Q1. A three-phase transformer rated $5\ MVA, 115/13.2\ kV$ has per phase series impedance of $(0.007 + j0.075)\ pu$. The transformer is connected to a short distribution line which can be represented by a series impedance per phase of $(0.02 + j0.10)\ pu$ on a base of $10\ MVA, 13.2\ kV$. The line supplies a balanced three phase load rated $4\ MVA, 13.2\ kV$, with lagging power factor of 0.85.

a) Draw impedance diagram of the system indicating all impedances in per unit. Choose $10\ MVA, 13.2\ kVA$ as the base at the load.

b) With the voltage at the primary side of the transformer held constant at $115\ kV$, the load at the receiving end of the line is disconnected. Find the voltage regulation of the load.

[Ans: 6.72 %]

Q2. Three identical single-phase transformers, each rated $1.2\ kV\ /\ 120\ V, 7.2\ kVA$ and having a leakage reactance of $0.05\ per\ unit$, are connected together to form a three-phase bank. A balanced Y- connected load of 5 Ω per phase is connected across the secondary of the bank. Determine the Y- equivalent per-phase impedance (in ohms and in per unit) seen from the primary side when the transformer bank is connected

a) $Y - Y,\ b) Y - \Delta,\ \ b)\ \Delta - Y,\ c)\ \Delta - \Delta$

[Ans: $(\mathbf{500 + j10})\Omega$; $(\mathbf{1500 + j10})\Omega$; $(\mathbf{166.67 + j3.33})\Omega$; $(\mathbf{500 + j3.33})\Omega$]

Q3. Three balanced Y- connected loads are installed on a balanced three phase four wire system. Load 1 draws a total power of 6 kW at unity PF, load 2 pulls 10 kVA at 0.96 lagging PF, and load 3 demands 7 kW at 0.85 lagging. If the phase voltage at the loads is 135 V, if each line has a resistance of 0.1 Ω, and if the neutral has a resistance of 1 Ω, find

a) The total power drawn by the loads;
b) The combined PF of the loads;
c) The total power lost in the four lines;
d) The phase voltage at the source;
e) The power factor at which the source is operating.

[Ans: 22.6 kW; 0.954 lag; 1027 W; 140.6 V; 0.957 lag]

Q4. A three-phase round rotor synchronous generator, rated $10\ kV, 50\ MVA$ has armature resistance $R\ of\ 0.1\ pu$ and synchronous reactance X_d of $1.65\ per\ unit$. The machine operates on a $10\ kV$ infinite bus delivering $2000\ A\ at\ 0.9$ power factor leading.

a) Determine the internal voltage E_f and the power angle δ of the machine. Draw a phasor diagram depicting its operation.
b) What is the open circuit voltage of the machine at the same level of excitation?
c) What is the steady state short circuit current at the same level of excitation?

Neglect all saturation effects

[Ans: $E_i\angle\delta = \mathbf{11.95\angle 61.83^0}\ \boldsymbol{kV}$; $\mathbf{11.95}\ \boldsymbol{kV}; \mathbf{2090.7}\ \boldsymbol{A}$]

Q5. The three-phase synchronous generator, rated $16\ kV\ and\ 200\ MVA$, has negligible losses and synchronous reactance of $1.65\ pu$ is operated on an infinite bus of voltage $15\ kV$ and delivers $100\ MVA\ at\ 0.8$ power factor lagging.

a) Determine the internal voltage E_i and the power angle δ, and the line current of the machine

b) If the field current of the machine is reduced by 10%, while the mechanical power input to the machine is maintained constant, determine the new value of δ and the reactive power delivered to the system.

c) The prime mover power is next adjusted without changing the excitation so that the machine delivers zero reactive power to the system. Determine the new power angle δ and the real power being delivered to the system.

d) What is the maximum reactive power that the machine can deliver if the level of excitation is maintained as in parts (b) and (c)?

Draw a phasor diagram for the operation of the machine in parts (a), (b), and (c).

[Ans: $\boldsymbol{E_i\angle\delta = 26.0\angle 25.7^0\ kV, I_a = 0.5334\ pu; 28.76^0, 39.2\ Mvar;}$ $\boldsymbol{50.15^0, 127.65\ MW;\ 59.74\ Mvar}$**]**

Q6. The single line diagram of an unloaded power system is shown in Fig.1. Reactances of the two sections of the transmission line are shown on the diagram. The generators and transformers are rated as follows:

Generator 1: $20\ MVA, 13.8\ kV, X_d'' = 0.20\ pu$

Generator 2: $30\ MVA, 18\ kV, X_d'' = 0.20\ pu$

Generator 3: $30\ MVA, 20\ kV, X_d'' = 0.20\ pu$

Transformer $\boldsymbol{T_1}$: $25\ MVA,\ 220Y\ /13.8\Delta\ kV, X = 10\%$

Transformer T2: single-phase units, each rated $10\ MVA, 127/18\ kV, X = 10\%$

Transformer T3: $35\ MVA, 220Y/22Y\ kV, X = 10\%$

a) Draw the impedance diagram with all reactances marked in per unit and with letters to indicate points corresponding to the single line diagram. Choose a base of $50\ MVA, 13.8\ kV$ in the circuit of generator 1.

b) Suppose that the system is unloaded and that the voltage throughout the system is $1.0\ pu$ and bases chosen in part a. If a three-phase short circuit fault occurs from bus C to ground, find the phasor value of the short circuit current (in amperes) if each generator is represented by its sub transient reactance.

c) Find the mega voltamperes supplied by each generator under the conditions of part (b).

[Ans: $\boldsymbol{|I_f| = 699\ A;\ |S_1| = 63.9\ MVA, |S_2| = 82.9\ MVA, |S_3| = 119.6\ MVA}$**]**

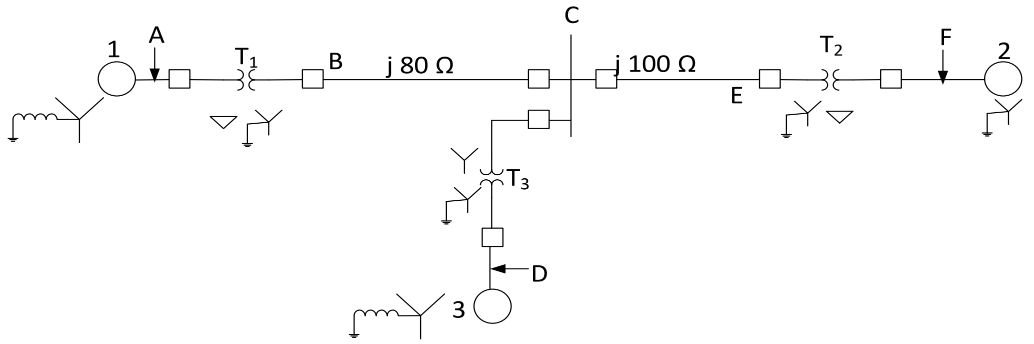

Fig. 1

Q7.**(a)** A three phase, 50 Hz overhead transmission line 100 km long with 132 kV between lines at the receiving end has the following constants:

Resistance per km per phase = 0.15 ohm

Inductance per km per phase = 1.20 mH

Capacitance per km per phase = 0.0084 μF

Determine, using nominal T method, the voltage, current and power factor of the sending end when the load at the receiving end is 70 MW at 0.8 power factor lag.

[Ans: $\boldsymbol{I_s = 369.06\ \angle{-34.24^0}\ A, V_{s-ph} = 89412.65\angle 5.28^0\ V, 0.741\ lagging}$**]**

(b) A 50 Hz, 3-phase transmission line is 200 km long. It has a total series impedance of $35 + j140\ \Omega$ and a shunt admittance of $930 \times 10^{-6}\ \angle 90^0$. It delivers 40 MW power at 220 kV with 0.9 power factor lagging. Find the magnitude of the sending end voltage. Consider nominal-π model of the line.

[Ans: $\boldsymbol{V_{s-ph} = 130.439\angle 1.97^0\ kV}$**]**

Q8.**(a)** There are six conductors in a double circuit transmission line. Each conductor has a radius of 12 mm. The six conductors are arranged horizontally. The centre to centre distance of conductors are from left to right as follows: a, b, c, a', b', c'. Calculate the inductance per km per phase of this system.

$[\boldsymbol{Ans}: \mathbf{0.5186\ } \boldsymbol{mH/km/phase}]$

(b) A 3-phase double circuit line is arranged as shown in Fig.2. The conductors are transposed. The radius of each conductor is 0.75 cm. Phase sequence is ABC. Find the inductance per phase per km.

$[\boldsymbol{Ans}: \mathbf{0.622\ } \boldsymbol{mH/km/phase}]$

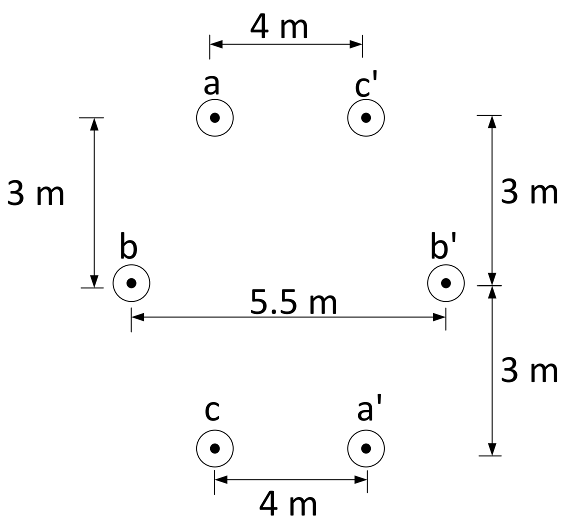

Fig. 2

Q9. A single-phase distributor has loop resistance of 0.3Ω and a reactance of 0.4Ω. The far end of the distributor has a load current of $80A$ and power factor of $0.8\ lagging\ at\ 220V$. The mid-point M of the distributor has a load current of $50A$ at a power factor of $0.707\ lagging$ with reference to voltage M. Calculate the sending end voltage and power factor.

$[\boldsymbol{Ans}: \boldsymbol{V_s = 271.04\angle 2.78^0\ V, 0.74\ lag}]$

Q10. A three-phase 60 Hz line has flat horizontal spacing. The conductors have an outside diameter of 3.28 $cm\ with$ 12 m between conductors. Determine the capacitive reactance to neutral in ohm-meters and the capacitive reactance of the line in ohms if its length is 125 mi. Also calculate the ground effect on these values by assuming that the conductors are horizontally placed 20 m above ground.

$[\boldsymbol{Ans}: \boldsymbol{X_c = 3.256 \times 10^8}\ \Omega.\boldsymbol{m}, \boldsymbol{X_c = 1619}\ \Omega;\ \boldsymbol{X_c = 3.218 \times 10^8}\ \Omega.\boldsymbol{m}, \boldsymbol{X_c = 1.6k}\Omega]$

Q11. A 2300 $V, 3-phase$ synchronous motor driving a pump is provided with a line ammeter and a field rheostat. When the rheostat is adjusted such that the ac line current is minimum, the ammeter reads 8.8 A. What is the power being delivered to the pump, neglecting losses? How should the rheostat be adjusted so that the motor operates at 0.8 $lead\ p.f.$? How many kvar's is the motor supplying to the system at this new power factor?

[Ans: 35.05 kW, 26.292 kVAR]

Q12. A three-phase, three winding $\Delta/\Delta/Y$ (1.1 kV/6.6 kV/400 V) transformer is energized from AC mains at the 1.1 kV side. It supplies 900 kVA load at 0.8 power factor lag from the 6.6 kV winding and 300 kVA load at 0.6 power factor lag from the 400 V winding. Determine the RMS line current in ampere drawn by the 1.1 kV winding from the mains.

[Ans: 620 to 630 A]

Q13. Fig.3 shows the one-line diagram of a simple three-bus power system with generation at bus 1. The magnitude of voltage at bus 1 is adjusted to 1.05 pu. The scheduled loads at buses 2 and 3 are as marked on the diagram. Line impedances are marked in per unit on a 100 MVA base and the line charging susceptances are neglected.

a) Using the Gauss-Seidel method, determine the phasor values of the voltage at the load buses 2 and 3 (P-Q buses) accurate to four decimal places.
b) Find the slack bus real and reactive power.
c) Determine the line flows and line losses. Construct a power flow diagram showing the direction of the line flow.

$[\boldsymbol{Ans}: \boldsymbol{V_2 = 0.98183\angle{-3.5035^0}\ pu}, \boldsymbol{V_3 = 1.00125\angle{-2.8624^0}\ pu};$
$\boldsymbol{P_1 = 409.5\ MW}, \boldsymbol{Q_1 = 189Mvar};$
Line losses are $\boldsymbol{S_{L\,12} = 8.5\ MW + j17\ Mvar}, \boldsymbol{S_{L\,13} = 5.0\ MW + j15\ Mvar},$
$\boldsymbol{S_{L\,23} = 0.8\ MW + j1.6\ Mvar}]$

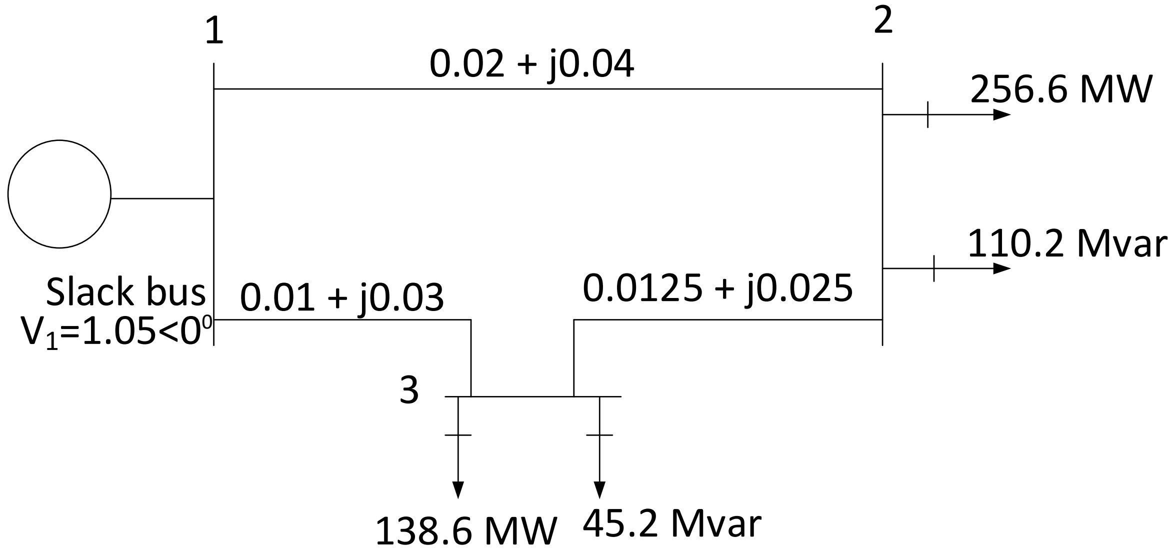
1
2
0.02 + j0.04
256.6 MW
110.2 Mvar
Slack bus
$V_1 = 1.05\angle 0^0$
0.01 + j0.03
0.0125 + j0.025
3
138.6 MW
45.2 Mvar

Fig. 3