KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

ELECTRICAL ENGINEERING DEPARTMENT

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EE 463

MAJOR EXAM II

Key Solution

December 8th , 2007

7:30 - 8:30 pm

Section:

Student Name:

Student I.D.#

Serial #:

Question # 1	
Question # 2	
Question # 3	
Total	

Problem 1

For a generating unit the fuel input in millions of Btu/h is expressed as a function of output P_g in megawatts by $0.032P_g^2 + 5.8P_g + 120$. Determine

a) the equation for incremental fuel cost in dollars per megawatthour as a function of P_g in megawatts based on a fuel cost of $2 per million Btu.

b) the average cost of fuel per megawatthour when P_g = 200 MW.

c) the approximate additional fuel cost per hour to raise the output of the unit from 200 MW to 201 MW. (30 Marks)

Solution:

(a) The input-output curve in dollars per MWh is

$$f = (0.032P_g^2 + 5.8P_g + 120) \times 2$$
$$= 0.064P_g^2 + 11.6P_g + 240 \text{ \$/MWh}$$

The incremental fuel cost is

$$\frac{df}{dP_g} = 0.128P_g + 11.6 \text{ \$/MWh}$$

(b) The average cost of fuel when $P_g = 200$ MW is

$$\left.\frac{f}{P_g}\right|_{P_g=200} = \frac{0.064(202)^2 + 11.6(200) + 240}{200} = 25.6 \text{ \$/MWh}$$

(c) The approximate incremental cost for an additional 1 MW generation when $P_g = 200$ MW is

$$\left.\frac{df}{dP_g}\right|_{P_e=200} = 0.128(200) + 11.6 = 37.2 \text{ \$/h}$$

Problem 2

The system shown below is initially on no load with generators operating at their rated voltage with their emfs in phase. The rating of the generators and the transformers and their respective percent reactances are marked on the diagram. All resistances are neglected. The line impedance is j160 ohm. A three-phase balanced fault occurs at the receiving end of the transmission line. Determine the short circuit current and the short-circuit MVA. (30 Marks)

Solution:

The base impedance for line is

$$Z_B = \frac{(400)^2}{100} = 1,600 \ \ \Omega$$

and the base current is

$$I_B = \frac{100,000}{\sqrt{3}(400)} = 144.3375 \ \ \mathrm{A}$$

The reactances on a common 100 MVA base are

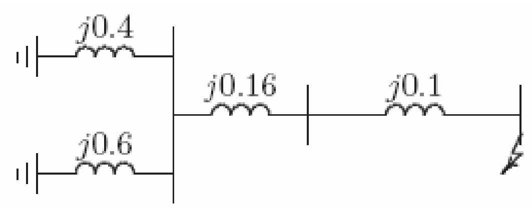
$$X'_{dg1} = \frac{100}{60}(0.24) = 0.4 \ \ \mathrm{pu}$$

$$X'_{dg2} = \frac{100}{40}(0.24) = 0.6 \ \ \mathrm{pu}$$

$$X_t = \frac{100}{100}(0.16) = 0.16 \ \ \mathrm{pu}$$

$$X_{line} = \frac{160}{1600} = 0.1 \ \ \mathrm{pu}$$

The impedance diagram is as shown



Impedance to the point of fault is

$$X = j\frac{(0.4)(0.6)}{0.4 + 0.6} + j0.16 + j0.1 = j0.5 \ \text{ pu}$$

The fault current is

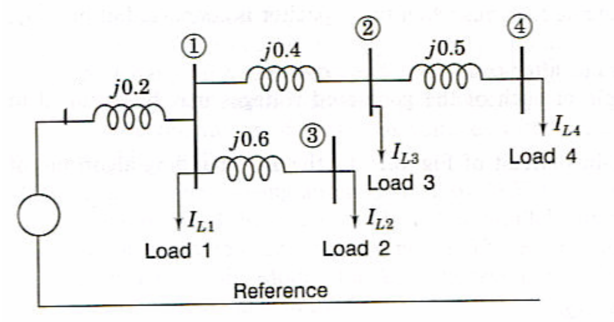
$$\begin{aligned} I_f &= \frac{1}{j0.5} = 2\angle{-90^\circ} \ \text{ pu} \\ &= (144.3375)(2\angle{-90^\circ}) = 288.675\angle{-90^\circ} \ \text{ A} \end{aligned}$$

The Short-circuit MVA is

$$\text{SCMVA} = \sqrt{3}(400)(288.675)(10^{-3}) = 200 \ \text{ MVA}$$

Problem 3

The impedance matrix and the bus injected current, in per-unit, of the four-bus system shown below are



$$Z_{BUS} = j\begin{bmatrix} 0.2 & 0.2 & 0.2 & 0.2 \\ 0.2 & 0.6 & 0.2 & 0.6 \\ 0.2 & 0.2 & 0.8 & 0.2 \\ 0.2 & 0.6 & 0.2 & 1.1 \end{bmatrix} \qquad I = j\begin{bmatrix} -5.9 \\ 0.1 \\ 0.2 \\ 0.2 \end{bmatrix}$$

a) Calculate the bus voltages.

b) Calculate the bus voltages when a capacitor of reactance 5.4 per-unit is connected between bus 4 and the reference, by using the bus impedance matrix building algorithm.

(40 Marks)

Solution:

a) The bus voltages are

$$\mathbf{Z}_{\text{bus}}\mathbf{I} = \begin{bmatrix} j0.2 & j0.2 & j0.2 & j0.2 \\ j0.2 & j0.6 & j0.2 & j0.6 \\ j0.2 & j0.2 & j0.8 & j0.2 \\ j0.2 & j0.6 & j0.2 & j1.1 \end{bmatrix} \begin{bmatrix} -j5.9 \\ j0.1 \\ j0.2 \\ j0.2 \end{bmatrix} = \begin{bmatrix} 1.08 \\ 0.96 \\ 0.96 \\ 0.86 \end{bmatrix} \text{ per unit}$$

b)

Z_{BUS} is augmented to add the shunt capacitor:

$$j\left[\begin{array}{cccc|c} 0.2 & 0.2 & 0.2 & 0.2 & 0.2 \\ 0.2 & 0.6 & 0.2 & 0.6 & 0.6 \\ 0.2 & 0.2 & 0.8 & 0.2 & 0.2 \\ 0.2 & 0.6 & 0.2 & 1.1 & 1.1 \\ \hline 0.2 & 0.6 & 0.2 & 1.1 & -4.3 \end{array}\right]$$

After kron reduction, Z_{BUS} is given by:

$$j\begin{bmatrix} 0.20930 & 0.22791 & 0.20930 & 0.25116 \\ 0.22791 & 0.68372 & 0.22791 & 0.75349 \\ 0.20930 & 0.22791 & 0.80930 & 0.25116 \\ 0.25116 & 0.75349 & 0.25116 & 1.38140 \end{bmatrix}$$

And the voltages are:

$$j\begin{bmatrix} 0.20930 & 0.22791 & 0.20930 & 0.25116 \\ 0.22791 & 0.68372 & 0.22791 & 0.75349 \\ 0.20930 & 0.22791 & 0.80930 & 0.25116 \\ 0.25116 & 0.75349 & 0.25116 & 1.38140 \end{bmatrix} \begin{bmatrix} -j5.9 \\ j0.1 \\ j0.2 \\ j0.2 \end{bmatrix} = \begin{bmatrix} 1.12 \\ 1.08 \\ 1.00 \\ 1.08 \end{bmatrix}$$