QUESTION ONE

a) What is the effect of load p.f. on regulation of a transmission line? {2.5 mks}

b) State the four key characteristic features that are required of all protection schemes {4 mks}

Quick oper
reliable
selectivity

c) A 3-ψ overhead line has resistance and reactance per phase of 5Ω and 20 Ω respectively. The load at the receiving end is 25 MW at 33kV and a p.f. of 0.8 lagging. Find the capacity of synchronous condenser required for this load condition if it is connected at the receiving end and the line voltages at both ends are maintained at 33 kV. {5.5 mks}

d) What is the justification in neglecting line capacitance in short transmission lines? {2 mks}

QUESTION TWO

a) What is *Electric Power supply system*? Draw a single line diagram of a typical a.c. power supply scheme. {5 mks}

b) A 3-ψ transmission line 200 km has the following constants:

V_S

Resistance/phase/km=0.16Ω

Reactance/phase/km=0.25 Ω.

Shunt admittance/phase/km=1.5×10-6S.

Calculate by rigorous method the sending end voltage and current when the line is delivering a load of 20MW at 0.8 p.f. lagging. The receiving end voltage is kept constant at 110 KV. {9mks}

$\frac{P}{I\cos\phi_R}$

QUESTION THREE

a) Discuss the requirements of a satisfactory electric supply system {6 mks}

b) Deduce an expression for voltage regulation of a short transmission line, giving the vector diagram. {8 mks}

$\left(\frac{V_S - V_R}{V_R}\right) \times 100$

V_S / V_R

✗ QUESTION FOUR

a) Discuss conditions necessary for successful parallel operation of transformers {5 mks}

b) Explain the construction and working of Brown-Boveri regulator with a neat sketch {9 mks}

✗ QUESTION FIVE

a) The present trend is towards *a.c.* for generation and distribution and *d.c.* for transmission. Discuss the reasons for it {4 mks}

b) Tests on 31.5MVA, 132/33KV star/delta 3-phase transformer gave the following results (loss values given are for 3 phases).

$\frac{P}{I\cos\phi_R}$

-open circuit test: 33KV, 5.5A, 21KW HV

-short circuit test: 13.2KV, 137.8A, 100KW. Calculate LV

i. Equivalent circuit parameters refered to LV side {3 mks}

ii. Efficiency at full load and half of full load with unit p.f. {4 mks}

iii. Regulation at full load with 0.8 p.f lagging. {3 mks}

✓ QUESTION SIX

a) Discuss the importance of voltage regulation in modern power systems {4 mks}

- Bulbs
- TV
- motors.

b) A 3-phase, 50 Hz, 16 km long overhead line supplies 1000 KW at 11kV, 0.8 p.f. lagging. The line resistance is 0.03Ω per phase per km and line inductance is 0.7 mH per phase per km. calculate the sending end voltage, voltage regulation and efficiency of transmission {7 mks}

c) A long transmission line is open circuited at the receiving end. Will there be any current in the line at the sending? Explain your answer {3 mks}

✓ QUESTION SEVEN

a) Discuss the terms *voltage regulation* and *transmission efficiency* as applied to transmission line {3 mks}

b) A 3-phase, 50Hz transmission line 100km long delivers 20MW at 0.9 p.f. lagging and at 110 KV. The resistance and reactance of the line per phase are 0.2Ω and 0.4Ω respectively while capacitance admittance is 2.5x10-6 Siemens/km/phase. Calculate:

i. The current and voltage at the sending end

ii. Efficiency of transmission. Use nominal T method {11 mks}

....the end.

Bonne chance

Ithigh
↑
$V = IZ$

[illegible]

$V_R = V_R\angle 0 \cdot \vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$V_1 = V_R + I_R Z/2 \cdot I_C = jYV_1$

$I_S = I_R + I_C \cdot V_S = V_1 + I_S Z/2$

Line value $= \sqrt{3}V_1$ losses $= 3I_S^2 R/2 + 3I_R^2 R/2$

~~3 phase~~

$\vec{V_S} = \vec{V_R} + \vec{I}\vec{Z}$

$V_S = V_R + IR\cos\phi_R + IX_L\sin\phi_R$

$X_L = 2\pi fL$

$X_C = \frac{1}{2\pi fC}$

Repetition

QUESTION ONE

Pf α 1/%Regn Pf α %Reg

~~P.f = $V_R\cos\phi_R + IR$~~

For lagging P.f ↓ Pf ↑ Regn

For leading P.f Pf α 1/Regn

a) What is the effect of load p.f. on regulation of a transmission line? {2.5 mks}

b) State the four key characteristic features that are required of all protection schemes {4 mks}

- Reliable
- quick response
- Manual handling control
- Instrument control

c) A 3-ψ overhead line has resistance and reactance per phase of 5Ω and 20 Ω respectively. The load at the receiving end is 25 MW at 33kV and a p.f. of 0.8 lagging. Find the capacity of synchronous condenser required for this load condition if it is connected at the receiving end and the line voltages at both ends are maintained at 33 kV. {5.5 mks}

d) What is the justification in neglecting line capacitance in short transmission lines? {2 mks}

QUESTION TWO

Check this

a) What is *Electric Power supply system*? Draw a single line diagram of a typical a.c. power supply scheme. {5 mks}

b) A 3-ψ transmission line 200 km has the following constants:

Resistance/phase/km=0.16Ω

Reactance/phase/km=0.25 Ω

Shunt admittance/phase/km=1.5×10⁻⁶S.

Calculate by rigorous method the sending end voltage and current when the line is delivering a load of 20MW at 0.8 p.f. lagging. The receiving end voltage is kept constant at 110 KV. {9mks}

QUESTION THREE

a) Discuss the requirements of a satisfactory electric supply system {6 mks}

b) Deduce an expression for voltage regulation of a short transmission line, giving the vector diagram. {8 mks}

QUESTION FOUR

a) Discuss conditions necessary for successful parallel operation of transformers {5 mks}

b) Explain the construction and working of Brown-Boveri regulator with a neat sketch {9 mks}

QUESTION FIVE

a) The present trend is towards *a.c.* for generation and distribution and *d.c.* for transmission. Discuss the reasons for it {4 mks}

- dc uses only 2 lines
- less potential stress hence need less insulation
- Has higher V Regn as it lacks L, C etc.
- less corona loss

b) Tests on 31.5MVA, 132/33KV star/delta 3-phase transformer gave the following results (loss values given are for 3 phases):

NO?

-open circuit test: 33KV, 5.5A, 21KW

-short circuit test: 13.2KV, 137.8A, 100KW. Calculate

i. Equivalent circuit parameters refered to LV side {3 mks}

ii. Efficiency at full load and half of full load with unit p.f. {4 mks}

iii. Regulation at full load with 0.8 p.f lagging. {3 mks}

QUESTION SIX

a) Discuss the importance of voltage regulation in modern power systems {4 mks}

b) A 3-phase, 50 Hz, 16 km long overhead line supplies 1000 KW at 11kV, 0.8 p.f. lagging. The line resistance is 0.03Ω per phase per km and line inductance is 0.7 mH per phase per km. calculate the sending end voltage, voltage regulation and efficiency of transmission {7 mks}

c) A long transmission line is open circuited at the receiving end. Will there be any current in the line at the sending? Explain your answer. {3 mks}

QUESTION SEVEN

a) Discuss the terms *voltage regulation* and *transmission efficiency* as applied to transmission line {3 mks}

b) A 3-phase, 50Hz transmission line 100km long delivers 20MW at 0.9 p.f. lagging and at 110 KV. The resistance and reactance of the line per phase are 0.2Ω and 0.4Ω respectively while capacitance admittance is 2.5 10⁻⁶ Siemens/km/phase. Calculate:

i. The current and voltage at the sending end

ii. Efficiency of transmission. Use nominal T method {11 mks}

....the end.

Bonne chance

$V_{SC} = I_1 Z_{01}$

$Z_{01} = \left(\frac{18.2\times10^3}{137.8A}\right) =$

$R_{01} = \left(\frac{W}{I_1^2}\right)$ ✓

$W = V_1 I_0 \cos\phi_0$

$\cos\phi_0 = \left(\frac{W}{V_1 I_0}\right) = \frac{21\times10^3}{33\times10^3\times5.5} = 0.1157$

$\sin\phi_0 = \sin\left[\cos^{-1}0.1157\right] = 0.9933$

$I_w = I_0\cos\phi_0 = 0.63635\ A$ ✓

$I_\mu = I_0\sin\phi_0 = 5.46315\ A$

$R_0 = \frac{V_1}{I_w} = \left(\frac{33\times10^3}{0.63635}\right) = 51.9\ k\Omega$

$X_0 = \frac{V_1}{I_\mu} = \left(\frac{33\times10^3}{5.46315}\right) = 6\ k\Omega$

I M

QUESTION ONE

a) What is the effect of load p.f. on regulation of a transmission line? {1 mk}

b) State the four key characteristic features that are required of all protection schemes {4 mks}

c) A 3-ɸ overhead line has resistance and reactance per phase of 5Ω and 20 Ω respectively. The load at the receiving end is 25 MW at 33kV and a p.f. of 0.8 lagging. Find the capacity of synchronous condenser required for this load condition if it is connected at the receiving end and the line voltages at both ends are maintained at 33 kV. {5 mks}

d) Describe *any four* equipment found/required in a transformer sub-station {4 mks}

QUESTION TWO

a) State four desirable characteristics of insulating materials used in cables {4 mks}

b) State any *three* advantages of reactors in control of short circuit currents {3 mks}

c) A 3-ɸ transmission line 200 km has the following constants:

Resistance/phase/km=0.16Ω

Reactance/phase/km=0.25 Ω

Shunt admittance/phase/km=1.5×10^{-6}S.

Calculate by rigorous method the sending end voltage and current when the line is delivering a load of 20MW at 0.8 p.f. lagging. The receiving end voltage is kept constant at 110 KV. {7mks}.

QUESTION THREE

a) State *three advantages* and *three disadvantages* of oil circuit breakers {6 mks}

b) Deduce an expression for voltage regulation of a short transmission line, giving the vector diagram. {8 mks}

QUESTION FOUR

a) Explain the *arc phenomenon* in a circuit breaker. {4 mks}

b) Explain the construction and working of Brown-Boveri regulator with a neat sketch {8mks}

c) Define the term *Bushings* {2 mks}

QUESTION FIVE

a) The present trend is towards *a.c.* for generation and distribution and *d.c.* for transmission. Discuss *four* reasons for it {4 mks}

∠ 57.38°

---

b) Tests on 31.5MVA, 132/33KV star/delta 3-phase transformer gave the following results (loss values given are for 3 phases):

-open circuit test: 33KV, 5.5A, 21KW

-short circuit test: 13.2KV, 137.8A, 100KW. Calculate

i. Equivalent circuit parameters refered to LV side {3 mks}

ii. Efficiency at full load and half of full load with unit p.f. {4 mks}

iii. Regulation at full load with 0.8 p.f lagging. {3 mks}

QUESTION SIX

a) Discuss the importance of voltage regulation in modern power systems {4 mks}

b) A load of 1000kW at 0.8 p.f lagging is received at the end of a 3-phase line 20 km long. The resistance and reactance of each conductor are 0.25Ω and 0.28Ω per km. if the receiving end line voltage is maintained at 11kV, calculate:

i. Sending end voltage {2 mks}

ii. Percentage regulation {2.5 mks}

iii. Transmission efficiency {2.5 mks}

c) A long transmission line is open circuited at the receiving end. Will there be any current in the line at the sending? Explain your answer. {3 mks}

QUESTION SEVEN

a) State two advantages and two disadvantages of fuses as protection devises {4 mks}

b) A 3-phase, 50Hz transmission line 100km long delivers 20MW at 0.9 p.f. lagging and at 110 KV. The resistance and reactance of the line per phase are 0.2Ω and 0.4Ω respectively while capacitance admittance is $2.5\ 10^{-6}$ Siemens/km/phase. Calculate:

i. The current and voltage at the sending end

ii. Efficiency of transmission. Use nominal T method {11 mks}

....the end

Bonne chance

6

1nSE

Repetition

for lag % reg = $\frac{I_R R \cos\phi_R + I X_L \sin\phi_R}{V_R}$

$\frac{I_R \cos\phi_R - I X_L}{V_R}$

QUESTION ONE

reg ↑ ↓ p.f on lag lo

↓ ↓ p.f for Lead

a) What is the effect of load p.f. on regulation of a transmission line? {2.5 mks} – lead

b) State the four key characteristic features that are required of all protection schemes {4 mks}

discriminati / Isolator – reliability – Allow for attachment of equip

– Quick operation – manual control

c) A 3-ψ overhead line has resistance and reactance per phase of 5Ω and 20 Ω respectively. The load at the receiving end is 25 MW at 33kV and a p.f. of 0.8 lagging. Find the capacity of synchronous condenser required for this load condition if it is connected at the receiving end and the line voltages at both ends are maintained at 33 kV. {5.5 mks}

$\frac{3 V_R I_m}{1000}$

d) What is the justification in neglecting line capacitance in short transmission lines? {2 mks}

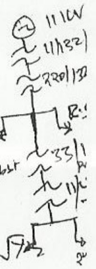
Short TL's are of length upto 100km and have line voltage <20kV thus the capacitance effects are very low and hence are neglected.

QUESTION TWO

conveyance of power (electric) from generating station to consumer premises.

a) What is *Electric Power supply system*? Draw a single line diagram of a typical a.c. power supply scheme. {5 mks}

gen, tx, dist of electric energy to cons.



$\sinh\sqrt{YZ} = \sqrt{YZ} + \frac{(YZ)^{3/2}}{6}$

b) A 3-ψ transmission line 200 km has the following constants:

Resistance/phase/km=0.16Ω

Reactance/phase/km=0.25 Ω

Shunt admittance/phase/km=1.5×10⁻⁶S.

$V_S = V_R \cosh\sqrt{YZ} + I_R\sqrt{\frac{Z}{Y}} \sinh\sqrt{YZ}$

$I_S = V_R\sqrt{\frac{Y}{Z}} \sinh\sqrt{YZ} + I_R \cosh\sqrt{YZ}$

$\cosh\sqrt{YZ} = 1 + \frac{ZY}{2} + \frac{Z^2Y^2}{24}$

V_S I_S

Calculate by rigorous method the sending end voltage and current when the line is delivering a load of 20MW at 0.8 p.f. lagging. The receiving end voltage is kept constant at 110 KV. {9mks}

QUESTION THREE

a) Discuss the requirements of a satisfactory electric supply system {6 mks}

Frequency
Efficiency
Voltage regulation

B ⇒ Balanced voltage
E ⇒ Efficiency
D ⇒ Dependability
F ⇒ Frequency
V ⇒ Voltage Regul

b) Deduce an expression for voltage regulation of a short transmission line, giving the vector diagram. {8 mks}

QUESTION FOUR

a) Discuss conditions necessary for successful parallel operation of transformers {5 mks}

→ same K
→ proper connection of polarity
→ If KVA different, the eq impeds should be invsly pr to the individ KVA's
→ same % impedances for X/R ratio
→ prims should be suitabl for the supply syst voltage

b) Explain the construction and working of Brown-Boveri regulator with a neat sketch {9 mks}

QUESTION FIVE

a) The present trend is towards *a.c.* for generation and distribution and *d.c.* for transmission. Discuss the reasons for it {4 mks}

no induction el

– It is possible to construct large a.c generators of upto 500MW. DC gens cannot be built higher than 5MW

– a.c can be efficiently raised or lowered for economic trans & distn

d.c has to be ge at low level

b) Tests on 31.5MVA, 132/33KV star/delta 3-phase transformer gave the following results (loss values given are for 3 phases):

$\cosh\sqrt{YZ} = 1 + \frac{YZ}{2} + \frac{(YZ)^2}{24}$

$\sinh\sqrt{YZ} = \sqrt{YZ} + \frac{(YZ)^{3/2}}{6}$

-open circuit test: 33KV, 5.5A, 21KW

-short circuit test: 13.2KV, 137.8A, 100KW. Calculate

i. Equivalent circuit parameters refered to LV side {3 mks}

ii. Efficiency at full load and half of full load with unit p.f. {4 mks}

iii. Regulation at full load with 0.8 p.f lagging. {3 mks}

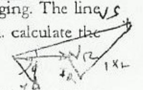
QUESTION SIX

a) Discuss the importance of voltage regulation in modern power systems {4 mks} – motor – lighting power loads

Short

b) A 3-phase, 50 Hz, 16 km long overhead line supplies 1000 KW at 11kV, 0.8 p.f. lagging. The line resistance is 0.03Ω per phase per km and line inductance is 0.7 mH per phase per km. calculate the sending end voltage, voltage regulation and efficiency of transmission {7 mks}

V_S η, reg η.



c) A long transmission line is open circuited at the receiving end. Will there be any current in the line at the sending? Explain your answer. {3 mks}

QUESTION SEVEN

a) Discuss the terms *voltage regulation* and *transmission efficiency* as applied to transmission line {3 mks}

b) A 3-phase, 50Hz transmission line 100km long delivers 20MW at 0.9 p.f. lagging and at 110 KV. The resistance and reactance of the line per phase are 0.2Ω and 0.4Ω respectively while capacitance admittance is 2.5 10⁻⁶ Siemens/km/phase. Calculate:

i. The current and voltage at the sending end

ii. Efficiency of transmission. Use nominal T method {11 mks}

$I_S = I_L + I_R$ V_S

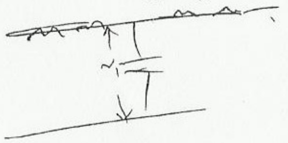
....the end.

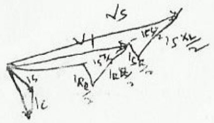
V_R I_L

Bonne chance

I_S V_S

$I_0 = \frac{5.5}{\sqrt{3}} = 3.2$





$X_L = 2\pi f L$

QUESTION ONE

a) Figure Q1 shows interconnected power systems A and B. In quadrant 1 of figure Q1a (ii) the direction of flow of active and reactive power is shown. Determine the direction of flow of active and reactive power in quadrants 2,3 and 4.

$S = P + jQ$

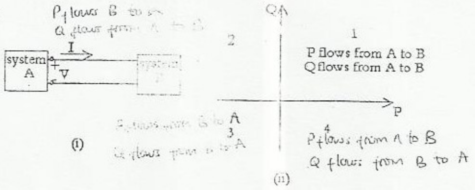


Figure 1a

(6 marks)

b) A three phase, 50 Hz, 415 V motor developes 10kW, the power factor being 0.75 lagging and efficiency 95%. A bank of capacitors is connected in delta across the supply terminals and power factor raised to 0.92 lagging. Each of the capacitance units is built of 5 similar 83 V capacitors. Determine the capacitance of each capacitor
(8 marks)

83 P = 10kW

QUESTION TWO

(a) Consider the circuit in Figure Q2. Given the following values:

$$\overline{V}_{an} = 100\angle 0°\ A$$
$$\overline{V}_{bn} = 50\angle 180°\ A$$
$$\overline{V}_{cn} = 50\angle 180°\ A$$
$$\overline{Z}_s = 8 + j10\ \Omega$$
$$\overline{Z}_{ab} = \overline{Z}_{bc} = \overline{Z}_{ca} = \overline{Z}_m = j4\ \Omega$$

$V = IX_C$

$S = VI$

$S = VI$

$8 + j10 +$

$8 + j10 - jX$

$V_a = I_a Z_s + Z_m(I_b + I_c)$

$X_C = \frac{1}{2\pi f C}$

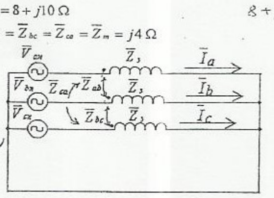


Figure Q2

$V = IX_C$

$\frac{V^2}{X_C} = S$

$10 \times 0.55 = 5500W$

$5500 \times 0.75 = 7125$

$= 8740$

$Q = 2375$

$\frac{760}{2161.5}$ Var

(a) Calculate $\overline{I}_a$, $\overline{I}_b$ and $\overline{I}_c$ without using symmetrical components
(b) Calculate $\overline{I}_a$, $\overline{I}_b$ and $\overline{I}_c$ using symmetrical components

$I_{abc} = [T]I_{012}$ $V_0 = \frac{1}{3}(V_a$ $I_{012} = [T]^{-1}Z_{abc}[T]I_{012}$ (10 marks)

QUESTION THREE

(a) Figure Q3 shows a single line diagram of a three-phase system. The percentage reactance of each generator is based on its own capacity. Find the short-circuit current that will flow into a solid three-phase short-circuit at F.

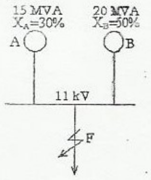


Figure Q3 Single line diagramme

(6 m

(b) An ideal wattmeter has a zero-impedance current coil and an infinite-impedance potential coil and the meter reads P=VI cos(α-β). Consider the following balanced 3-ϕ situation shown in Figure Q3b.

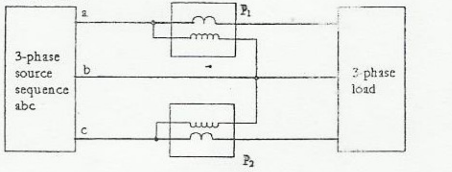


Figure Q3b

(i) Prove that the top wattmeter reads $P_1 = V_L I_L \cos(\psi + 30°)$
(ii) Prove that the bottom wattmeter reads $P_1 = V_L I_L \cos(\psi - 30°)$
(iii) Show that $P_1 + P_2 = V_L I_L \sqrt{3} \cos\psi$
(iv) Show that $P_1 - P_2 = V_L I_L \sqrt{3} \sin\psi = \frac{Q_{3\phi}}{\sqrt{3}}$

(8 m

QUESTION FOUR

(a) Three-phase currents I_a, I_b and I_c can be represented using symmetrical components I_0, I_1 and I_2. Derive equations expressing:
(i) I_0, I_1 and I_2 in terms of I_a, I_b and I_c
(ii) I_a, I_b and I_c in terms of I_0, I_1 and I_2

$V_a = V_0 + V_1 + V_2$
$V_b =$
V_c

(8 m

$I_a = I_0 + I$
$I_b = I_0 +$

QUESTION 1

a) A star connected load consists of three equal resistors of 1 Ω resistance. The load is assumed to be connected to unsymmetrical 3-phase supply line voltages are V_{AB}=240 V, V_{BC}=240 V and V_{CA}=415 V. Find:
(i) the magnitudes of currents in phase A, B and C;
(ii) symmetrical components I_{A1}, I_{A2}, I_{A0}, I_{B1}, I_{B2}, I_{B0}, I_{C1}, I_{C2} and I_{C0}.
(10 marks)

b) Draw and explain an equivalent diagram of a long transmission line and explain all elements.
(4 marks)

$\frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$ $1 + \frac{1}{3} = \frac{4}{3}$

QUESTION 2

(a) A 3-phase, 5 MVA, 11 kV generator with a solidly earthed neutral point supplies a feeder. The relevant impedances of the generator and feeder in Ohms are as under.

	Generator	Feeder
Positive sequence impedance	j1.2	j1.0
Negative sequence impedance	j0.9	j1.0
Zero sequence impedance	j0.4	j1.0

If a fault from one phase to earth occurs on the far end of the feeder (phase A), calculate:
(i) the magnitude of fault current;
(ii) line to neutral voltage at the generator.
(9 marks)

(b) list the functions of circuit breakers in power systems
(5 marks)

$V_R = E_R - I_0(Z_1 + Z_2 + Z_3)$

$I_2 = I_1 = I_0 = \frac{E_R}{Z_1 + Z_2 + Z_3}$

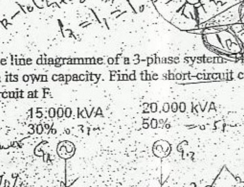
QUESTION 3

(a) Figure Q3 shows the single line diagramme of a 3-phase system. The percentage reactance of each generator is based on its own capacity. Find the short-circuit current that will flow into a complete 3-phase short circuit at F.

Total kVA for G_A and G_B
35 000 kVA — Base power

$\% X_{G_A} = \left(\frac{35{,}000}{15{,}000} \times 0.30\right) = 70\%$

$\% X_{G_B} = \left(\frac{35{,}000}{20{,}000} \times 50\right) = 87.5\%$

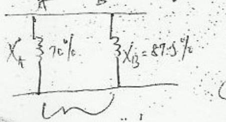


Single line diagramme

Base Current $= \frac{35{,}000}{11{,}000}$ = 3,181.82 Total Current

(7 marks)

(b) The currents in three phase unbalanced system are $\overline{I}_a = (12 + j8)$ A; $\overline{I}_b = (10 + j10)$ A; $\overline{I}_c = (25 + j10)$ A. The phase sequence is ABC. Calculate the zero, positive and negative sequence components of the currents.
(7 marks)



Combined Reactance $S = \sqrt{3} V I_{base}$

$= \frac{(70 \times 87.5)}{(70 + 87.5)} = 38.9\%$

$I_{SC} = 4{,}723.4$ A

~~Short circuit current at F = 38.9% Base Current~~

38.9% reactance gives 1237.02

QUESTION 4

a) Give two reasons why reactors are used in a power system (3 marks)

b) Prove that $\frac{1-a^2}{a-a^2} = -a$ (1 mark)

$\frac{1 - a^2 - a - a^2}{a - a^2}$

$a^2 + a + 1$

c) An overhead 3-phase transmission line delivers 10,000 kW at 11 kV at 0.8 power factor lagging. The resistance and reactance of each conductor is 4 Ω and 6 Ω respectively. Determine:
(i) Sending end voltage; $V_S = V_R + IZ$
(ii) Percentage regulation;
(iii) Transmission efficiency.

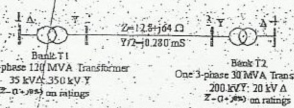
$V_S = V_R + IZ$

(10 marks)

$I_S = I(\cos\phi - j\sin\phi)$

QUESTION 5

(a) Consider the 3-phase system in fig 10. at bus 2, $S_{3\phi base}$=100 MVA and V_{Lbase}=220 kV.



6350.35

1.962

1.9

(i) Tabulate all four base values (S_{base}, V_{base}, I_{base}, Z_{base}) at all four buses (16 values total)
(ii) Draw the positive-sequence equivalent circuit for the given system locating all the four buses.
(iii) Convert all impedance data provided into per unit, and enter those values in the circuit in (ii).
(iv) Draw the zero sequence equivalent circuit for the system locating all the four buses.
(14 marks

QUESTION 6

For the circuit in figure Q6 the prefault (before switch is closed) currents are $\overline{I}_1 = -\overline{I}_2 = 1\angle 0°$.

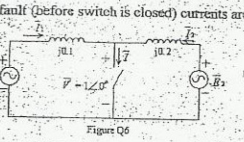


Figure Q6

113.36

(a) Calculate the fault currents $\overline{I}$, $\overline{I}_1$ and $\overline{I}_2$ (switch closed) by calculating correct values for $\overline{E}_1$ and $\overline{E}_2$ first;

(3 marks)

$I = 1136.36$

(b) A balanced star connected load takes 60 A from a balanced 3-phase, 4-wire supply. If the fuses in the Y and B phases are removed, find the symmetrical components of the line currents:
  (i) before the fuses are removed
  (ii) after the fuses are removed

(6 marks)

QUESTION FIVE

(a) A star connected load consists of three equal resistors of 1 Ω resistance. The load is assumed to be connected to an unsymmetrical 3-phase supply, whose magnitudes of line voltages are V_{ab}=208 V, V_{bc}=360 V and V_{ca}=416 V. Find the magnitude of the current in phase 'a' using symmetrical component method. *(Note: $\overline{V}_{ab}+\overline{V}_{bc}+\overline{V}_{ca}=0$)*

(10 marks)

(b) (i) Explain the causes of unsymmetrical and unbalanced supply in power systems
  (ii) Explain the measures taken in transmission lines to ensure that the supply is symmetrical and balanced.

(4 marks)

QUESTION SIX

(a) Derive an expression for fault current for double line-to-ground fault by symmetrical components method.

(10 marks)

(b) (i) What is the justification in neglecting line capacitance in short transmission lines
  (ii) a long transmission line is open circuited at the receiving end. Explain whether there will be any current in the line

(4 marks)

QUESTION SEVEN

(a)
  (i) Explain the functions of a circuit breaker **(1 marks)**
  (ii) Name four types of circuit breakers **(2 marks)**
  (iii) Give advantages and disadvantages of the circuit breakers given in (ii).

(6 marks)

(b) Explain the following terms as used in power systems
  (i) Bushing
  (ii) Instrument transformers
  (iii) Bus-bars
  (iv) Isolators

(5 marks)

Answer any five of the given seven questions. All questions carry equal marks.

QUESTION ONE

(a) For given three impedances in a network, connected in star, derive the delta connected impedances that would replace the star but maintain the currents and voltages to the points of connection.

(6 marks)

(b) Assume a balanced 3-phase voltage source with $\overline{V}_{an}=E\angle 0^\circ$, and phase sequence abc.
  (i) Compute and locate on phasor-diagram $\overline{V}_{ab}, \overline{V}_{bc}, \overline{V}_{ca}, \overline{V}_{an}, \overline{V}_{bn}$ and $\overline{V}_{cn}$.
  (ii) Connect the three-phase source terminals (abc) to a balanced delta load such that $\overline{Z}_\Delta = Z_\Delta\angle\psi$.
  (iii) For the diagram in (ii) compute the load currents $\overline{I}_a$, $\overline{I}_b$ and $\overline{I}_c$ and add them to your diagram.
  (iv) Determine the wye impedance, $\overline{Z}_Y$, (in terms of $\overline{Z}_\Delta = Z_\Delta\angle\psi$) that could be used to replace the delta so that the line currents would remain unchanged, in both magnitude and phase.

(8 marks)

QUESTION TWO

(a) Explain why electrical power transmitted over a long distance is done at high voltage.

(2 marks)

(b) What is the percentage saving in copper feeder if the line voltage in a 2-wire d.c. system is raised from 220V to 500 V for the same power transmitted over the same distance and having the same power loss?

(4 marks)

(c) Consider the circuit in Figure Q2. Suppose $\overline{V}_{an}=100\angle 0^\circ$, $\overline{V}_{bn}=50\angle 180^\circ$, $\overline{V}_{cn}=50\angle 180^\circ$, $\overline{Z}_s=8+j10$, and $\overline{Z}_{ab}=\overline{Z}_{bc}=\overline{Z}_{ca}=\overline{Z}_m=j4$

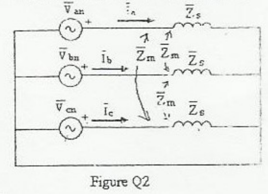


Figure Q2

(i) Calculate $\overline{I}_a$, $\overline{I}_b$ and $\overline{I}_c$ without using symmetrical components,
(ii) Calculate $\overline{I}_a$, $\overline{I}_b$ and $\overline{I}_c$ using symmetrical components.

(8 marks)

$V_a = V_0 + V_1 + V_2$

Answer any five of the given seven questions. All questions carry equal marks.

QUESTION THREE

(a) Explain the following terms:
  (i) Geometric mean radius (GMR) of a wire
  (ii) Equivalent geometrical spacing of conductors.

(4 marks)

(b) Determine the equivalent geometric spacing of conductors A, B and C spaced as follows: distance between A and B is d_1; B and C is d_2; and A and C is d_3.

(2 marks)

(c) A single phase a.c. system supplies a load of 200 kW and if this system is converted to 3-phase, 3-wire a.c. system by running a third similar conductor, calculate the 3-phase load that can now be supplied if the voltage between the conductors is the same. Assume the power factor and transmission efficiency to be the same in the two cases.

(8 marks)

QUESTION FOUR

(a) A long transmission line is open circuited at the receiving end. Explain whether there will be any current in the line at the sending end.

(3 marks)

(b) A single-phase transmission line has two parallel conductors 3 m apart, the radius of each conductor being 1 cm. Calculate the loop inductance per km length of the line if the material of the conductor is:
  (i) copper
  (ii) steel with relative permeability of 100

(5 marks)

(c) A3-phase, 50 Hz, 66 kV overhead line conductor are placed in a horizontal plane. The conductor diameter is 1.25 cm. If the line length is 100 km, assuming complete transposition of the line, calculate:
  (i) capacitance per phase,
  (ii) Charging current per phase.

(6 marks)

QUESTION FIVE

(a) What is the importance of short circuit calculations?

(1 mark)

(b) Explain why ~~a~~ reactors are used in the power systems

(2 marks)

(c) A 4-winding ideal transformer has windings with the following numbers of turns: N_1=1000 turns, N_2=500 turns, N_3=2000 turns, N_4=3000 turns. The windings are terminated as follows:
  1. Source $V_1=1000\angle 0^\circ$ V.
  2. impedance $\overline{Z}_2=10\ \Omega$
  3. impedance $\overline{Z}_3=40-j30\ \Omega$
  4. impedance $\overline{Z}_4=j100\ \Omega$

(i) Draw a circuit diagram, defining all circuit currents and voltages
(ii) Solve for all winding currents and voltages
(iii) Calculate the complex power into winding 1
(iv) Calculate the winding power out of winding 2, 3 and 4,
(v) Suppose V_{1base}=1000V and I_{1base}=100 A, Calculate V_{2base}, V_{3base}, V_{4base}, I_{2base}, I_{3base}, I_{4base}, S_{1base}, S_{2base}, S_{3base} and S_{4base}.

(11 marks)

Answer any five of the given seven questions. All questions carry equal marks.

QUESTION SIX

(a) Prove that $\frac{1-a}{1+a^2}=1-a^2$.

(2 marks)

(b) Consider the power system terminated as shown in Figure Q6. Derive the appropriate interconnections between sequence networks.

$a^3 = 1$

$\frac{a^3-a}{(a^3+a^2)}$

$\frac{a^2-1}{a(a^2+a)}$

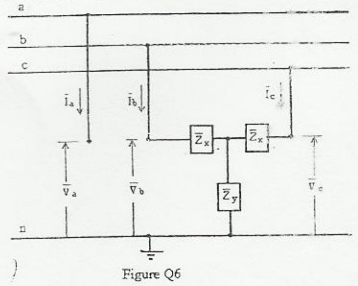


Figure Q6

(12 marks)

QUESTION SEVEN

(a) Do the sequence components physically exist in a 3-phase system? Explain.

(3 marks)

(b) Consider the system in figure Q7. Derive Thevenin equivalent sequence networks looking in at bus 1.

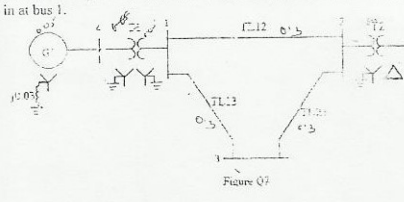


Figure Q7

$a^3 = 1$

(11 marks)

ECE 372: POWER SYSTEMS I

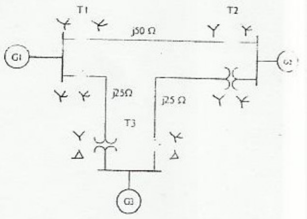
CONSOLIDATED ASSIGNMENT

QUESTION ONE

A three-bus system is given in the figure below. The ratings of the various components are as listed hereunder:

Generator 1: 50 MVA, 13.8 kV, x = 0.15 p.u.
Generator 2: 40 MVA, 13.2 kV, x = 0.2 p.u.
Generator 3: 30 MVA, 11 kV, x = 0.25 p.u.
Transformer 1: 45 MVA, 11/110 (Δ/Y) kV, x = 0.1 p.u.
Transformer 2: 25 MVA, 12.5/115 (Δ/Y) kV, x = 0.15 p.u.
Transformer 3: 40 MVA, 12.5/115 (Δ/Y) kV, x = 0.1 p.u.

The line impedances are indicated on the diagram. Determine impedance diagram based on 50 MVA and 13.8 kV as base quantities in Generator #1.



QUESTION TWO

Determine the sending-end voltage, current and power factor of a single phase 50 Hz, 76.2 kV transmission line delivering 12 MW at 0.8 p.f. lagging. The line constants are R = 25 ohm, inductance = 200 mH and capacitance between lines = 2.5 μF. Also determine the voltage regulation and efficiency of the line.

QUESTION THREE

Determine the efficiency and voltage regulation of a three-phase, 50 Hz, 150 km long transmission line having three conductors spaced 3.5 m delta formation when the receiving end delivers 25 MVA at 120 kV and 0.9 p.f. lagging. The resistance of the conductor is 0.25 Ω/km and the effective diameter is 0.75 cm. Neglect leakage and use:

(i) Nominal-T equivalent line model

(ii) Nominal-π equivalent line model

QUESTION FOUR

Shown below is a 35 kV network supplying three step-down substations A, B and C from a generating station S. The whole network is made of aluminum conductor having a cross-sectional area of 120 mm (r_c = 0.27 Ω/km, x_c = 0.405 Ω/km). The lengths of the network sections (in km) and the substation loads are indicated on the diagram. Determine power flow along the line sections and the maximum voltage drop under normal operating conditions.