Electrical Engineering - Optional For IAS (UPSC)

Power Systems - 2015-2021

UPSC – ELECTRICAL Engineering optional – 2015 Questions

1. A transmission line of inductance 0.1 H and resistance of 5 ohms is applied with a voltage $v = 100\sin(\omega t + \alpha)$, α represents the instant on voltage wave when short circuit occurs. What should be the instant of short circuit so that DC offset current is (i) zero and (ii) maximum? Assume supply frequency as 50 Hz. **[10M]**

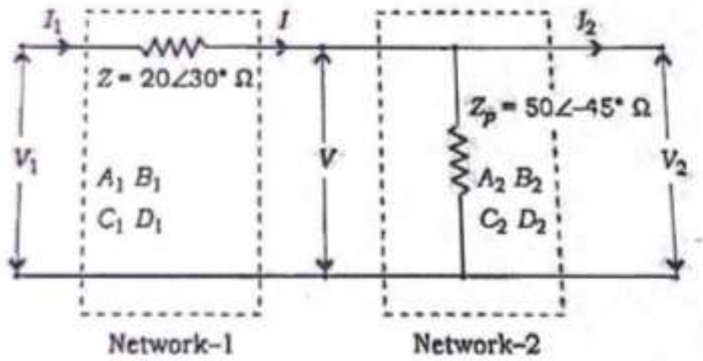
2. An 11 kV, 50 MVA, 3-phase solidly grounded generator has fault currents at its terminals for different types of faults as follows:

$I_{LLL} = 1870$ A
$I_{LL} = 2590$ A
$I_{LG} = 4130$ A

Determine $p.u.$ values of sequence reactances of the generator. **[10M]**

3. A synchronous generator is feeding 250 MW to a large 50 Hz power system network over a double-circuit line. The maximum steady-state power that can be transmitted over line with both the circuits in operation is 500 MW and is 350 MW with one circuit in operation. A solid 3-phase fault occurring at network end of one of the lines causes it to trip. Estimate critical clearing angle in which circuit breaker must trip so that synchronism is not lost. What further information is needed to estimate critical clearing time? **[20M]**

4. (i)Determine the equivalent ABCD constants of Network-1 connected in tandem with Network-2 as shown in the figure given below: **[10M]**



(ii) A transmission line has its electrical length of 5 electrical degrees. Find its physical length. The frequency of supply is 50 Hz. Express the physical length in terms of wavelength of the line. **[10M]**

5. A system consists of two plants (plants 1 and 2) connected by a tie-line and load is located at plant 2. When 100 MW is transmitted from plant 1, a loss of 10 MW takes place on the tie-line. Determine the generation schedule at both the plants and the power received by the load when λ for the system is ₹ 25 per MW-hr and fuel inputs to the two plants are given by

$F_1 = 0.015{P_1}^2 + 17P_1 + 50$₹ **/hr**

$F_2 = 0.03{P_2}^2 + 19P_2 + 30$₹ **/hr** **[20M]**

UPSC – ELECTRICAL Engineering optional – 2016 Questions

1. Two sub-stations are connected by two lines in parallel with negligible impedance, but each containing a tap-changing transformer of reactance 0.18 p.u. on the basis of its rating of 200 MVA. Find the net absorption of respective power when the transformer taps set to $1{:}\,11$ and $1{:}\,0.9$ respectively. Assume p.u. voltage to be equal at the two ends and also at the sub-stations. **[10M]**

2. A system consists of two plants connected by a transmission line and a load at power plant 2 as shown in Figure 2(b). Data for the loss equation consists of the information that 200 MW transmitted from plant 1 to the load results in a transmission loss of 20 MW. Find the optimum generation schedule considering transmission losses to supply a load of 204.41 MW. Also evaluate the amount of financial loss that may be incurred if at the time of scheduling transmission losses are not co-ordinated. Assume that the incremental fuel cost characteristics of plant 1 and plant 2 are given by **[20M]**

$$\frac{dF_1}{dP_{G_1}} = 0.025P_{G_1} + 14 \text{ ₹}/MWh$$

$$\frac{dF_2}{dP_{G_2}} = 0.025P_{G_2} + 16 \text{ ₹}/MWh$$

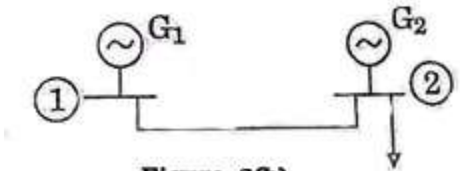


Figure. 2(b)

3. A three-phase generator rated 11 kV, 20 MVA has a solidly grounded neutral. Its positive, negative and zero sequence reactances are 60%, 25% and 15% respectively.

(i) Calculate the value of reactance that should be placed in the generator neutral such that the current for single line-to-ground fault does not exceed the rated current.

(ii) What value of the resistance in the neutral will serve the same purpose? **[20M]**

4. Form [B′] and [B′′] matrices used in Fast Decoupled Load Flow (FDLF) for the power system shown in Figure 5(b) and line date given in Table I. **[20M]**

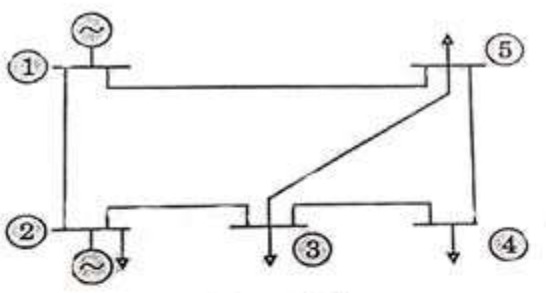


Figure 5(b)

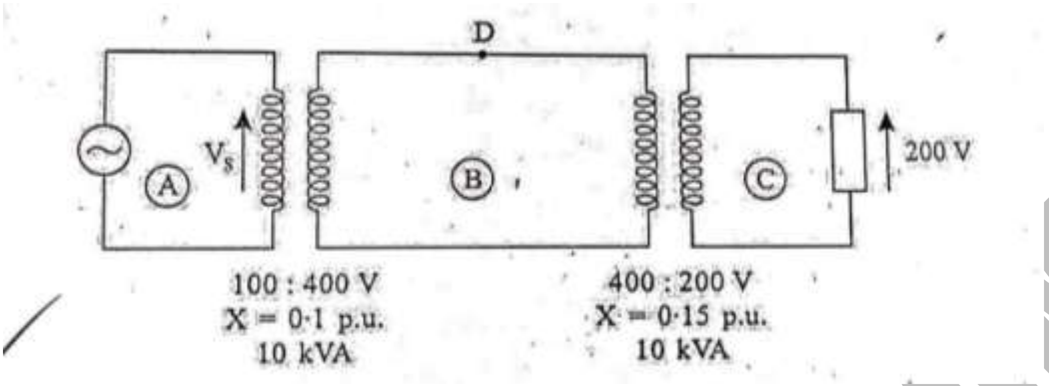
Bus Code (i - j)	Impedance (z_{ij}) (in p.u.)	Half-line Charging Admittance (in p.u.)
1-2	(0.02 + j 0.04)	j 0.020
2-3	(0.04 + j 0.20)	j 0.020
3-5	(0.15 + j 0.40)	j 0.025
3-4	(0.02 + j 0.06)	j 0.010
4-5	(0.02+ j 0.04)	j 0.010
1-5	(0.08+ j 0.20)	j 0.020

Table I: Line data

5. What is Load Flow solution ? What do you understand by (i) Adjustable Load Flow, and (ii) Unadjustable Load Flow? Which method will provide the accurate solution? **[10M]**

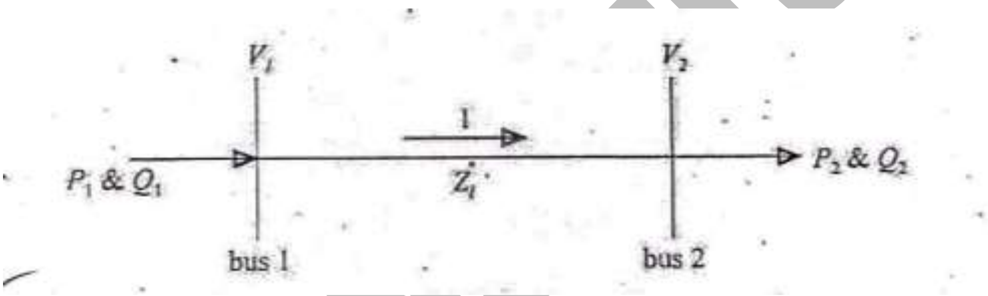
UPSC – ELECTRICAL Engineering optional – 2017 Questions

1.



In a system shown in the above figure, two single phase transformers supply a 10 kVA resistance load at 200 V. Show that the p.u. load is the same for each part of the circuit (like part A, B and C) and calculate the voltage at point D. **[15M]**

2.



In the above figure, $V_1 = 1\angle 0°$,$Z_1 = (0.05 + j0.02)pu$ and $P_2 + jQ_2 = (1.0 + j\ 0.6)pu$. Using load flow study iteratively compute V_2 and $P_1 + jQ_1$. Also determine the reactive power that must be injected to bus 2 to maintain $|V_1| = |V_2| = 1.0\ pu$. **[20M]**

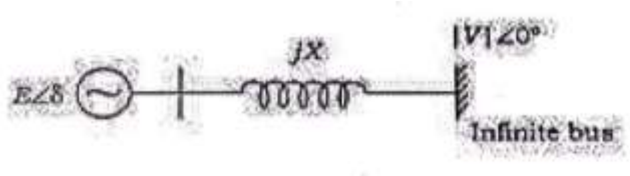
4. Derive an expression for the critical clearing angle for a power system consisting of a single machine supplying to an infinite bus, for a sudden load increment. **[20M]**

6. For a certain lagging power factor load, the sending end and receiving end voltage of a short transmission line of impedance $R + jX$ are equal. Prove that $\frac{X}{R}$ ratio is $\sqrt{3}$ for maximum power transmitted over the line under steady state condition. **[15M]**

7. A synchronous generator and motor are rated 30,000 kVA, 13.2 kV, and both have subtransient reactances of 20%. The line connecting them has a reactance of 10% on the base of the machine ratings. The motor is drawing 20,000 KW at 0.8 power factor leading and a terminal voltage of 12.8 kV when a symmetrical three phase fault occurs at the motor terminal. Find the subtransient currents (i) in the generator, (ii) in the motor and (iii) in the fault by using the internal voltages of the machines. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2018 Questions

1. A generator is connected to an infinite bus are shown in the figure. Derive the expressions for real power and reactive power supplied by the generator to the infinite bus: **[10M]**

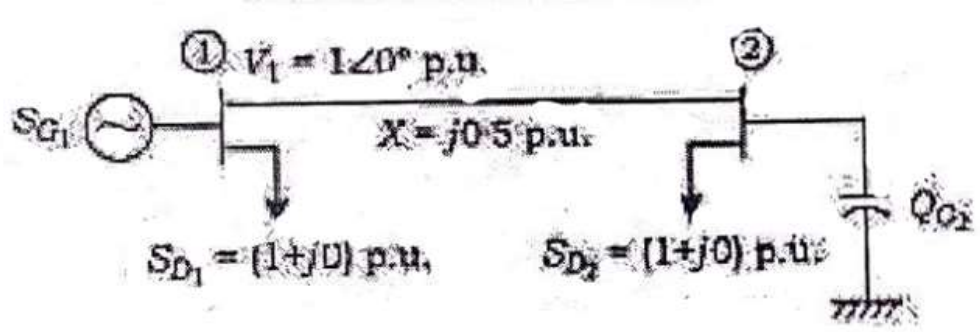


2. A 3-phase, 11 kV transmission line delivers a load of 2395 kVA at 0.8 p.f. (lag) over a distance of 25 km. The transmission line has an impedance per phase of $(3.25 + j7.55)ohms$. Determine the sending-end voltage and sending-end power factor. **[20M]**

3. An 11 kv, 100 MVA alternator is provided with differential protection. The percentage of winding to be protected against phase-to-ground fault is 85%. The relay is set to operate when there is 20% out of balance current. Determine the value of the resistance to be placed in the neutral-to-ground connection. **[10M]**

4. A three-phase power system consists of a synchronous machine connected through a lossless transmission line to an infinite bus. A fault occurs on the transmission line. The maximum power transfer of this system when there is no fault is 5 p.u. and the power transfer is 2.5 p.u. The power angle curves during the fault and post-fault conditions have peak values of 2 p.u. and 4 p.u. respectively. Determine the permissible increase in the angular displacement between the voltages at the two ends of the system beyond which the circuit breakers could not clear the fault in time for the system to remain in synchronism. **[20M]**

5. For the system shown in the figure, S_{D_1} and S_{D_2} are complex power demands at bus-1 and bus -2 respectively. If $|V_2| = 1$ p.u., compute VAR rating of the capacitor (Q_{G_2}) connected at bus-2 in MVAr : **[10M]**



6. A three-phase generator rated 11 kV, 20 MVA has a solidly grounded neutral. Its positive, negative and zero sequence reactances are 60%, 25% and 15% respectively. Calculate the value of the reactance that should be placed in generator neutral such that the current for single line-to-ground fault does not exceed the rated current. **[10M]**

7. Two substations are connected by two lines in parallel with negligible impedance, but each containing a tap-changing transformer of reactance 0.18 p.u. on the basis of its rating of 200 MVA. Find the net absorption of reactive power in MVAr when the transformer taps are set to $(1:1.1)$ and $(1:0.9)$ respectively. Assume per unit voltages to be equal at two ends of the substation. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2019 Questions

1. An 11 kV single-core cable has a conductor radius of 8.8 mm and an insulation thickness of 4.6 mm. Find the maximum and minimum electric stress. **[10M]**

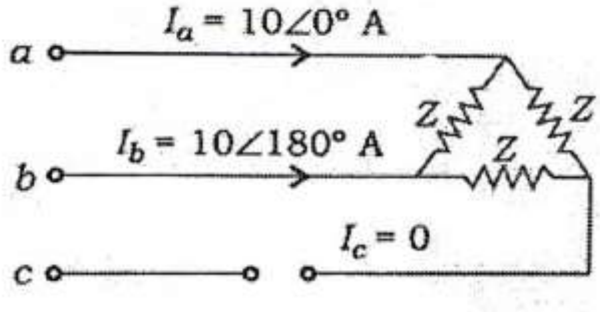
2. A system consists of two plants connected by a transmission line and a load that is located at plant 2. Data for the loss equation consists of the information that 100 MW transmitted from plant 1 to the load results in a loss of 10 MW. Find the required generation from each plant and power received by the load when λ for the system is ₹ 2.5 per megawatt-hour. Assume that the incremental fuel costs can be given by the following equations:

$$\frac{dF_1}{dP_1} = 0.003\,P_1 + 1.7 \ \text{₹/MWh}$$

$$\frac{dF_2}{dP_2} = 0.006\,P_2 + 1.9 \ \text{₹/MWh}$$ **[20M]**

3. Describe briefly various kinds of DC links used in HVDC transmission. **[10M]**

5. One conductor of a three-phase line is open. The current flowing to the Δ-connected load through line a is 10 A.



With the current in line a as reference and assuming that line c is open, find the symmetrical components of the line currents. **[10M]**

6. A three-phase generator delivers $1.0\ \text{p.u.}$ power to an infinite bus through a transmission network when a fault occurs. The maximum power which can be transferred in pre-fault, during fault and post-fault conditions are $1.75\ \text{p.u.}, 0.4\ \text{p.u.}$ and $1.25\ \text{p.u.}$ respectively. Find the critical clearing angle. **[20M]**

7. The primitive impedance matrix of a power system network is given below:

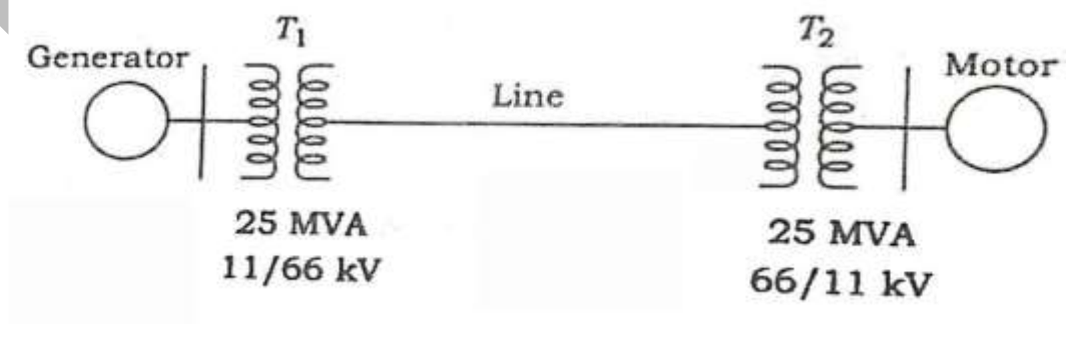
e \ e	1	2	3	4	5
1	0.6	0.1	0	0.2	0
2	0.1	0.5	0	0	0
3	0	0	0.5	0	0
4	0.2	0	0	0.4	0
5	0	0	0	0	0.2

Find its primitive admittance matrix. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2020 Questions

1. Find the steady-state power limit of a system consisting of a generator with equivalent reactance $0.50\ \text{p.u.}$ connected to an infinite bus through a series reactance of $1.0\ \text{p.u.}$ The terminal voltage of the generator is held at $1.20\ \text{p.u.}$ and the voltage of the generator is held at $1.20\ \text{p.u.}$ and the voltage of the infinite bus is $1.0\ \text{p.u.}$ **[10M]**

2. A synchronous generator and a synchronous motor each rated 25 MVA, 11 kV having 15% subtransient reactance are connected through transformers and a line as shown in the figure below. The transformers are rated 25 MVA, 11/66 kV and 66/11 kV with leakage reactance of 10% each. The line has a leakage reactance of 10% on a base of 25 MVA, 66 kV. The motor is drawing 15 MW at 0.8 power leading and a terminal voltage of 10.6 kV when a symmetrical 3-phase fault occurs at the motor terminals. Find the subtransient current in the generator, motor and fault. **[20M]**



3. A synchronous generator of reactance $1.20\,\text{p.u.}$ is connected to an infinite bus bar $(|V| = 1.0\,\text{p.u.})$ through transformers and a line of total reactance of $0.60\,\text{p.u.}$The generator no-load voltage is $1.20\,\text{p.u.}$ and its inertia constant is $H = 4\text{ MW } s/\text{MVA}$. The system frequency is 50 Hz. Calculate the frequency of natural oscillations if the generator is loaded to 80% of its maximum power limit. **[10M]**

4. Show that the fault current for a single line to ground fault at the terminals of an alternator with solidly grounded neutral is more than that for symmetrical three-phase short circuit. The alternator has sequence reactances X_1, X_2 and X_0 such that $X_1 = X_2 \gg X_0$. **[10M]**

5. (i) What are the advantage of per unit representation?

(ii) Using the nominal π method, find the sending-end voltage and voltage regulation of a 250 km, 3-phase, 50 Hz transmission line delivering 25 MVA at 0.8 lagging power factor to a balanced load at 132 kV. The line conductors are spaced equilaterally 3 m apart. The conductor resistance is $0.11\ \Omega/\text{km}$ and its effective diameter is 1.6 cm. Neglect leakance. **[20M]**

6. (i) What informations are obtained from load flow analysis? Explain the necessity of load flow studies.

(ii) Explain the advantages of using bus admittance matrix, Y_{bus} in load flow analysis.

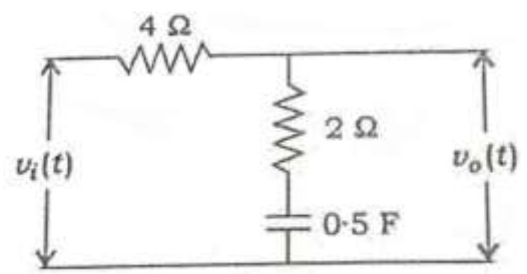
(iii) A power system has two generating plants and the power is being dispatched economically with $P_1 = 150$ MW and $P_2 = 275$ MW. The loss coefficient's are

$$B_{11} = 0.10 \times 10^{-2}\ \text{MW}^{-1}$$
$$B_{12} = -0.10 \times 10^{-3}\ \text{MW}^{-1}$$
$$B_{22} = 0.13 \times 10^{-2}\ \text{MW}^{-1}$$

To raise the total load on the system by 1 MW will cost an additional ₹200 per hour. Find the penalty factor for Plant 1 and the additional cost per hour to increase the output of Plant 1 by 1 MW. **[20M]**

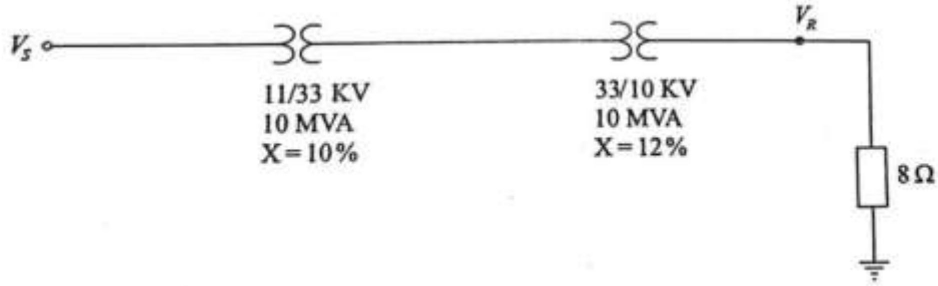
7. A sinusoidal voltage $v_i(t)$ is applied to the lag network shown in the figure below. $v_i(t)$ is adjusted to produce a sinusoidal steady-state output voltage

$v_0(t) = 2\sin(\omega t + 45°)$ volts. If $\omega = 1\ \text{rad/sec}$, determine the input voltage $v_i(t)$. **[10M]**

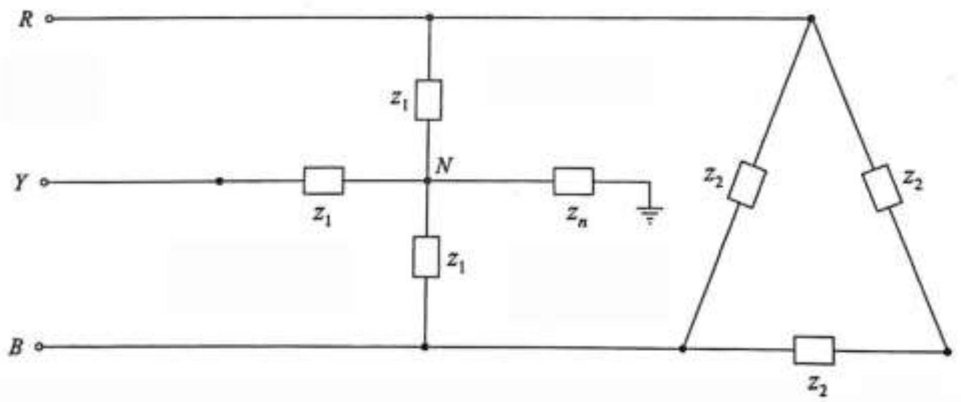


UPSC – ELECTRICAL Engineering optional – 2021 Questions

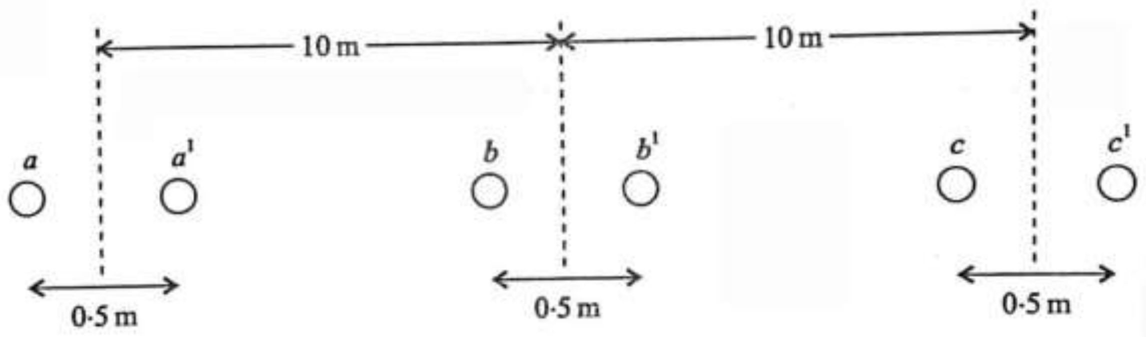
1. A single phase, single line diagram of a power system is shown in figure. Find the sending end voltage and the value of load resistance in p. u. referred to sending end if the voltage across load resistance is 9.8 KV. **[10M]**



2. Draw the sequence networks and calculate the load sequence impedances of a load circuit as shown in figure. The load circuit is connected to a balanced three phase supply. The value of z_1, z_2 and z_n are $(4 + j6)\Omega, -j45\Omega$ *and* $j4\ \Omega$. **[20M]**

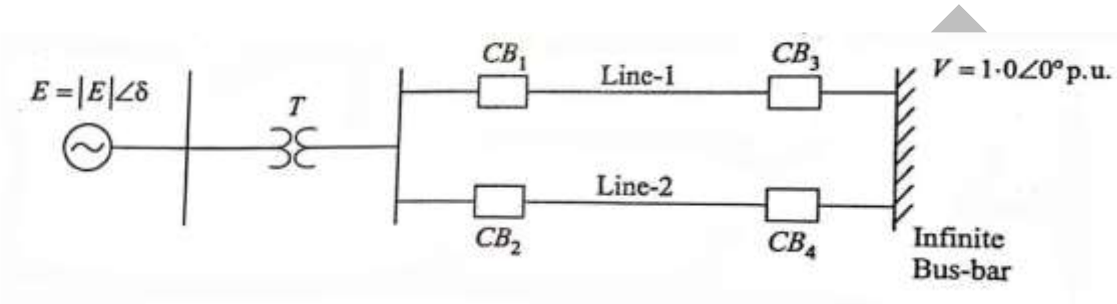


3. The configuration of a 400 KV 3 phase line is shown in figure. The radius of each sub-conductor is 2 cm. Calculate the charging mega volt-amperes if line is operating at 50 Hz and has a length of 300 km. **[10M]**

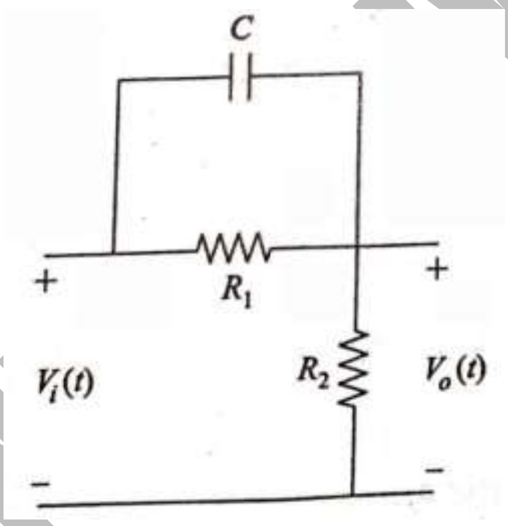


4. Calculate the most economical overall diameter of insulation of a cable to be operated at 400 KV, 3 phase power system if maximum stress is limited to 100 KV/cm. **[10M]**

5. A synchronous machine is connected to an infinite bus through a transformer and a double circuit line as shown in figure. The infinite bus voltage is $V = 1.0\,\angle 0°\ \mathrm{p.u.}$ The direct axis transient reactance of the machine is $0.20\ \mathrm{p.u.}$, the transformer reactance is $0.10\ \mathrm{p.u.}$ and the reactance of each of the transmission lines is $0.4\ \mathrm{p.u.}$ all the values are to a base of the rating of the synchronous machine. Initially, the machine is delivering $0.8\ \mathrm{p.u.}$ power with a terminal voltage $|V_t| = 1.05\ \mathrm{p.u.}$ The inertia constant $H = 5\ \mathrm{MJ/MVA}$. All resistances are neglected. Determine the equation of motion of the machine rotor. **[20M]**



6. A sinusoidal voltage of $10\ \mathrm{V}$ amplitude at $100\ \mathrm{Hz}$ is applied to a lead network shown in figure. The phase difference between the input voltage $V_i(t)$ and output voltage $V_o(t)$ is $44.43°$. If $C = 0.1\ \mu F$ and $R_1 = 100\ k\Omega$, determine the value of R_2 and the magnitude of steady state output voltage **[20M]**



7. For a 3-bus power system, assume **[10M]**

Voltage at bus $-$ 1 : $V_1 = (1.05 + j\,0)$pu

Voltage at bus $-$ 2 : $V_2 = (0.9812 - j\,0.0522)$pu and

Voltage at bus $-$ 3 : $V_3 = (0.999 - j\,0.0468)$ pu.

The line impedances are shown below:

Bus code	*Impedances (in p.u.)*
$1-2$	$(0.02 + j\,0.04)$
$1-3$	$(0.01 + j\,0.03)$
$2-3$	$(0.0125 + j\,0.025)$

Compute Real and Reactive power loss in all the lines and also compute total system loss.