Second Semester Examination
2022/2023 Academic Session

July/August 2023

# EEK372 –POWER SYSTEM ANALYSIS

**Duration: 3 hours**

Please ensure that this examination paper consists of SIX (6) pages including appendix material before you begin the examination.

**Instructions:** This question paper consists of **FOUR (4)** questions. Answer **ALL** questions. All questions carry the same marks.

1. (a) The single-line diagram of a three-phase power system is shown in Figure 1. The length of transmission line has is 64 km with series reactance of 0.5 ohm/km. The ratings of the components are given in Table 1. Using the common base $S_b$ = 300 MVA and $V_b$ = 20 kV at the generator, draw the reactance diagram in per unit.

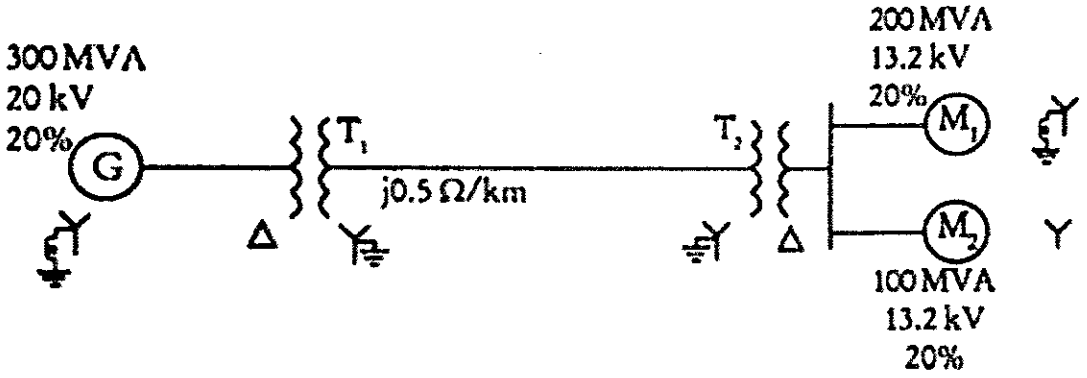


**Figure 1**

**Table 1**

| Component | Power (S) | Voltage (V) | Reactance X |
|---|---|---|---|
| Generator G | 300 MVA | 20.0 kV | 20% |
| Transformer $T_1$ | 350 MVA | 230/20 kV | 10% |
| Transformer $T_2$ | 300 MVA | 220/13.2 kV | 10% |
| Motor M1 | 200 MVA | 13.2 kV | 20% |
| Motor M2 | 100 MVA | 13.2 kV | 20% |

(55 marks)

(b) A three-phase line with an impedance of (0.2 + j1.0) ohm/phase feeds three balanced three-phase loads connected in parallel.

Load 1: absorbs a total of 150 kW and 120 kvar

Load 2: delta connected with an impedance of (150 - j48) ohm/phase

Load 3: 120 kVA at 0.6 power factor leading

If the line-to-neutral voltage at the load end of the line is 2000 V (rms), calculate the magnitude of the line-to-line voltage at the source end of the line.

(45 marks)

2. (a) A three-phase overhead transmission line is designed to deliver 15 MW, power factor 0.8 lagging at 132 kV at its receiving end. The transmission line loss is 5 % of the delivered power. The transmission line has resistance 0.572 Ω per km. Given the resistivity of the conductor material to be 2.84 x $10^{-8}$ ohm-m, determine the length of the line and conductor diameter. Neglect power losses due to insulator leakage currents and corona.

(35 marks)

(b) Assuming that there are 4 sub-conductors arranged symmetrically in a circle of radius R. These sub-conductors are equal in size with a diameter of 6 cm. Determine the radius of the circle, R if the geometric mean radius of this bundle conductor is 12 cm.

(25 marks)

(c) A single-phase transmission line has two conductors, each of 10 mm radius. The distance between them is 1 m. It is then converted to a three-phase transmission line by introducing a third conductor of the same radius. This new conductor is fixed at an equal distance, D from the two single-phase conductors. The three-phase lines is fully transposed. The inductance per phase of the three-phase system is 5 % more than that of the inductance per conductor of the single-phase system. Calculate the distance, D. Determine the ratio of the capacitance per phase of the three-phase system to the line-to-neutral capacitance of the single-phase system.

(40 marks)

...4/-

3. The one-line diagram of a simple three-bus power system and its data are shown in Figure 3 and Table 3. The neutral of each generator is grounded through an impedance of 0.25 per unit on a 100-MVA base. The generators are running on the no-load condition at rated voltage and frequency with their EMF in phase.

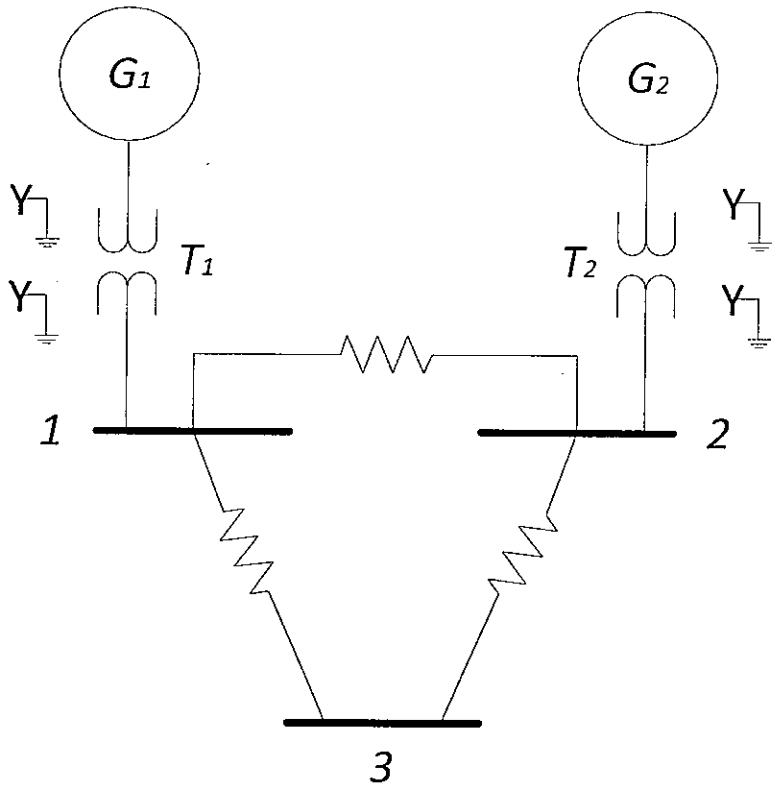


**Figure 3: Three-bus power system**

**Table 3: List of Data**

| Item | Base MVA | Voltage Rating (kV) | $X^1$ | $X^2$ | $X^3$ |
|---|---|---|---|---|---|
| $G_1$ | 100 | 20 | 0.15 | 0.15 | 0.05 |
| $G_2$ | 100 | 20 | 0.15 | 0.15 | 0.05 |
| $T_1$ | 100 | 20/220 | 0.10 | 0.10 | 0.10 |
| $T_2$ | 100 | 20/220 | 0.10 | 0.10 | 0.10 |
| $L_{12}$ | 100 | 220 | 0.125 | 0.125 | 0.30 |
| $L_{13}$ | 100 | 220 | 0.15 | 0.15 | 0.35 |
| $L_{23}$ | 100 | 220 | 0.25 | 0.25 | 0.7125 |

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Determine the followings:

(a) The positive, negative and zero sequence Thevenin impedance seen from bus 3.

(60 marks)

(b) Fault current when a single line-to-ground fault occurred at bus 3 with $Z_f = 0.1j$ per unit.

(40 marks)

4. Based on Question Three (Q3), determine:

(a) Fault current when a line-to-line fault occur at bus 3 with $Z_f = 0.1j$ per unit.

(50 marks)

(b) Fault current when a double line-to-ground fault occur at Bus 3 with $Z_f = 0.1j$ per unit.

(50 marks)

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APPENDIX A

| QUESTION NUMBER | CO | PO |
|---|---|---|
| 1 | 1 | 2 |
| 2 | 1 | 2 |
| 3 | 3 | 2 |
| 4 | 3 | 3 |