withstand-voltage 1 min to earth.

Table II: High Voltage Circuit Breakers (ANSI C37.06-1979)

Type	Nominal Voltage (kV)	Maximum Rated (kV)	Crest Voltage (kV)	Rated Current (A)	Breaking Current (kA)	Making Current (kA)	Cycles
HV1	14	15	75	1200	18	37	5
HV2	23	25	95	1200	11	38	5
HV3	34	38	145	1200	22	58	5
HV4	69	72.5	325	1200 2000	19 37	37 55	5
EHV1	115	121	450	1200 2000 3000	20 40 60	32 64 100	3
EHV2	230	245	850	1600 2000 3000	31 40 63	50 64 100	3
EHV3	345	362	1050	2000 3000	40	64	3
EHV4	500	550	1425	2000 3000	40	64	2
EHV5	700	765	1800	2000 3000	40	64	2