Engineering Services (Main)
Examination, 2026

SNCS–T–ELEE

ELECTRICAL ENGINEERING

PAPER—II

Time Allowed : Three Hours	Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are **EIGHT** questions divided in **TWO** Sections.

Candidate has to attempt **FIVE** questions in all.

Question Nos. **1** and **5** are **compulsory** and out of the remaining, **THREE** are to be attempted choosing at least **ONE** question from each Section.

The number of marks carried by a question/part is indicated against it.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly.

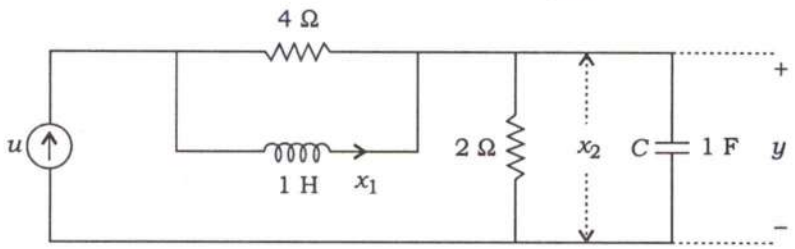
Any page or portion of the page left blank in the Question-cum-Answer (QCA) Booklet must be clearly struck off.

Answers must be written in **ENGLISH** only.

SECTION—A

1. *(a)* In an 8085 microprocessor, 16 binary numbers are stored at memory locations from address F040 to F04F. Write 8085 assembly language program to divide these numbers by two and rearrange them in descending order. 12

(b) In the circuit shown in the figure below, u is a current source and y is the voltage across the capacitor C. Check the observability of the circuit. Give a physical interpretation of the result directly from the circuit.

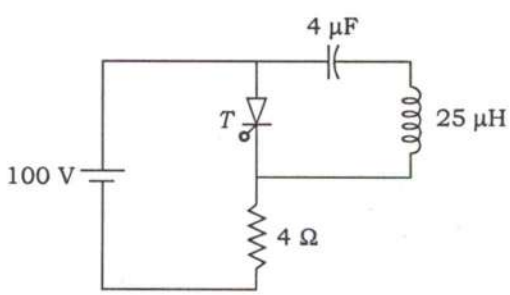


12

(c) A 240 V/110 V, single-phase transformer is undergoing open-circuit test with supply connected to LV side. For a supply voltage of 110 V at 50 Hz, the input power and current are 150 W and 5·0 A respectively. It takes input power of 60 W when the supply voltage is 55 V at 25 Hz. Find the input power, input current and input power factor when the supply voltage is 77 V at 35 Hz. Neglect HV and LV side resistance and leakage reactances, core saturation. Also assume sinusoidal supply voltage. 12

(d) A porcelain bushing is having $\varepsilon_r = 4$. The internal and external diameters of the bushing are 2·8 cm and 8 cm respectively. A conductor with 2·2 cm diameter is passed centrally through this bushing. The voltage between the conductor and an earthed clamp surrounding the porcelain is 21 kV r.m.s. Find whether corona will be present in the air space round the conductor. 12

(e) The circuit given in the figure below reaches steady state when thyristor T is in off condition. At $t = 0$, the thyristor is triggered. Assuming the latching and holding current for the thyristor to be zero, find *(i)* the thyristor peak current, *(ii)* the time duration for which the thyristor will remain on after it is turned on and *(iii)* the minimum value of capacitance and the corresponding thyristor on-time, with other parameters of the circuit unaltered, for successful turnoff of the thyristor after it is turned on.



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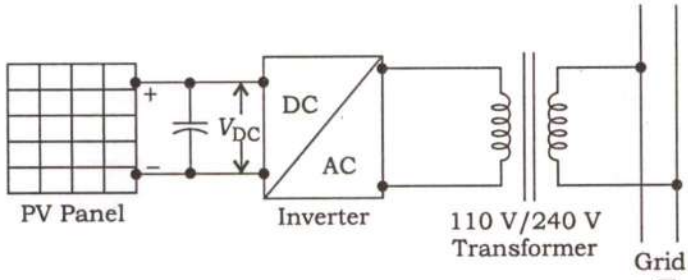
2. *(a)* Prove that in a dual slope A/D converter, the count in the counter is direct numeric equivalent of the applied voltage, provided the known reference voltage $V_R = 2^N$, where N represents the number of bits in the binary counter. 20

(b) A 5 kVA, 110 V/240 V, single-phase transformer has its maximum efficiency of 95% at 80% of its load capacity at u.p.f. and has maximum voltage regulation of 0·08 p.u. It is used for interconnection of PV generated power to grid as per the diagram given in the figure below. The grid voltage is $V_g = 240\sqrt{2}\sin(314t)$ volts. The rated power of 5 kVA at u.p.f. is to be supplied to the grid. Determine *(i)* the r.m.s. value of transformer input voltage and *(ii)* the transformer input power and power factor.
(Assume constant transformer fixed losses and sinusoidal inverter output voltage)



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(c) *(i)* Prove the relation

$$\sum_{m=-\infty}^{+\infty} \delta(n+mN) = \frac{1}{N}\sum_{k=0}^{N-1} e^{j\left(\frac{2\pi}{N}\right)nk}$$

where n stands for discrete time instants and N is a finite non-negative and non-zero integer. 10

(ii) Design a second-order digital low-pass Butterworth filter that has a cutoff frequency of 10 rad/s and a passband gain of 1 dB, using bilinear transformation. Assume the highest significant frequency to be 2 Hz. 10

3. *(a)* A 4-pole DC series motor is lap-wound with 1200 conductors. The resistance of each conductor is 10 mΩ. It is driving a load for which the torque is proportional to the cube of the speed. It is running at 1000 r.p.m. for a supply voltage of 200 V, while taking a current of 20 A. Its field copper loss at this current is 100 W.

(i) Find the supply voltage to bring the motor speed down to half of its initial value.

(ii) Also find the value of the additional resistance that can be connected in series with the armature to bring the speed to half of its initial value without altering the supply voltage.

(iii) Calculate the values of total copper losses that will occur in steady state at half of the initial speed for the above two cases.

(Assume linear magnetic circuit) 20

(b) (i) The bandwidth and power content of a normalized modulating signal $m_n(t)$ are 5000 Hz and 0·7 W respectively. The power content of the sinusoidal carrier of f_0 Hz is 100 W. Calculate the bandwidth and power content of the modulated signal, if—

(1) $m_n(t)$ modulates carrier using SSB amplitude modulation;

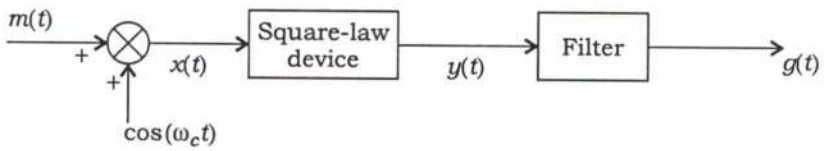
(2) $m_n(t)$ modulates carrier using DSB-SC type amplitude modulation;

(3) $m_n(t)$ modulates carrier using conventional amplitude modulation.

Also calculate the bandwidth and power content of the modulated signal, if the modulation is frequency modulation with $k_f = 20000$.

(Assume that the spectrum of $m_n(t)$ does not contain any impulses at the origin) 10

(ii) Consider a square-law AM modulator as shown in the figure below :



The square-law device has the transfer relation as $y(t) = 2x(t) + x^2(t)$. Assuming that the average value of the message signal $m(t)$ is zero, and the maximum value of $|m(t)|$ is M, answer the following :

(1) Give suitable expression for $y(t)$ and sketch its approximate spectrum.

(2) Determine the necessary filter type and its frequencies of interest (assume filter to be ideal one).

(3) What value of M will yield a modulation index of 0·8?

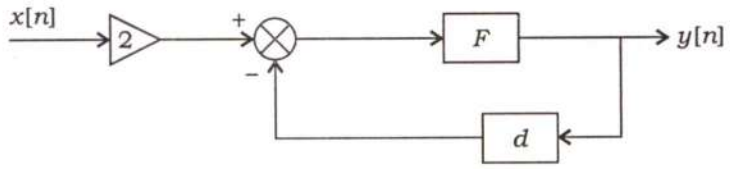
(Assume the bandwidth of the message signal $m(t)$ as ω_m) 10

(c) (i) Sketch the magnitude and angle of the Fourier transform of

$$x(t) = (1 - 2t)e^{-2t}u(t)$$

Use linear scale and clearly label the important magnitudes, angles and frequencies. 10

(ii) In the figure shown below, the system F is defined by the input-output relationship $F\{z[n]\} = z[n] - z[n-1]$, and d is the unit delay $d\{w[n]\} = w[n-1]$. Write down the linear difference equation describing the system.



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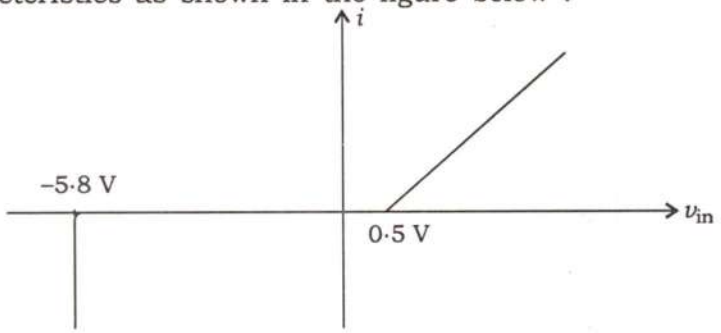
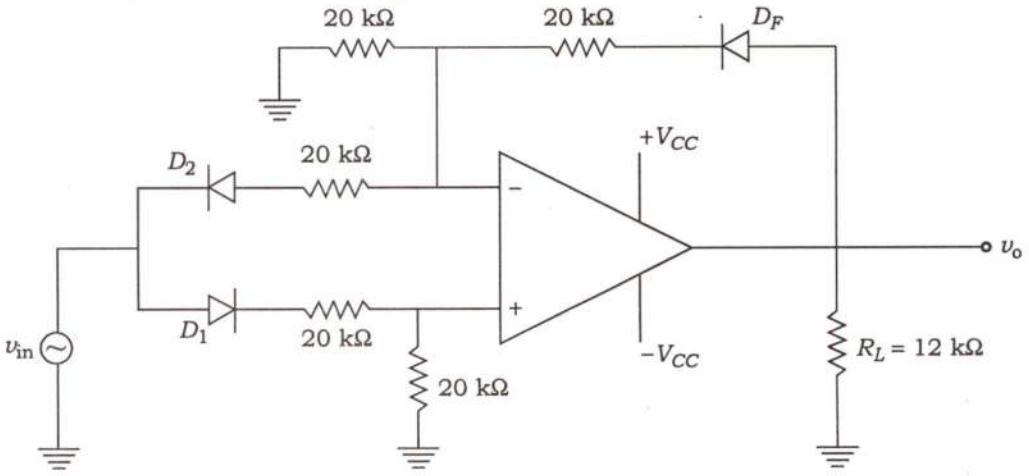
4. *(a)* (i) Give schematics and explain the working of a voltage limiter circuit that uses op-amp, resistors and certain non-linear semiconductor devices. The non-linear semiconductor devices involved have the following input-output characteristics as shown in the figure below :



Also sketch the output voltage waveform of the voltage limiter circuit when $v_{in} = 200$ mV peak-to-peak sinusoidal with frequency 50 Hz. The resistances used in the circuit may be assumed to be of the value 1 kΩ. (The op-amp(s) is/are supplied with ±14 V supply) 10

(ii) For the circuit shown below, find the analytical relation between the output v_o and the input v_{in} :



Also sketch the output voltage waveform for $v_o(t)$ when the input voltage is $v_{in} = 4\sin(100\pi t)$ volts. Also state which component(s) is/are responsible for compensating forward drops across D_1 and D_2. 10

(b) A 3-phase, 415 V, star-connected, 4-pole, 50 Hz, 1440 r.p.m. induction motor has the per phase parameters referred to stator at 50 Hz as $R_s = 1\,\Omega$, $R_r = 1 \cdot 5\,\Omega$, $X_{ls} = X_{lr} = 3 \cdot 0\,\Omega$. Magnetizing reactance and core loss resistances are so large that their effects on equivalent circuit can be neglected. The motor is driven via inverter in constant V/f mode which is kept at rated value.

(i) Find the frequency and voltage that can be applied by the inverter to obtain the maximum torque at starting.

(ii) Find the speed at which the motor will deliver its rated torque for the above applied voltage and frequency.

(Assume sinusoidal inverter supply voltage and neglect skin effect) 20

(c) (i) The A, B, C, D parameters of a 3-phase transmission line are

$A = D = 0 \cdot 94 + j0 \cdot 018$

$B = (34 + j142)\Omega$

$C = (-5 + j910) \times 10^{-6}$ ℧

The load at the receiving end is 60 MW at 220 kV with a power factor of 0·9 lagging. Find the magnitude of the sending-end voltage and voltage regulation.

(Assume that the magnitude of the sending-end voltage remains constant) 10

(ii) Find the characteristic impedance, surge impedance, propagation constant, attenuation constant and phase constant of a 3-phase, 50 Hz, 250 km transmission line with series impedance of $(0 \cdot 2 + j0 \cdot 4)$ ohm per km and a shunt admittance of $j5 \cdot 0 \times 10^{-6}$ mho per km. 10

SECTION—B

5. (a) A signal $f(t) = \text{sinc}(150\pi t)$ is sampled by a periodic pulse train $p_T(t)$. The output of the sampler is fed to an ideal low-pass filter of bandwidth B Hz and having unity gain. Sketch the spectrum of the input signal $f(t)$. Also sketch the spectrum of the filter output signal when—

(i) the sampling frequency is 160 Hz and the filter bandwidth $B = 80$ Hz;

(ii) the sampling frequency is still 160 Hz, but the filter bandwidth is increased to $B = 100$ Hz.

Further, comment on the reconstructibility of $f(t)$ from the filter output for each of the above cases. 12

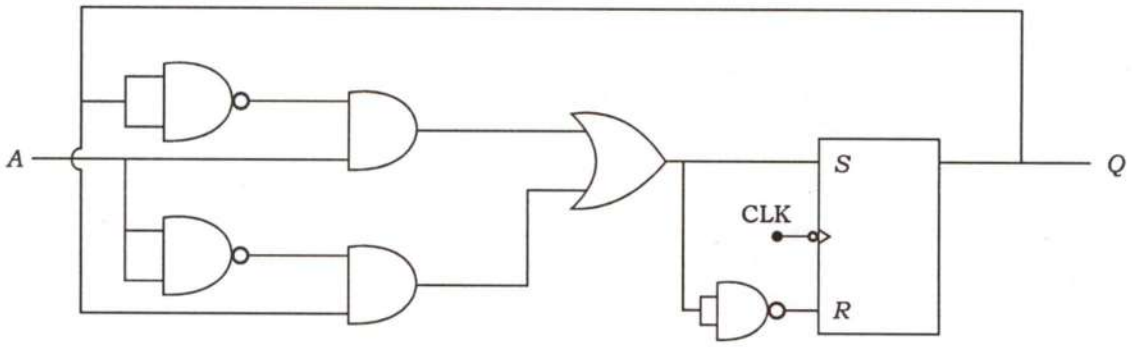
(b) Consider a linear system with the transfer function

$$G(s) = \frac{3 \cdot 5}{s^2 + 2s + 7}$$

If the system response at the steady state is $2 + 4\sin 3t + \sin 5t$, determine the input to the system. 12

(c) (i) A Boolean function f is expressed in terms of minterm expression as $f = \Sigma m(0, 1, 2, 5, 7, 9, 12, 15)$. Implement this function using 8×1 multiplexer and suitable gates. 6

(ii) Build the truth table for the following digital circuit :



Also find which type of flip-flop, the overall circuit acts like. 6

(d) The maximum demand of a generating station is 150 MW. The generating station has a load factor of 70%, a plant capacity factor of 50% and plant use factor of 72%. Determine (i) the installed capacity of the plant, (ii) the daily energy produced, (iii) the reserve capacity of the plant and (iv) the maximum energy that could be produced daily, if the plant is running at full load. 12

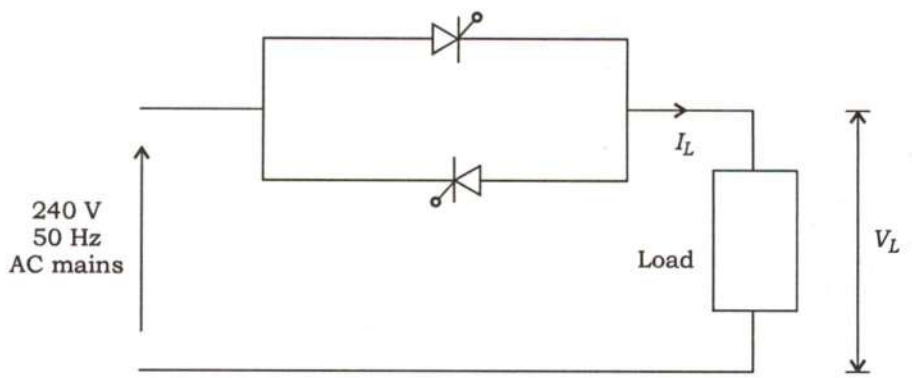
(e) An inductive load is connected with 240 V, 50 Hz, single-phase AC mains through back-to-back thyristors as shown in the figure below. The triggering angle for both the thyristors is 60°. The load current is discontinuous and continues up to 40° beyond voltage zero in each half-cycle. The load is consuming a power of 1250 W and has a resistance of 10 Ω.

(i) Sketch the load voltage and load current waveforms.

(ii) Find the input side p.f. at the AC mains.

(iii) Calculate the load r.m.s. voltage.

(Assume ideal thyristors with zero voltage drop during conduction)



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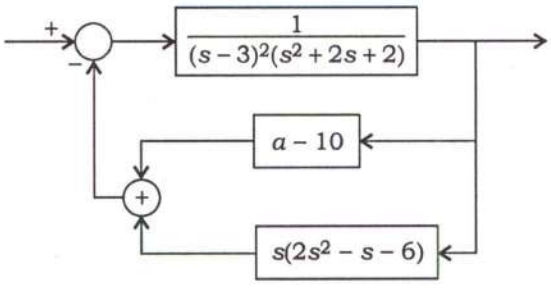
6. *(a)* *(i)* A 3-phase, 50 MVA, 400/40 kV transformer is star-delta connected. Select the standard CT ratios on the two sides of the transformer for percentage differential protection of the transformer. Would an auto-transformer be required? If so, what should be its current ratio? 10

(ii) An alternator of rating 20 MVA, 13·2 kV, star-connected is protected by an earth fault relay having 20% setting. If the neutral resistance limits the maximum earth fault current to about 40% of the full-load current, determine the percentage of the winding protected. 10

(b) The open-loop transfer function of the feedback system shown in the figure below has a double pole at $s = -2$. Draw the complete root locus of the system when a is varied from 0 to $-\infty$.



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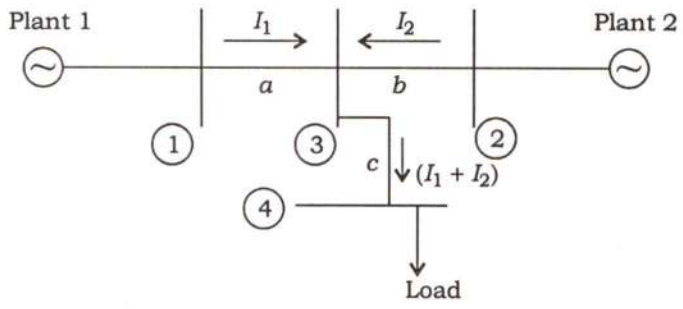
(c) A single-phase fully controlled rectifier is driving an inductive load so that the load current is flat at 100 A value. The load is consuming a power of 10 kW. The converter is fed from a 240 V, 50 Hz, single-phase AC source through a connecting cable which has a resistance of 0·25 Ω/phase with negligible inductance. Find *(i)* the converter output voltage, converter triggering angle and *(ii)* the AC source side input power and input power factor. Neglect any resistance and inductance of the connecting cable between the rectifier and load. Also ignore any phase angle of rectifier input current for calculation purpose. 20

7. *(a)* The open-loop transfer function of a unity feedback system is given by

$$G(s) = \frac{K(2s-3)}{(s+8)(s^2-2s+3)}$$

Use Nyquist stability criterion to determine the range of K for closed-loop stability. 20

(b) A system consists of two generating plants and one load whose single-line diagram is shown in the figure below :



If the voltage at bus 3 is $V_3 = 1 \cdot 0 \angle 0°$ p.u., $I_1 = 0 \cdot 9 \angle 0°$ p.u. and $I_2 = 0 \cdot 75 \angle 0°$ p.u., find the loss coefficients and transmission loss. The line impedances are $0 \cdot 02 + j0 \cdot 08$ p.u., $0 \cdot 03 + j0 \cdot 12$ p.u. and $0 \cdot 01 + j0 \cdot 04$ p.u. for *a*, *b* and *c* sections respectively. Also derive the formula used for transmission loss calculation. 20

(c) A 6·6 kV, star-connected, three-phase, salient-pole alternator has per phase values of $X_d = 4 \cdot 5\,\Omega$, $X_q = 1 \cdot 5\,\Omega$ and negligible armature resistance.

(i) Find its excitation voltage (L-L) when it is delivering a power of 2·5 MW at u.p.f., at rated voltage.

(ii) Also find the maximum power it can deliver with same excitation, the corresponding load angle, armature current and power factor.

(iii) Find the power it can deliver when its excitation is lost due to field fault while delivering its maximum power. 20

8. (a) The armature of a 10 kW, 400 V, 1250 r.p.m. DC separately excited motor is supplied from a 3-phase half-controlled converter with freewheeling diode. The input voltage to the converter is 280 V (L-L), 3-phase, 50 Hz. The motor has rated copper loss of 250 W. The motor is to be driven at 950 r.p.m. taking a flat and ripple-free load current of 15 A.

(i) Find the converter triggering angle, input power and power factor at the AC side.

(ii) Now if one of the supply phases gets open circuited due to fault and subsequently the converter triggering angle is adjusted to 45° for the remaining phases, find the new speed of the motor, input power and p.f. at the AC side, if the load current is to remain same at 15 A as before.

(Assume ideal switches and no cable resistance) 20

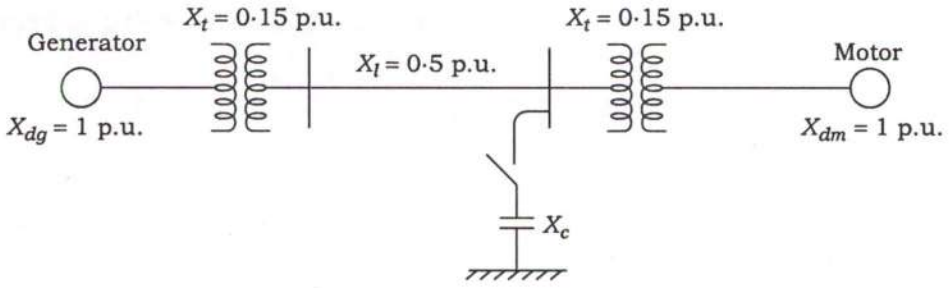
(b) (i) The capacitances of a 3-core belted cable are measured and found to be as follows :

(1) Between 3 cores bunched together and the sheath 18 μF

(2). Between conductor and other two connected together to the sheath 6 μF

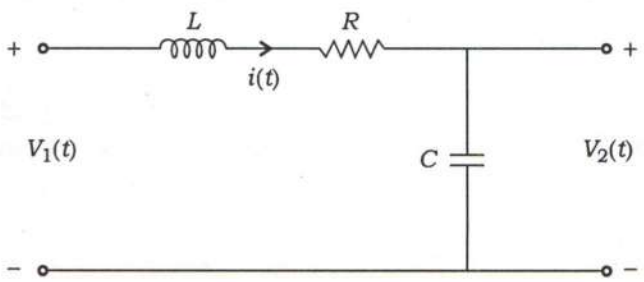
Calculate the capacitance to neutral and the total charging kVA when the cable is connected to a 3-ϕ, 50 Hz, 33 kV supply. Derive any formula used for the above capacitance calculation. 10

(ii) In the power system shown in the figure below, a three-phase static capacitive reactor of reactance 0·9 p.u. per phase is connected through a switch at motor bus bar. Calculate the steady-state power with and without reactor switch closed.



(Assume the internal voltage of the generator to be 1·2 p.u. and that of the motor to be 1·0 p.u.) 10

(c) (i) For the circuit shown in the figure below, determine the value of R that will result an overshoot of no more than 25% in the output $V_2(t)$. The input $V_1(t)$ is a unit step voltage, $L = 10$ mH and $C = 4$ μF.



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(ii) Consider the system $\dot{X} = AX$, $y = CX$. If the A matrix is partially given as

$$A = \begin{bmatrix} \alpha & -2 \\ 1 & 0 \end{bmatrix}$$

(1) find the initial state $X(0)$ which gives an output response $y(t) = 4e^{-t}$, when $C = [-1 \ 1]$;

(2) find the output matrix C for which the output response is $y(t) = 4e^{-t}$, when $X(0)$ is $\begin{bmatrix} 1 \\ -2 \end{bmatrix}$. 12

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