S. KARAKI AMERICAN UNIVERSITY OF BEIRUT FALL 2001/2002

FACULTY OF ENGINEERING AND ARCHITECTURE

FINAL EXAM

POWER SYSTEMS FUNDAMENTALS (ELEG 071E)

CLOSED BOOK (3 HOURS) February 4, 2002

PROGRAMMABLE CALCULATORS ARE NOT ALLOWED.
THIS QUESTION SHEET MUST BE RETURNED WITH THE ANSWER BOOKLET.
BRIEFLY EXPLAIN CALCULATIONS BY SHOWING FORMULAE USED AND OTHERWISE IF NEEDED.

NAME: _________________________ **ID#:** _________________________

1. Consider the single circuit 3-Φ 50 Hz transmission system shown in Fig. 1 below. Each conductor is of type Ostrich, which has the following data:

   Aluminum area= 300 kcmil (1kcmil= 0.5067 mm^2)
   Outside diameter= 0.680 in (1in= 0.0254 m)
   AC resistance at 50 °C= 0.3372 Ω/mile (1mile= 1.604 km)
   GMR= 0.0229 ft (1ft= 0.305 m)

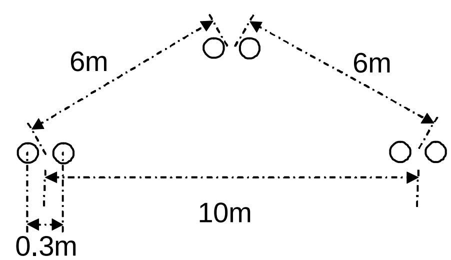

Fig. 1.

   a) What are the series resistance (Ω/km), inductance (H/ km) and inductive reactance of the line?
   b) What are the shunt capacitance (F/ km) and corresponding admittance (μS/ km) of the line?
   c) If the transmission voltage is 230 kV and the current density is 2 A/mm^2, what would be thermal power capability of the line in MVA and what would be its surge impedance loading (P_{SIL})?
   d) Considering the universal power handling capability curve (Fig. 2), explain why the proposed design is not appropriate for a short line of about 75 km. For what distance approximately is the design appropriate?

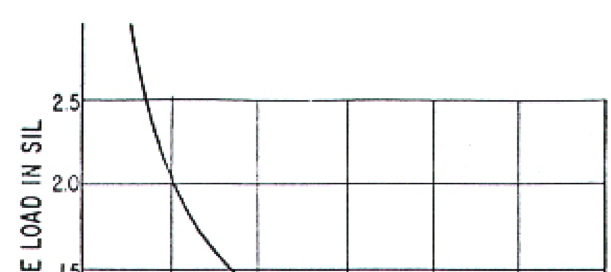

Fig. 2.

2. Consider the following power system shown in Fig. 3 below.

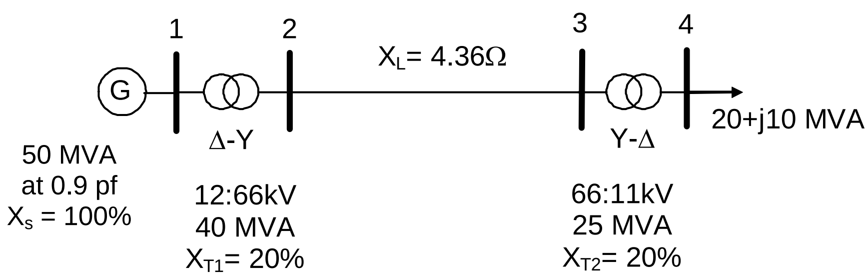

Fig. 3

a) Select a base voltage for each region (node) of the network and use a common 10 MVA base to determine the different base impedances required.
b) Calculate the load and all impedances in per unit.
c) If the load is modeled as a constant series-impedance that consumes the specified power at nominal voltage, determine the active and reactive power supplied by the generator and the voltage at node 4 (V_4). Draw the per unit impedance diagram and solve. Consider the voltage at the generator's terminal (V_1) to be regulated to 1 per unit.
d) What would be the voltage at node 4 if a shunt capacitance is added at that node to provide 10 MVAr at nominal voltage?
e) What are the generator's reactive power limits when it delivers rated active power?

3. Consider the following power system for which a load flow is to be solved using the fast-decoupled Newton-Raphson approach. The powers are given in MVA and the line reactances

are given in per-unit on 100 MVA base. Node 1 is the reference node with a voltage $V_1 = 1\angle 0$.

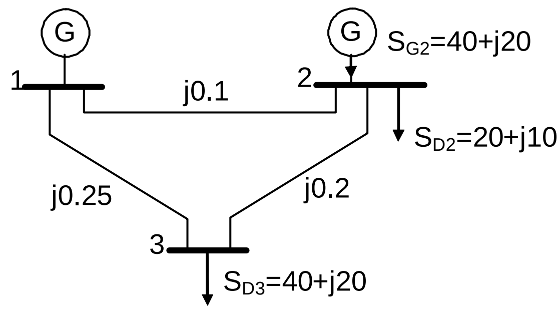

Fig. 4.

a) Determine the unreduced nodal admittance matrix ($\mathbf{Y_{BUS}}$) of the above network.
b) Write expressions for $\Delta P_i = P_i^c - P_i$ and $\Delta Q_i = Q_i^c - Q_i$ for i= 2, 3 in terms of voltage magnitudes and phase angles at nodes 1, 2, and 3.
c) Set up the two iterative decoupled Newton-Raphson matrix equations for the calculation of $\boldsymbol{\theta}$ and $\mathbf{V}$. Note that $\boldsymbol{\theta} = [\ \theta_2\ \theta_3\ ]^T$ and $\mathbf{V} = [\ V_2\ V_3\ ]^T$.
d) Starting from $\boldsymbol{\theta}^0 = [\ 0\ \ 0\ ]^T$ and $\mathbf{V}^0 = [\ 1\ \ 1\ ]^T$ evaluate the inverse Jacobian matrix and the active and reactive power mismatches $\Delta\mathbf{P}$ and $\Delta\mathbf{Q}$, and the voltages (θ and $\mathbf{V}^1$) at the end of the first iteration. Note the following:

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \frac{1}{ad - bc}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

4. Consider a generation system consisting of two units for which it is required to perform an economic load dispatch study. The units have the following fuel-cost curves and limits.

$C_1(P_{G1}) = 400 + 7\ P_{G1} + 0.012\ P_{G1}^2$ \$/h
$C_2(P_{G2}) = 350 + 8\ P_{G2} + 0.018\ P_{G2}^2$ \$/h

$120 \le P_{G1} \le 600$ MW
$100 \le P_{G2} \le 500$ MW

a) Determine the optimum point of operation of the system, its incremental cost and the power delivered by each unit when the demand is equal to 700 MW.
b) What is the optimum operating point of the system, its incremental cost and the power delivered by each unit when the demand is raised to 1000 MW?