UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION

JULY 2018

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Power System Analysis and Operation

COURSE CODE : EE552

TIME ALLOWED: Three Hours

INSTRUCTIONS:

1. **There are five questions in this paper.**
2. **Answer any four questions. Each question carries 25 marks.**
3. **If you think not enough data has been given in any question you may assume any reasonable values.**

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THIS PAPER CONTAINS FOUR (4) PAGES INCLUDING THIS PAGE

Question 1 *(25 Marks)*

The cost characteristic equations of two units in a plant are

$$C_1 = 0.4P_1^2 + 160P_1 + 600 \qquad E/h$$

$$C_2 = 0.45P_2^2 + 120P_2 + 450 \qquad E/h$$

$$C_3 = 0.6P_3^2 + 140P_3 + 500 \qquad E/h$$

$$30 \leq P_1 \leq 90\ MW$$

$$30 \leq P_2 \leq 100\ MW$$

$$30 \leq P_3 \leq 90\ MW$$

Where P_1 and P_2 and P_3 are power outputs in MW.

(a) Find the optimum load allocation between the three units when the total load is 250 MW. **[19]**

(b) What will be the daily loss if the units are loaded equally? **[6]**

Question 2 *(25 Marks)*

(a) Discuss the effect of acceleration factor in the load flow solution algorithm. [2]

(b) What is Jacobian matrix? How the elements of Jacobian matrix are computed in load flow solution? [2]

(c) What are the advantages and disadvantages of Newton-Raphson method? [3]

(d) The per unit reactance diagram of a three bus network shown in Fig Q.2 has the bus impedance matrix given by

$$Z_{Bus} = j\begin{bmatrix} 0.48 & 0.32 & 0.44 \\ 0.44 & 0.48 & 0.36 \\ 0.36 & 0.36 & 0.57 \end{bmatrix}$$

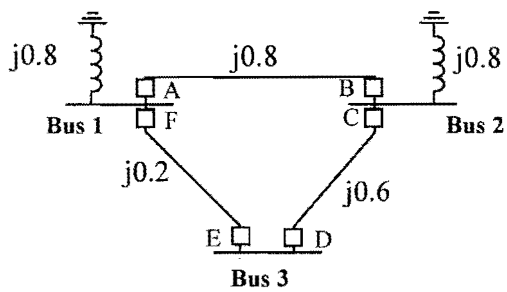

Fig. Q.2 Three Bus Network

i. A three-phase fault occurs at bus 3 through a fault impedance of $Z_f = 0.012$ per unit. Using the bus impedance matrix calculate the *fault current*, *bus voltages*, and *line currents* during fault. **[8]**

ii. Determine the new bus impedance matrix when breakers **A** and **B** are opened due to a fault. **[10]**

Question 3 *(25 Marks)*

(a) For a fault at a given location, rank the various faults in the order of severity. **[5]**

(b) Given the positive, negative and zero sequence impedance of a power system as follows $Z_+ = j0.5$ $Z_- = j0.7$ and $Z_0 = j0.2$ find the voltages and currents at the fault point for a line-to-line fault through an impedance $Z_f = j0.02$ pu **[20]**

Question 4 *(25 Marks)*

(a) Show that for a three winding transformer shown in Fig. Q.4, $V_{1pu} = V_{2pu}$ [10]

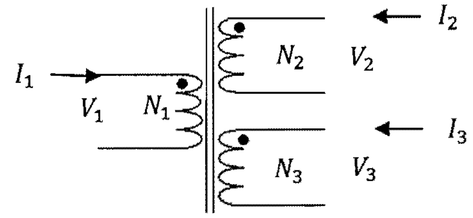

Fig. *Q.4 Three winding Transformer*

(b) A 300 kV transmission line has the following line constants:
$A = 0.65\angle 3°$, $B = 300\angle 77°$

i. Determine the power at unity power factor that can be received if the voltage profile at each end is to be maintained at 300 kV. [6]

ii. What type and rating of compensation equipment would be required if the load is 200 MW at unity power factor with the same voltage profile as in part (i). [6]

iii. With the load as in part (ii), what should be the receiving-end voltage if the compensation equipment is not installed? [3]

Question 5 *(25 Marks)*

(a) Show that the ratio of ac line loss to the corresponding dc loss is $\frac{4}{3}$ assuming equal power transfer and equal peak voltages for both options and unity power factor for ac case. [10]

(b) In the power system network shown in Fig. Q.5

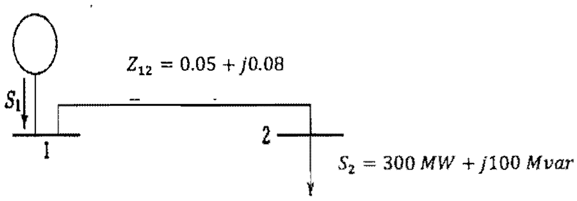

Fig. Q.5 Two Bus Power System

(i) Using Gauss-Seidel method, determine V_2 after two iterations. [5]

(ii) If after several iterations voltage at bus 2 converges to $V_2 = 0.76 - j0.2$ determine S_1 and the real and reactive power loss in the line. [10]

Useful Information

$$\overline{V}_i = \frac{1}{\overline{Y}_{ii}}\left[\frac{P_i - jQ_i}{\overline{V}_i^{\,*}} - \sum_{\substack{j=1 \\ \neq i}}^{n} \overline{Y}_{ij}\overline{V}_j\right]$$

$$\overline{S}_i = P_i + jQ_i = \overline{V}_i \overline{I}_i^{\,*}$$

$$P_i = \sum_{j=1}^{n} |V_i|\,|V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j)$$

$$Q_i = -\sum_{j=1}^{n} |V_i|\,|V_j||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j)$$

$$\boldsymbol{\lambda} = a_T\, P_T + b_T$$

$$a_T = \left(\sum_{i=1}^{n} \frac{1}{a_i}\right)^{-1} \qquad b_T = a_T\left(\sum_{i=1}^{n} \frac{b_i}{a_i}\right)$$