2016 – 17

ELECTRICAL ENGINEERING

SECOND PAPER

Full Marks : 200

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer *any* **ten** questions

1. In Fig. 1 as given below, consider spring constant as K, coefficient of viscous friction in the dashpot as B, mass of the body as M, $f(t)$ as the instantaneous pulling force applied on the body and $x(t)$ as the instantaneous displacement of the body from the reference $x(0) = 0$:

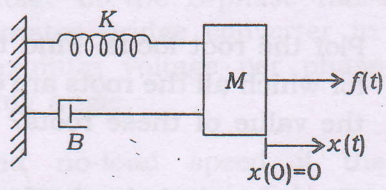

Fig. 1

(a) Draw the free-body diagram of the system given in Fig. 1. 4

(b) Obtain the differential equations describing the dynamics of the system and obtain the transfer function $\frac{X(s)}{F(s)}$ of the system given in Fig. 1. 4+4=8

(c) Find the type, order, open-loop poles and open-loop zeros of the system given in Fig. 1. 2×4=8

2. (a) How do you determine the point of intersection of the root locus with the imaginary axis and the critical value of K? 5+5=10

(b) A unity feedback control system has an open-loop transfer function of

$$G(s) = \frac{K\left(\frac{s^4}{3}\right)}{s^2(s+12)}$$

Plot the root locus. Find the value of K for which all the roots are equal. What is the value of these roots? 10

3. (a) The characteristic of a feedback control system is given by

$$s^6 + 5s^5 + 11s^4 + 25s^3 + 36s^2 + 30s + k = 0$$

Determine the range of k for which the system is stable. 10

(b) Sketch the polar plot of the following transfer function. Determine whether the plot crosses the real axis. If so, determine the frequency at which it crosses the real axis and the corresponding magnitude $|G(j\omega)|$: 10

$$G(s) = \frac{1}{s(1+s)(1+2s)}$$

4. A 3-phase half-controlled thyristor bridge converter with 400 V, 3-phase, 50 Hz supply is feeding a separately excited d.c. motor. Armature resistance of the d.c. motor is $0 \cdot 2\ \Omega$ and rated armature current is 100 A. The motor back e.m.f. is given by $E_b = kN$, where N is the speed of the motor in revolutions per minute (r.p.m.) and $k = 0 \cdot 25$ V/r.p.m.

(a) Derive the expression for average output voltage of the 3-phase half-controlled thyristor bridge converter in terms of maximum voltage per phase and the firing angle. 10

(b) Find no-load speed if the no-load armature current is 5 A and the firing angle is 45°. 5

(c) Compute the firing angle to obtain a speed of 1500 r.p.m. at rated armature current. 5

5. *(a)* Draw a triggering circuit using UJT for an SCR based 1-phase controlled rectifier. Explain how the triggering angle can be varied. 10

(b) Explain the working principle of an inverter. Discuss briefly about classification of invertors. 10

6. *(a)* Explain how a synchronously rotating magnetic field with constant magnitude is produced in a 3-phase induction motor when a balanced 3-phase supply is applied to its stator winding. Explain why 3-phase induction motor cannot run at synchronous speed. 6+2=8

(b) The power input to a 500 V, 50 Hz, 6-pole, 3-phase induction motor running at 975 revolutions per minute, is 40 kW. The stator losses are 1 kW and the friction and windage losses are 2 kW. Calculate the following : 4+4+4=12

(i) Slip

(ii) The rotor copper loss

(iii) The efficiency

7. *(a)* What is meant by infinite bus bars? State the conditions required to be satisfied by connecting a synchronous generator to an infinite bus bar. Explain how the instant for synchronizing can be determined. 10

(b) A 3-phase, 50 Hz alternator has 10 poles, 2 two-layer slots per pole, 4 conductors per slot, 150 degree coil span and 0·12 Wb flux per pole. The analysis of the air gap flux density shows a 20% third harmonic. All the coils of a phase are connected in series. Determine the root-mean-square value of fundamental electromotive force per phase. 10

8. (a) Explain the operation and working of an amplidyne machine as a power amplifier. Indicate how this machine can be converted into metadyne. 10

(b) A 3-phase, 415 V, 6-pole, 50 Hz star-connected synchronous motor has e.m.f. of 520 V (L-L). The stator winding has a synchronous reactance of 2 Ω per phase and the motor develops a torque of 220 N-m. The motor is operating at 415 V, 50 Hz bus.

(i) Calculate the current drawn from the supply and its power factor.

(ii) Draw the phasor diagram representing all the relevant quantities. 10

9. (a) What is the effect of load power factor on regulation and efficiency of a transmission line? Derive the expressions for sending end voltage and current for a long transmission line. 4+6=10

(*b*) A 100 km long, 3-phase, 50 Hz transmission line has the following line constants :

Resistance/phase/km = $0 \cdot 1\ \Omega$

Reactance/phase/km = $0 \cdot 5\ \Omega$

Susceptance/phase/km = 10×10^{-6} s

If the line supplies a load of 20 MW at 0·9 p.f. lagging at 66 kV at the receiving end, calculate (*i*) sending end power factor, (*ii*) regulation and (*iii*) transmission efficiency. 10

10. A synchronous generator and a synchronous motor each rated 25 MVA, 11 kV having 15% sub-transient reactance are connected through transformers and a line as shown in Fig. 2 below. The transformers are rated as 25 MVA, 11/66 kV and 66/11 kV with leakage reactance of 10% each. The line has a reactance of 10% on a base of 25 MVA, 66 kV. The motor is drawing 15 MW at 0·8 power factor (leading) and a terminal voltage of 10·6 kV. A symmetrical 3-phase fault occurs at the motor terminals :

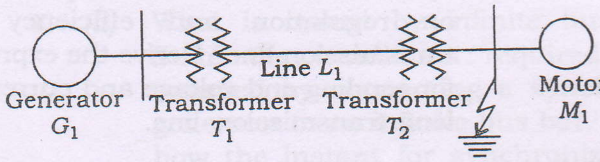

Fig. 2

(a) Calculate the pre-fault generator e.m.f. and motor back e.m.f. in per unit and draw the pre-fault equivalent circuit showing all voltages and parameters in per unit. 4+4+3=11

(b) Find the sub-transient current in the generator, motor and fault in amperes. 3×3=9

11. *(a)* Derive the expression for most economical power factor when kW demand is constant with necessary power triangle diagram. 10

(b) A load of 1500 kW at 0·71 lagging power factor is taken by a consumer from a utility which charges a demand charge of ₹ 400 per kVA of maximum demand per year. The total cost of installation of capacitor for power factor improvement is ₹ 640 per kVAR, the annual interest and depreciation being 10%.

(i) Find the most economical power factor for the consumer. 5

(ii) Determine the kVAR rating of capacitor to improve power factor to this value. 5

12. *(a)* Give a block schematic diagram of closed-loop speed control of d.c. motor incorporating both armature control and field control, and explain its operation. 10

(b) A slab of insulating material of area 130 cm^2 and of 1 cm thick, is to be heated by dielectric heating. The power required is 380 W at 30 MHz frequency. Material has a relative permittivity of 5 and power factor of 0·05. Consider absolute permittivity as $8 \cdot 854 \times 10^{-12}$ F/m.

(i) Determine the necessary voltage for heating. 5

(ii) If the voltage were limited to 230 V, what will be the frequency to get the same loss? 5

13. *(a)* Define amplitude modulation (AM) and derive the expression of instantaneous AM voltage in terms of amplitude modulation index. 6

(b) Define frequency modulation (FM) and derive the expression of instantaneous FM voltage in terms of frequency modulation index. 6

(c) A frequency modulated (FM) wave is represented by the following equation :

$$v = 10\sin(5\times10^{8}t + 4\sin 1250t)$$

(i) What are the carrier and modulating frequencies in Hz? 2

(ii) Determine the modulation index and maximum deviation. 4

(iii) What power is dissipated by this FM wave in a 5 Ω resistor? 2

14. *(a)* What is pulse modulation? Describe about the classification of pulse modulation. 2+5=7

(b) What is antenna isolation? Will an antenna designed for one frequency work on another frequency? 3+4=7

(c) A 2-stage amplifier has the following characteristics :

Gain of first stage $A_1 = 20$

Gain of second stage $A_2 = 30$

Input resistance of first stage $R_{i_1} = 2$ kΩ

Input resistance of second stage $R_{i_2} = 4$ kΩ

Output resistance of first stage $R_{o_1} = 2$ kΩ

Output resistance of second stage

$R_{o_2} = 2\ \text{k}\Omega$

Source resistance $R_s = 2\ \text{k}\Omega$

Calculate the equivalent noise resistance of the amplifier. 6

15. What is microwave? What are the properties of microwave? Why are microwaves not reflected by ionosphere? What are the reasons that microwaves are used in communication engineering? Mention the merits and demerits of microwaves. Also, explain about a microwave system. 2+3+3+4+4+4=20

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