CBCS SCHEME

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21EE53

# Fifth Semester B.E. Degree Examination, June/July 2024
## Power System Analysis – I

Time: 3 hrs. Max. Marks: 100

***Note: Answer any FIVE full questions, choosing ONE full question from each module.***

**Module-1**

1 a. Define a per unit system. State its advantages and disadvantages. **(06 Marks)**

b. Show that the pu impedance of a transformer is same either referred to primary or secondary side of it. **(06 Marks)**

c. A single line diagram of a power system is shown below in Fig. Q1 (c). Draw its pu impedance diagram.

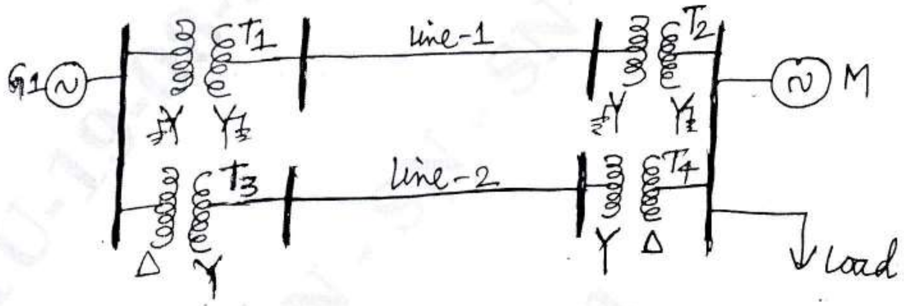


Fig. Q1 (c)

$G_1 = 90\text{ MVA}, 11\text{ KV}, X'' = 18\%$, M = 85 MVA, 11 kV, $X'' = 13\%$

$T_1 = 70\text{ MVA}, 11/110\text{ KV}, X = 15\%$

$T_2 = 60\text{ MVA}, 110/11\text{ KV}, X = 10\%$

$T_3$ = Three 1 $\phi$ units each rated 10 MVA, 11/127 KV, X = 9%

$T_4$ = Three 1 $\phi$ units each rated 16.6667 MVA, 127/11 KV, X = 12%

Line – 1, Z = j80 Ω, Line – 2, Z = j120 Ω

The load absorbs 74 MVA, 0.8 pf lagging at 6.5 KV.

Select a common base of 100 MVA, 11 KV on the generator G1 side. **(08 Marks)**

**OR**

2 a. Draw and explain the circuit models of the following power system components in steady state mode: (i) Synchronous machine (ii) 2-winding transformer (iii) transmission line (iv) loads. **(08 Marks)**

b. Define a single line diagram. List out any four important components in power system and draw its symbol used in its single line diagram. **(04 Marks)**

c. A 3-lens power system is shown in Figure Q2 (c) below. The ratings of various components are also given below:

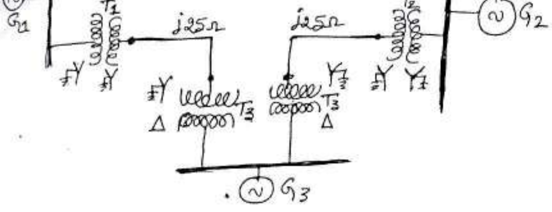


Fig. Q2 (c)

$G_1 = 50$ MVA, 13.8 KV, $X'' = 0.15$ pu ; $G_2 = 40$ MVA, 13.2 KV, $X'' = 0.2$ pu.
$G_3 = 30$ MVA, 11 KV, $X'' = 0.25$ pu ; $T_1 = 45$ MVA, 11/110 KV, $X = 0.1$ pu.
$T_2 = 25$ MVA, 12.5/115 KV, $X = 0.15$ pu ; $T_3 = 40$ MVA, 12.5/115 KV, $X = 0.1$ pu.
Determine the pu impedance diagram based on 50 MVA and 13.8 KV in generator $G_1$. **(08 Marks)**

## Module-2

3 a. Define a fault that occur in a power system. Classify the fault and define each type. **(04 Marks)**

b. Briefly explain how a synchronous machine on no-load offers a time varying reactance when subjected to a sudden 3ϕ short circuit across its terminals. **(08 Marks)**

c. A transformer of 3ϕ rated at 50 MVA having a SC reactance of 5% is connected to the bus bar which is supplied through two 66 KV feeder cables each having an impedance of (1.5+j2.5) Ω. One of the feeders is connected to a generating station rated at 80 MVA and having a SC reactance of 10% and the other feeder is connected to another generating station rated at 100 MVA and having SC reactance of 15%. Determine the MVA at fault point in the event of a SC between secondary terminals of transformer. Choose base MVA as 400 and base KV as 66 on the generator side. **(08 Marks)**

**OR**

4 a. A single line diagram of a simple 3-lens power system is shown in Fig. Q4 (a) below. All the impedances are expressed in pu on a common base of 100 MVA and respective base KVs. Assume all generators are running at their rated voltage. Determine the fault current and the currents through generators during the fault when a balanced 3ϕ fault with a fault impedance of j0.16 pu occurs on bus 3.

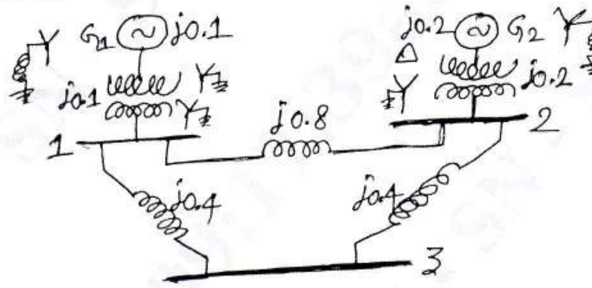


Fig. Q4 (a) **(10 Marks)**

b. Explain with a neat circuit model, the short circuit transients on a transmission line with the assumptions involved. Also explain the doubing effect on the line under 3ϕ short circuit with the neat waveforms of currents. **(10 Marks)**

## Module-3

5 a. Determine the symmetrical components of the asymmetrical phasors given below :
$V_R = 100\angle 250^\circ$ volts, $V_Y = 50\angle -110^\circ$ volts and $V_B = 40\angle 100^\circ$ volts. **(06 Marks)**

b. For the power system shown below in Fig. Q5 (b), draw all the sequence networks in pu. Choose a base of 50 MVA, 220 KV in j50 Ω transmission lines and mark all reactances in pu. The ratings of the components are,
$G_1 = 25$ MVA, 11 KV, $X''_d = 20\%$,
$G_2 = 25$ MVA, 11 KV, $X''_d = 20\%$,
$T_1$ to $T_4$ : Three 1ϕ units each rated at 6.6667 MVA, 6.35 KV/127 KV, X = 15%.
The negative sequence reactance of each machine is its subtransient reactance. The zero sequence reactance of each machine is 8%. Assume that the zero sequence reactances of lines are 250% of their positive sequence reactance's.

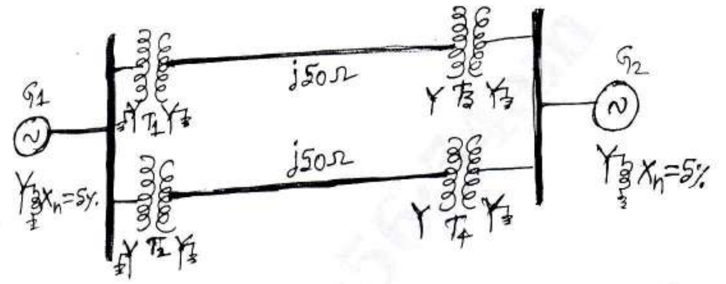


Fig. Q5 (b) **(14 Marks)**

**OR**

6 a. The symmetrical components of phase A in a 3ϕ-Y connected system of phase voltages are $V_{a1} = 200\angle 30^\circ V$, $V_{a2} = 60\angle 60^\circ V$ and $V_{a0} = 20\angle -30^\circ V$. The symmetrical components of line currents of phase A are, $I_{a1} = 20\angle 10^\circ A$, $I_{a2} = 5\angle 20^\circ A$ and $I_{a0} = 3\angle -10^\circ A$. Determine the 3ϕ power in KVA and also in pu, if the base power is 1 KVA. Also compute the active and reactive powers. **(06 Marks)**

b. A single line diagram of the power system is shown in Fig. Q6 (b) below. The positive, negative and zero sequence reactances of the components are given below along with their ratings. Draw the positive, negative and zero sequence networks of this power system on the base of generator ratings.

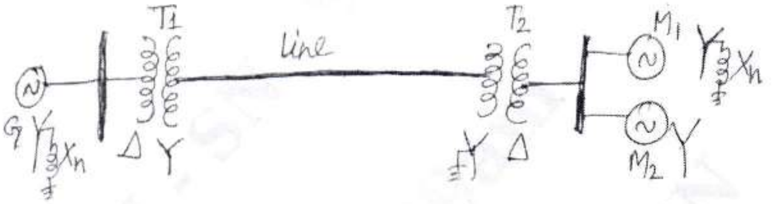


Fig. Q6 (b)

G : 30MVA, 13.8 kV, $X'' = 0.15$ pu, $X_2 = 0.15$ pu and $X_0 = 0.05$ pu, $X_n = 2\ \Omega$

$M_1$: 20 MVA, 12.5 KV; $X'' = 0.2$ pu, $X_2 = 0.15$ pu and $X_0 = 0.05$ pu, $X_n = 2\ \Omega$

$M_2$: 10 MVA, 12.5 KV, $X'' = 0.2$ pu, $X_2 = 0.15$ pu and $X_0 = 0.05$ pu,

$T_1$: 35 MVA, 13.2/115 KV, $X = 0.1$ pu

$T_2$: Three 1 ϕ units each rated at 10 MVA, 12.5/67 KV, $X = 0.1$ pu

Line : $X_1 = X_2 = 80\ \Omega$ and $X_0 = 250\ \Omega$ **(14 Marks)**

## Module-4

7 A 25 MVA, 11 KV 3 ϕ generator has a subtransient reactance of 20 %. The generator supplies two motors over a transmission line with transformers at both ends. The motors have rated inputs of 15 and 7.5 MVA, both at 10 KV with the subtransient reactance of 25%. The 3ϕ transformers are both rated at 30 MVA, 10.8/121 KV with a leakage reactance of 10% each. The series reactance of the line is 100 Ω. Assume that the negative sequence reactance of each machine is equal to its sub-transient reactance. Also, assume the zero sequence reactances for the generator and motors as 0.06 pu on its own ratings. The current limiting reactors of 2.5 Ω each are connected in the neutral of generator and motor. The zero sequence reactance of the line is 300 Ω. Select a base of 25 MVA and 11 KV in generator circuit, then draw the positive, negative and zero sequence networks of the system. If a solid LG fault occurs at the point F as shown in Fig. Q7 below, calculate the fault current at the fault point F. Neglect the prefault current.


Fig. Q7 **(20 Marks)**

**OR**

8 a. List out and explain the different types of open conductor faults occurs in a power system. **(06 Marks)**

b. Derive an equation of fault current, if a LLG fault occurs with a fault impedance $Z_f$ on an unloaded synchronous generator, whose neutral is grounded through an impedance $Z_n$. The generator has balanced emfs and sequence impedances of $Z_1$, $Z_2$ and $Z_0$. **(08 Marks)**

c. A 3$\phi$, 50 MVA, 11 KV, Y-connected, neutral solidly grounded generator operating on no-load at rated voltage gave the following sustained fault currents for the specified faults. Determine the three sequence impedances in $\Omega$ and also in pu for the base values of 50 MVA and 11 KV.
3$\phi$ fault : 2000 A, L – L fault : 1800 A, L-G fault : 2200 A **(06 Marks)**

## Module-5

9 a. Derive a swing equation of a synchronous generator connected to an infinite bus bar with usual notations. **(08 Marks)**

b. Define steady state stability and transient stability. List out the ways to improve their limits. **(06 Marks)**

c. A 50 Hz, four pole turbo generator rate 100 MVA, 11 KV has an inertia constant of 8 MJ/MVA :
(i) Find the stored energy in the rotor at synchronous speed.
(ii) If the mechanical input is suddenly raised to 80 MW for an electrical load of 50 MW, find the rotor acceleration neglecting mechanical and electrical losses.
(iii) If the above mentioned acceleration is maintained for 10 cycles, find the change in torque angle and rotor speed at the end of this period. **(06 Marks)**

**OR**

10 a. Derive a power angle equation of a non-salient pole synchronous machine as generator with usual notations. **(08 Marks)**

b. Define Equal Area Criterion and explain it in detail applicable for stability. **(06 Marks)**

c. A 50 Hz, four pole turbo generator rated at 20 MVA, 11 KV has an inertia constant of 9 KWsec/KVA. Find the kinetic energy stored in the rotor at synchronous speed. Determine the acceleration if the input powerless the rotational losses is 26,800 HP and the electric power developed is 16 MW. If the acceleration computed for the generator is constant for a period of 10 cycles, determine the change in torque angle in that period and the change in speed in rpm at the end of cycles. Assume that the generator is synchronized with infinite lens and has no accelerating torque before 10 cycle period begins. **(06 Marks)**

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