UNIVERSITY OF ESWATINI

MAIN EXAMINATION, FIRST SEMESTER

DECEMBER 2018

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Power System Analysis & Operation

COURSE CODE : EE552

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. There are five questions in this paper. Answer any four questions. Each question carries 25 marks.
2. Useful information is provided on the last page of this paper.
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 SEVEN (7) PAGES INCLUDING THIS PAGE

Question 1 (25 Marks)

(a) Discuss the advantages of the p.u. form of representation in power system analysis. [4]

(b) The one-line diagram of a three-phase power system is shown in Fig. Q.1, The transformer is rated 80 MVA, 22/115 kV and 20% and the line impedance is Z = j66.125 Ω. The load at bus 2 is $S_2 = 178\ MW + 7.8\ Mvar$ at bus 3 is $S_3 = 175.0\ MW + 40\ Mvar$. It is required to hold the voltage at bus 3 at $115\angle 0°\ kV$. Working in per unit, determine voltages V_1 and V_2 at buses 1 and 2 respectively choose MVA base of 100. [13]

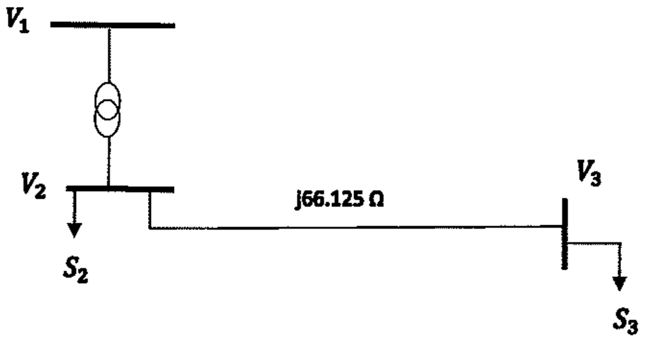

Fig. Q.1

(c) The ABCD Constants of a three phase transmission line are

$A = D = 0.936\angle 0.98°$

$B = 142\angle 76.4°$

$C = 0.000914015\angle - 82.6°$

The load at the receiving end is 50 MW at 220kV with a power factor of 0.9 lagging. Find the magnitude of the sending end voltage and regulation. Assume the magnitude of the sending end voltage remains constant [8]

Question 2 (25 Marks)

(a) Compare Gauss-Seidel (G-S) method and Newton-Raphson (N-R) methods of load flow solutions. [5]

(b) Describe the procedure for power flow Solution by the Network-Raphson Method[10]

(c) For the power system shown in Fig. Q.2(c)

(i) Determine the admittance matrix given the reactance. [6]

(ii) Modify the admittance matrix in (i) by adding a second branch between bus 1 and bus 3. [4]

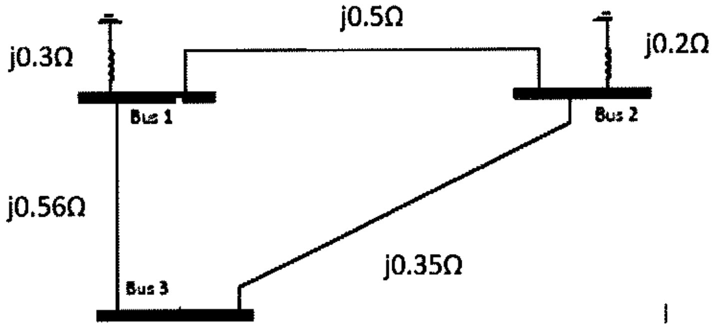

Fig. Q.2 (c)

Question 3 (25 Marks)

(a) Given the following data pertaining the three units in a plant.

Unit 1: Max. = 600 MW

$C_1 = 0.1562P_1^2 + 792P_1 + 56100 \quad E/hr$

Unit 2: Max. = 400 MW

$C_2 = 0.194\, P_2^2 + 785\, P_2 + 31000 \quad E/hr$

Unit 3: Max. = 200 MW

$C_3 = 0.5784\, P_3^2 + 956.4\, P_3 + 9360 \quad E/hr$

Obtain the priority list based on average production cost. [6]

(b) Given that the limits for the units in (a) are as follows:

$$30 \leq P_1 \leq 400\ MW$$

$$30 \leq P_2 \leq 600\ MW$$

$$30 \leq P_3 \leq 200\ MW$$

Where P_1 and P_2 and P_3 are power outputs in MW. Find the optimum load allocation between the three units when the total load is 700 MW. [19]

Question 4 (25 Marks)

(a) Discuss the following types of short circuit faults.

(i) Symmetrical faults: [3]

(ii) Unsymmetrical faults: [3]

(b) Comment if the two – sequence transformations obtained by taking **'a'** phase and **'b'** phase as reference are identical or not. [5]

(c) The impedance matrix of the system for a three bus system is given as

$$Z_{bus} = j\begin{bmatrix} 0.45 & 0.24 & 0.18 \\ 0.24 & 0.48 & 0.25 \\ 0.18 & 0.25 & 0.65 \end{bmatrix}$$

If there is a line outage and the line from bus 1 to bus 3 is removed by opening breakers, if the branch impedance to be removed is $Z_b = j0.12$. Determine the new Z_{bus} [10]

(d) A 3-phase, 3-wire system has a normal voltage of 10.4 kV between the lines. It is supplied by a generator having positive, negative and zero sequence reactances as follows

$X_+ = j0.6\ \Omega$

$X_- = j0.5\ \Omega$

$X_0 = j0.2\ \Omega$

Calculate the fault current which flows when a line-to-line fault occurs at the generator terminals. [4]

Question 5 (25 Marks)

(a) Discuss the following terms as used in power system stability studies.

(i) Steady-state stability [2]

(ii) Dynamic stability [2]

(iii) Transient stability studies [3]

(b) Given the system shown Fig .Q.4, where a three-phase fault is occurred at the point P. Find the critical clearing angle and hence the critical clearing time for clearing the fault with simultaneous opening of the breakers 1 and 2. The reactance values of various components are indicated on the diagram. The generator is delivering 1.0 p.u power at the instant preceding the fault. Assume that the generator is 60 Hz synchronous machine with inertia constant of 10 MJ/MVA. [18]

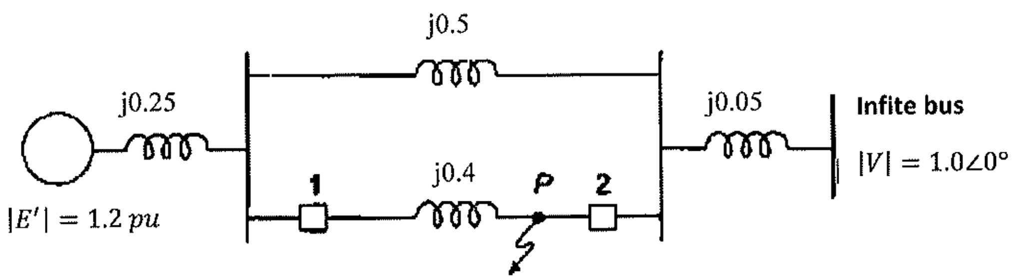

Fig. Q.4

Useful Information

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

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

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

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

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

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

$$[\Delta P] = [H][\Delta\delta]$$

$$[\Delta Q] = [L]\left[\frac{\Delta|V|}{|V|}\right]$$

$$H_{ij} = L_{ij} = |V_i||V_j|\begin{pmatrix} C_{ij}\sin\delta_{ij} - B_{ij}\cos\delta_{ij} \\ i \neq j \end{pmatrix}$$

$$H_{ii} = -B_{ii}|V_i|^2 - Q_i$$

$$L_{ii} = -B_{ii}|V_i|^2 + Q_i$$