UNIVERSITY OF ESWATINI

MAIN EXAMINATION, FIRST SEMESTER

APRIL 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 SIX (6) PAGES INCLUDING THIS PAGE

Question 1 (25 Marks)

(a)Explain why load flow studies are performed? [2]

(b) Discuss the classification of power system buses. [8]

(c) Given the reactance diagram of a four-bus power system as shown in **Fig. Q1**

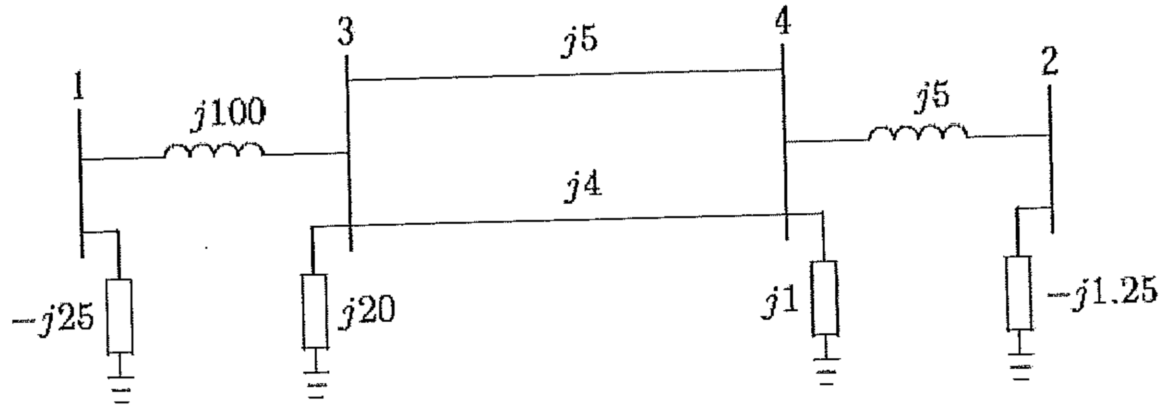

Fig. Q1 Four Bus Power System

Construct the Y_{bus} Matrix [6]

(d) With a neat flow chart explain the load flow solution by Gauss-Seidel method. [9]

Question 2 (25 Marks)

(a) Discuss the following terms as used in power systems operations

i. Spinning reserve [2]

ii. Incremental cost [2]

iii. Minimum up time [2]

(b) The cost characteristic equations of two units in a plant are

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

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

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

$$30 \leq P_1 \leq 90 \text{ MW}$$

$$30 \leq P_2 \leq 100 \text{ MW}$$

$$30 \leq P_3 \leq 90 \text{ MW}$$

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 250 MW. [14]

(c) On a system consisting of two generating plants, the incremental costs in E/MWh with P_{G1} and P_{G2} in MW are:

$$\frac{dc_1}{dP_{G1}} = 0.008P_{G1} + 8.0 \qquad \frac{dc_2}{dP_{G2}} = 0.012P_{G2} + 9.0$$

The system is operating on economic dispatch with $P_{G1} = P_{G2} = 500$ MW and $\frac{dP_L}{dP_{G2}}$.

Find the penalty factor of Plant-1. [5]

Question 3 (25 Marks)

(a) Define the following terms:

i. Load Frequency Control [2]

ii. Single area [2]

iii. What is meant by dynamic response in LFC? [2]

(b) Why should the system frequency be maintained constant? [3]

(c) Find the static frequency drop if the load is suddenly increased by 25 MW on a system having the following data: [10]

Rated capacity P = 500 MW

Operating Load P = 250 MW

Inertia constant H = 5 s

Governor regulation R = 2 Hz p.u.

Frequency f = 50 Hz

Also find the additional generation.

(d) The Eswatini Electricity Company (EEC) power system with H_{EEC} = 3 MJ/MVA is connected through a tie line with a reactance of 0.65 p.u. to the South African (ESKOM) power system with H_{ESKOM} = 8 MJ/MVA. If the load angle is 25°. Calculate the frequency of inter area oscillation. The voltages in the EEC and ESKOM systems are 1.05 p.u. and 1.03 p.u. respectively. [6]

Question 4 (25 Marks)

(a) Define swing curve. [1]

(b) Give an expression for swing equation. [2]

(c) List the methods of improving the transient stability limit of a power system. [4]

(d) Given the system shown Fig. Q4, where a three-phase fault is occurred at the point P. Find the critical clearing angle for the fault with simultaneous opening of the breakers C and D. The reactance values of various components are indicated on the diagram. The generator is delivering 1.2 p. u power at the instant preceding the fault [18]

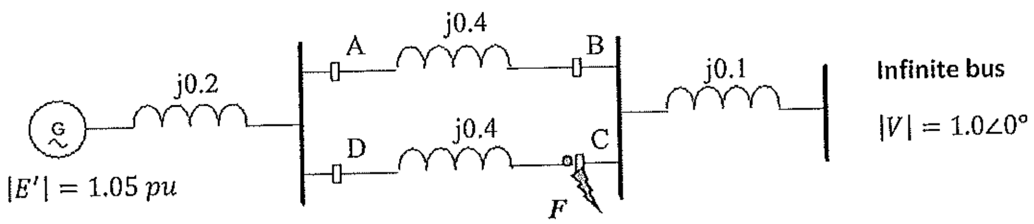

Fig. Q4

Question 5 (25 Marks)

(a) A periodic, sinusoidal voltage given by

$$V(t) = \sqrt{2}\,[200\sin(\omega t) + 40\sin(5\omega t + 55°)] \quad \text{V}$$

is applied to a series, linear, resistance-inductance load of resistance 4Ω and fundamental frequency reactance 10Ω. Calculate:

(i) THD_V [1]

(ii) THD_I [3]

(iii) Power factor [2]

(b) A new dc transmission system is compared with a three-phase ac system transmitting the same power and having the same losses and size of conductor. Assume that the direct voltage for breakdown of an insulator string is equal to the peak value of alternating voltage to cause break down. Show that the dc line will not only have two conductors instead of three for ac line but in addition the insulation level will be 87% of that of the ac line. [9]

(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 $Z_b = j0.12$ p.u. Determine the new Z_{bus} p.u. [10]

Useful Formulae

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

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

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

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

$$\lambda = a_T P_T + b_T$$

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

$$t_c = \sqrt{\frac{4H(\delta_{cr} - \delta_0)}{\omega_s P_m}}$$

$$Z_{bus(new)} = Z_{bus(orig)} - \frac{\Delta Z \Delta Z^T}{Z_{bb}}$$

$$Z_{bb} = Z_{jj} + Z_{kk} - 2Z_{jk} + Z_b$$

$$\begin{bmatrix} V_+ \\ V_- \\ V_0 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix}$$

$$f(t) = \frac{4}{\pi} \sum_{h=1,3,5,7,9}^{\infty} \frac{\sin(2h\pi ft)}{h}$$