UNIVERSITY OF ESWATINI

SIT/RE-SIT EXAMINATION, FIRST SEMESTER

MAY 2021

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Power System Analysis and Operation

COURSE CODE : EEE551

TIME ALLOWED: Three Hours

INSTRUCTIONS:

1. There are five questions in this paper.
2. Answer any Four questions
3. Each question carries 25 Marks
4. Some useful information is provided at the end of this paper, 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) Define steady state operating condition of a power system. [2]

(b) Discuss the effect of acceleration factor in the load flow solution algorithm. [3]

(c) List the quantities specified and the quantities to be determined from load flow study for various types of buses. [6]

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

(e) For the small power system shown in Fig. Q1 the line data in (p.u) is given on the table below.

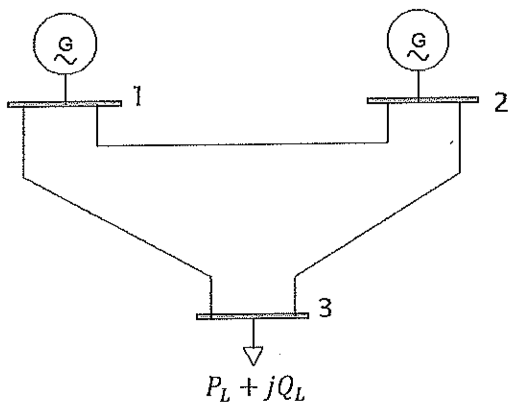


Fig. Q1

Line Data

i	j	X_{ij}	B_{ij}
1	2	0.9	0.02
1	3	0.6	0.01
2	3	0.8	0.05

Determine the bus admittance matrix of this system [9]

Question 2 (25 Marks)

(a) Discuss Fast Decoupled Newton-Raphson method in terms of convergence, computation speed and application **[5]**

(b) Suppose that the P-Q load is known at each of the buses for the power system in Fig. Q2 and that synchronous generators are connected to buses 2 and 3. For a power flow Study, identify the ΔP and ΔQ mismatches and state the variables associated with each bus, choose bus 1 as slack. **[10]**

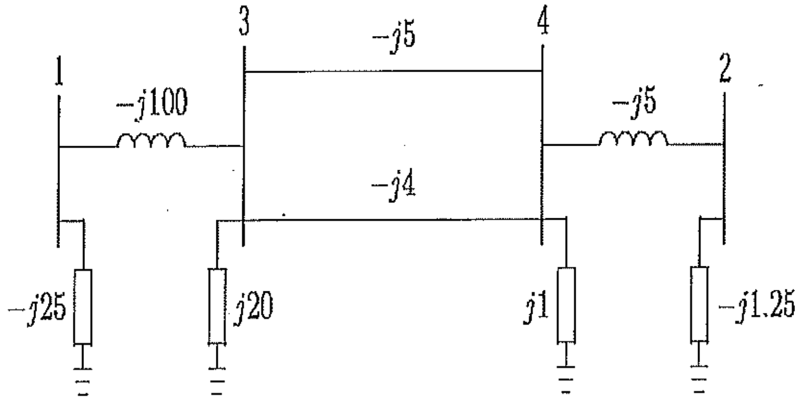


Fig. Q2 Four Bus Network

(c) For the system described in (b), state the following

(i) Number of load flow equations. **[2]**

(ii) Total number of variables. **[2]**

(iii) Based on your answers in (i) and (ii) above, discuss how to solve the load flow problem. **[2]**

(d) Find the real and reactive power injection in bus 3 of Fig. Q2 assuming the following data ,

$$Y_{Bus} = j\begin{bmatrix} -125 & 0.00 & 100 & 0.00 \\ 0.00 & -6.25 & j0.00 & 5.00 \\ 100 & 0.00 & -89 & 9.00 \\ 0.00 & 5.00 & 9.00 & -13.0 \end{bmatrix} \text{ p.u}$$

$V_1 = 1.0\angle 0^\circ$ p.u $\quad V_2 = 0.92\angle 5^\circ$ p.u $\quad V_3 = 0.85\angle 16^\circ$ p.u
$V_4 = 0.94\angle 15^\circ$ p.u **[4]**

Question 3 (25 Marks)

(a) What are the quantities whose base values are required to represent the power system by reactance diagram? **[2]**

(b) Show that for a three winding transformer shown in Figure , $V_{1pu} = V_{2pu}$ **[10]**

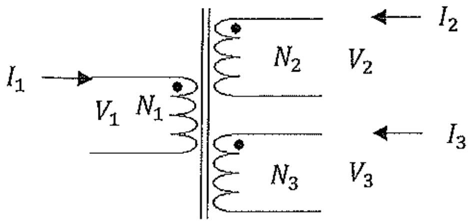


Fig. Q3(b)

(c) 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% on a base of 100 MVA 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∠0° kV. Working in per unit, determine voltages V_1 and V_2 at buses 1 and 2 respectively. **[13]**

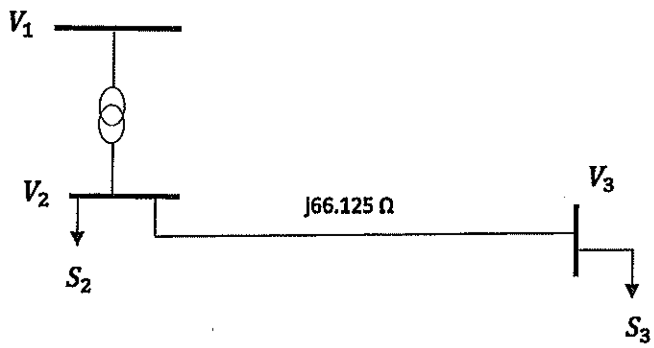


Fig. Q3(c)

Question 4 (25 Marks)

(a) What is meant by symmetrical fault? [2]

(b) Write the relative frequency of occurrence of various types of faults. [4]

(c) The power system shown in Fig. Q4(c) is working at no load when a symmetrical 3 phase fault is developed on bus 2.

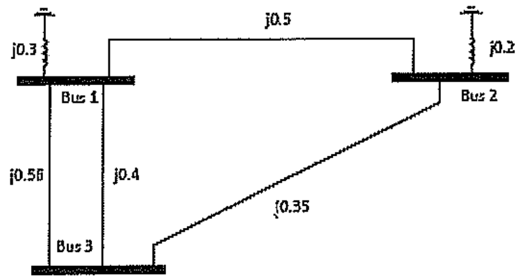


Fig. Q4(c)

Given that the per-phase per-unit impedance matrix is

$$Z_{bus} = j\begin{bmatrix} 0.183 & 0.078 & 0.141 \\ 0.078 & 0.148 & 0.106 \\ 0.141 & 0.106 & 0.267 \end{bmatrix}$$

(i) Calculate the per-unit sub transient fault current I_f'' at bus 2. [2]

(ii) Calculate the per-unit voltage at every bus in the system during the sub transient period. [6]

(iii) Calculate the per-unit current I_{23} flowing in line $L_{2\text{-}3}$ during the sub transient period of the fault. [1]

(d) The per unit reactance diagram of a three bus network shown in Fig. Q4(d) has the bus impedance matrix given by

$$Z_{Bus} = j\begin{bmatrix} 0.30 & 0.20 & 0.28 \\ 0.20 & 0.40 & 0.25 \\ 0.28 & 0.25 & 0.42 \end{bmatrix}$$

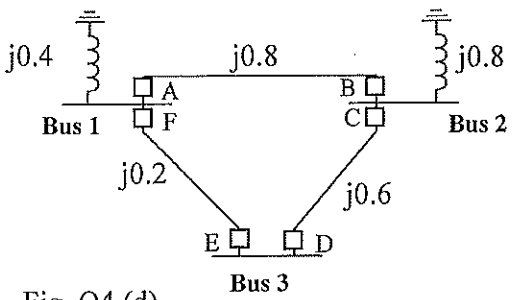


Fig. Q4 (d)

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

Question 5 (25 Marks)

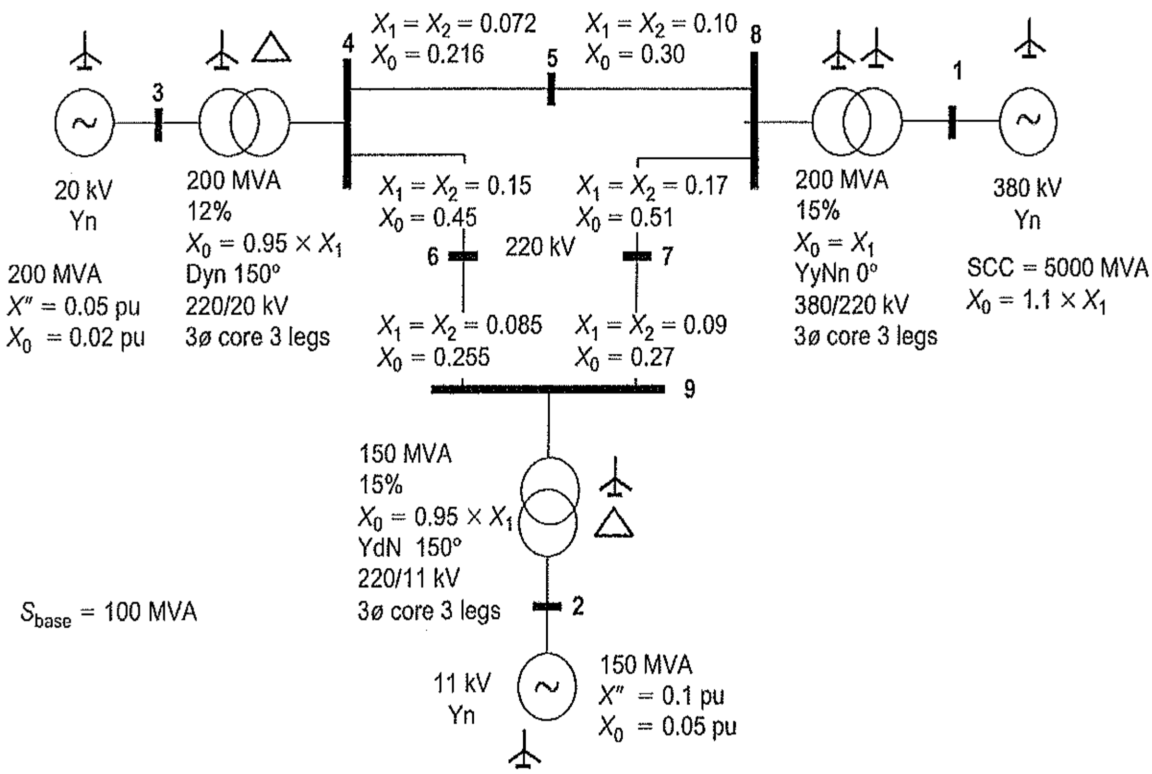
(a) Define the following terms:

i. Voltage stability [2]

ii. Voltage collapse [2]

(b) A 3-ϕ overhead line has resistance and reactance per phase of 25 and 90 Ω, respectively. The supply voltage is 145 kV while the load-end voltage is maintained at 132 kV for all loads by an automatically controlled synchronous phase modifier. If the kVAr rating of the modifier has the same value for zero loads as for a load of 50 MW, find the rating of the synchronous phase modifier. [6]

(c) Given the system shown in Fig.Q.5 Draw the positive, negative and zero sequence diagrams. [15]



Useful Formulae

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

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

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

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

$$\lambda = a_T\,P_T + b_T$$

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

$$V_s^{\,2} = A^2V_r^2 + B^2\left[\frac{P_r^2}{V_r^2} + \frac{Q_r^2}{V_r^2}\right] + 2ABP_r\cos(\alpha - \beta) - 2ABQ_r\sin(\alpha - \beta)$$