CBCS SCHEME

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18EE741

Seventh Semester B.E. Degree Examination, Dec.2023/Jan.2024
Industrial Drives and Applications

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. What are electrical drives? Draw a block diagram of an electrical drive and explain the parts of an electrical drive. **(07 Marks)**

b. A motor drive has a load which has rotational motion, coupled through a reduction gear with a = 0.1 and efficiency of 85%. The load has a moment of inertia of $10kg\text{-}m^2$ and a torque of 10N-m. Motor has an inertia of $0.2kg\text{-}m^2$ and runs at a constant speed of 1420rpm. Determine equivalent inertia referred to the motor shaft and power developed by the motor. **(06 Marks)**

c. Explain with a block diagram, the closed-loop converter fed dc motor drives. **(07 Marks)**

OR

2 a. Explain the factors on which the choice of an electrical drive depends on. **(07 Marks)**

b. A motor equipped with a flywheel is to supply a load torque of 2000N-m for 8 sec followed by a light load period of 180N-m long enough for flywheel to regain its steady-state speed. It is desired to limit the motor torque to 800N-m. Motor has an inertia of $10kg\text{-}m^2$. Its no load speed is 500rpm and slip at a torque of 500N-m is 5%. Assuming, speed-torque characteristics of motor to be a straight line, calculate the moment of inertia of the fly wheel. **(07 Marks)**

c. Explain modes of operation of an electrical drive. **(06 Marks)**

Module-2

3 a. With circuit diagram and necessary waveforms, explain single phase fully controlled rectifier control of dc separately excited motor. Derive the expression of average voltage. **(10 Marks)**

b. A separately excited dc motor is fed from a 230V, 50Hz supply through a single phase, half controlled bridge rectifier. Armatures resistance and inductance are respectively 0.3Ω and 0.06H. The motor voltage constant is K_ϕ = 0.9V/A rad/s and field resistance is R_f = 104Ω. The field current is set to maximum possible value. The load torque is T_L = 50N-m at 900rpm. Assuming armature and field current are continuous and ripple free, compute the field current and firing angle of the converter in armature circuit. **(10 Marks)**

OR

4 a. Explain first quadrant operation of a class A chopper connected to a dc separately excited motor. **(07 Marks)**

b. Explain chopper control of dc series motor. **(07 Marks)**

c. A separately excited dc motor with an armature resistance of 0.01Ω works on a dc supply 220V, it draws an armature current of 100A and rated speed is 1000rpm. It is fed from chopper controller. Assuming continuous conduction, calculate duty ratio at rated torque with speed of 500rpm during motoring. **(06 Marks)**

Module-3

5 a. Explain stator voltage control of Induction motors. Draw typical speed-torque curves for variation in stator voltage. **(06 Marks)**

b. For a 3-ϕ star connected 4 pole, 50Hz, 415V, 1460rpm squirell cage induction motor has $R_1 = 0.65\Omega$, $R_2 = 0.35\Omega$, $X_1 = 0.95\Omega$, $X_m = 28\Omega$, $X_2 = 1.43\Omega$. The motor is operated by varying stator voltage and frequency keeping V/F ratio constant at the rated condition. Determine the maximum torque and speed at which it occurs for stator frequencies of i) 50Hz, ii) 35Hz. **(09 Marks)**

c. Explain single phasing of induction motors. **(05 Marks)**

OR

6 a. Explain Variable Voltage Frequency (V/F) control of induction motors. **(06 Marks)**

b. A 440V, 3ϕ, 50Hz, 6 pole, 945rpm delta connected induction motor has following parameters referred to stator side. $R_1 = 2\Omega$, $R_2 = 2\Omega$, $X_1 = 3\Omega$, $X_2 = 4\Omega$. Motor speed is controlled by stator voltage control to run motor at 800rpm. Calculate:

i) Torque developed by the motor
ii) Voltage to be applied to motor
iii) The current drawn. **(09 Marks)**

c. Explain operation of three phase induction motor with unbalanced motor impedances. **(05 Marks)**

Module-4

7 a. Explain with necessary diagrams the control of induction motors by current source inverter. **(08 Marks)**

b. For a 3-phase, delta connected 6-pole 50Hz, 400V, 925rpm squirell cage induction motor, $R_s = 0.2\Omega$, $X_s = 0.5\Omega$, $X_r = 1.1\Omega$. The motor is operated from voltage source inverter with constant V/F ratio from 0 to 50Hz and having constant voltage of 400V above 50Hz frequency. Calculate:

i) Speed for a frequency of 35Hz with half full load torque.
ii) Torque for a frequency of 35Hz for a speed of 650rpm. **(06 Marks)**

c. Explain with a diagram, the variable frequency control of synchronous motors (multiple motors). **(06 Marks)**

OR

8 a. Explain with diagrams, cycloconverter control of three phase induction motors. **(08 Marks)**

b. Explain speed-torque characteristics of a synchronous motor with a fixed frequency supply. **(06 Marks)**

c. Explain speed control of single phase induction motors. **(06 Marks)**

Module-5

9 a. Explain self controlled synchronous motor drive employing load commutated thyristor inverter. **(10 Marks)**

b. Explain industrial drives used in

i) Textile mills
ii) Steel rolling mills. **(10 Marks)**

OR

10 a. Explain torque versus stepping rate characteristics of a stepper motor. **(06 Marks)**

b. Write short notes on Brushless DC motor drives. **(08 Marks)**

c. Explain industrial drives used for cranes and hoists. **(06 Marks)**

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1.a.

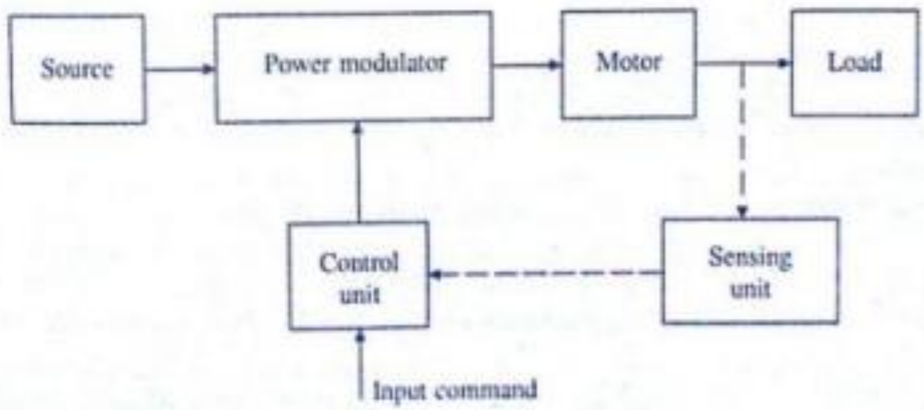


Fig. 1.1 Block diagram of an electrical drive

(i) Modulates flow of power from the source to the motor in such a manner that motor is imparted speed-torque characteristics required by the load.

(ii) During transient operations, such as starting, braking and speed reversal, it restricts source and motor currents within permissible values; excessive current drawn from source may overload it or may cause a voltage dip.

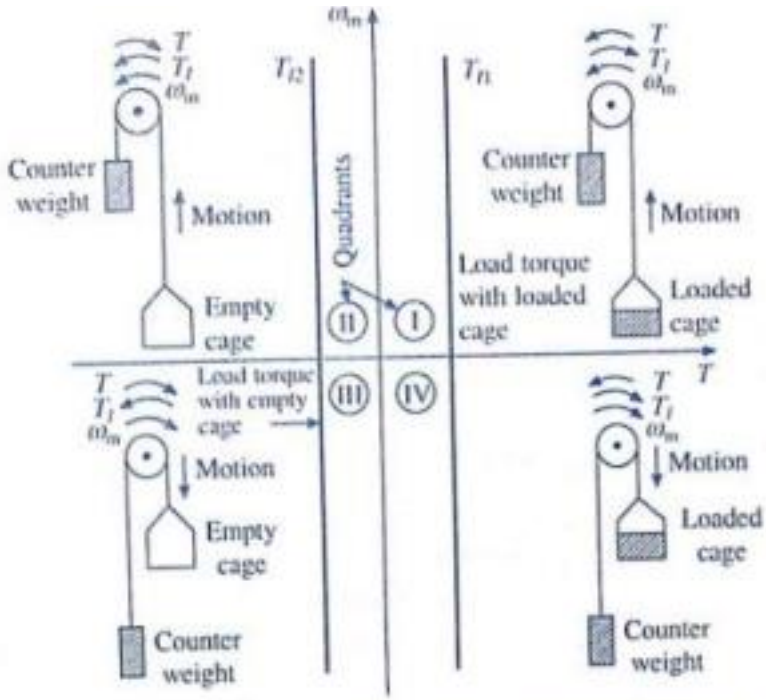
(iii) Converts electrical energy of the source in the form suitable to the motor, e.g. if the source is dc and an induction motor is to be employed, then the power modulator is required to convert dc into a variable frequency ac.

(iv) Selects the mode of operation of the motor, i.e. motoring or braking.

(2+2 marks)

c. With a neat diagram, explain the four quadrant operation of a motor driving a hoist load.

[CO1, L2]



Four quadrant operation of a motor driving a hoist load

(3 marks)

Explanation for each quadrant – 1 marks * 4 = 4 marks

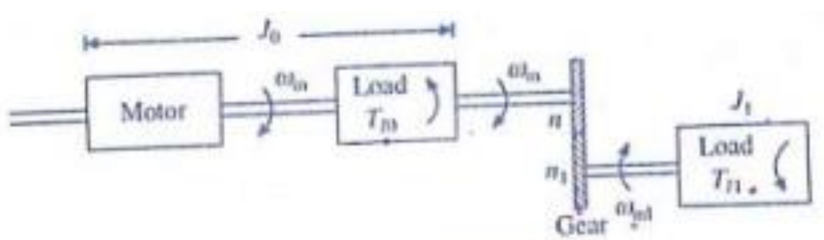
2 a. Derive expressions for equivalent values of moment of inertia and torque as referred to motor shaft for loads with rotational motion. **(07 Marks)**

b. A motor equipped with a flywheel is to supply a load torque of 1000N.m for 10 sec followed by a light load period of 200 N.m long enough for the flywheel to regain its steady state speed. It is desired to limit the motor torque to 700 N.m. What should be the moment of inertia of flywheel? Motor has an inertia of 10 kg-m^2. Its no load speed is 500 rpm and slip at a torque of 500 N.m is 5%. Assume speed-torque characteristic of motor to be straight line in the region of interest. **(05 Marks)**

c. Explain how a current limit control functions in closed loop control of drives. **(04 Marks)**

[CO1, L2,L3]

a.



(a) Loads with rotational motion

1 mark

2.3.1 Loads with Rotational Motion

Let us consider a motor driving two loads, one coupled directly to its shaft and other through a gear with n and n_1 teeth as shown in Fig. 2.4(a). Let the moment of inertia of motor and load directly coupled to its shaft be J_0, motor speed and torque of the directly coupled load be ω_m and T_{l0} respectively. Let the moment of inertia, speed and torque of the load coupled through a gear be J_1, ω_{m1} and T_{l1} respectively. Now,

$$\frac{\omega_{m1}}{\omega_m} = \frac{n}{n_1} = a_1 \tag{2.3}$$

where a_1 is the gear tooth ratio.

If the losses in transmission are neglected, then the kinetic energy due to equivalent inertia must be the same as kinetic energy of various moving parts. Thus

$$\frac{1}{2} J\omega_m^2 = \frac{1}{2} J_0\omega_m^2 + \frac{1}{2} J_1\omega_{m1}^2 \tag{2.4}$$

From Eqs. (2.3) and (2.4)

$$J = J_0 + a_1^2 J_1 \tag{2.5}$$

Power at the loads and motor must be the same. If transmission efficiency of the gears be η_1, then

(3 Marks)

$$T_l\omega_m = T_{l0}\omega_m + \frac{T_{l1}\omega_{m1}}{\eta_1} \tag{2.6}$$

where T_l is the total equivalent torque referred to motor shaft.

From Eqs. (2.3) and (2.6)

$$T_l = T_{l0} + \frac{a_1 T_{l1}}{\eta_1} \tag{2.7}$$

If in addition to load directly coupled to the motor with inertia J_0 there are m other loads with moment of inertias $J_1, J_2, \ldots, J_m$ and gear teeth ratios of $a_1, a_2, \ldots a_m$ then

$$J = J_0 + a_1^2 J_1 + a_2^2 J_2 + \ldots + a_m^2 J_m \tag{2.8}$$

If m loads with torques $T_{l1}, T_{l2}, \ldots, T_{lm}$ are coupled through gears with teeth ratios $a_1, a_2, \ldots a_m$ and transmission efficiencies $\eta_1, \eta_2, \ldots, \eta_m$, in addition to one directly coupled, then

$$T_l = T_{l0} + \frac{a_1 T_{l1}}{\eta_1} + \frac{a_2 T_{l2}}{\eta_2} + \ldots + \frac{a_m T_{lm}}{\eta_m} \tag{2.9}$$

If loads are driven through a belt drive instead of gears, then, neglecting slippage, the equivalent inertia and torque can be obtained from Eqs. (2.8) and (2.9) by considering $a_1, a_2, \ldots, a_m$ each to be the ratios of diameters of wheels driven by motor to the diameters of wheels mounted on the load shaft.

(3 marks)

b.

$$J = \frac{T_r}{(\omega_{m0} - \omega_{mr})}\left[\frac{t_h}{\log_e\left(\dfrac{T_{th} - T_{min}}{T_{th} - T_{max}}\right)}\right]$$

Here no load speed $= \frac{500 \times 2\pi}{60} = 52.36$ rad/sec

Speed at 500 N-m = (1 – 0.05) 52.36 = 49.74 rad/sec

(2 marks)

$$\frac{T_r}{(\omega_{m0} - \omega_{mr})} = \frac{500}{52.36 - 49.74} = 190.84$$

$T_{th} = 1000$ N-m, $T_{max} = 700$ N-m, $T_{min}' = T_{ll} = 200$ N-m, $t_h = 10$ S.

Substituting in Eq. (1)

$$J = 190.84\left[\frac{10}{\log_e\left(\dfrac{1000 - 200}{1000 - 700}\right)}\right] = 1871.8 \text{ kg-m}^2$$

Moment of inertia of the flywheel = 1871.8 – 10 = 1861.8 kg-m^2.

(3 marks) c.

3.3.1 Current-Limit Control

Current-limit control scheme of Fig. 3.3 is employed to limit the converter and motor current below a safe limit during transient operations. It has a current feedback loop with a threshold logic circuit. As long as the current is within a set maximum value, feedback loop does not affect

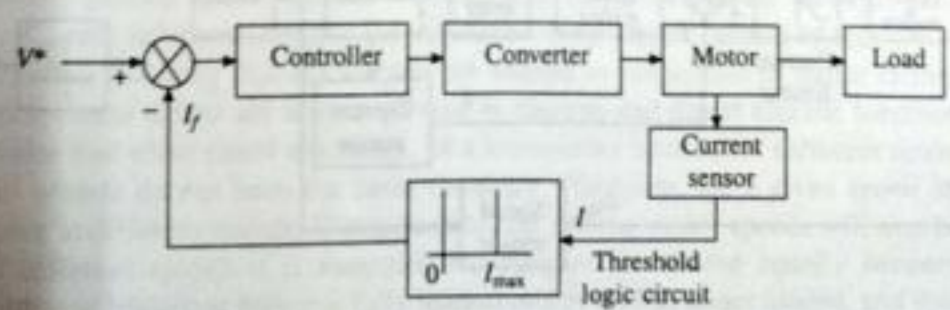


Fig. 3.3 Current limit control

(2 marks)

operation of the drive. During a transient operation, if current exceeds the set maximum value, feedback loop becomes active and current is forced below the set maximum value, which causes the feedback loop to become inactive again. If the current exceeds set maximum value again, it is again brought below it by the action of feedback loop. Thus the current fluctuates around a set maximum limit during the transient operation until the drive condition is such that the current does not have a tendency to cross the set maximum value, e.g. during starting, current will fluctuate around the set maximum value. When close to the steady-state operation point, current will not have tendency to cross the maximum value, consequently, feedback loop will have no effect on the drive operation.

(2 marks)

Module-2

3 a. Derive an expression for temperature rise of a motor during normal operation. (10 Marks)

b. A 50KW, 3 phase, 440V, 50Hz, 1440 rpm squirrel – cage induction motor has constant loss to variable loss at full load in the proportion 1 : 3. Its rated temperature rise is 55°C and its heating and cooling time constants are 40 and 60 minutes respectively. Find the intermittent rating if periodic load of half hour duration are applied at an interval of half hour. (06 Marks)

[CO2, L1,L2]

a.

Heating and Cooling Curves of Electrical Drives:

An accurate prediction of Heating and Cooling Curves of Electrical Drives rise inside an electrical motor is very difficult owing to complex geometrical shapes and use of heterogeneous materials. Since conductivities of various materials do not differ by a large amount, a simple thermal model of the machine can be obtained by assuming machine to be a homogeneous body. Although inaccurate, such a model is good enough for a drive engineer whose job is only to select the motor rating for a given application ensuring that temperatures in various parts of motor body do not exceed the safe limits.

Let the machine, which is assumed to be a homogeneous body, and the cooling medium has following parameters at time t:

P_1 = Heat developed, joules/sec or watts.

P_2 = Heat dissipated to the cooling medium, joules/sec or watts.

W = Weight of the active parts of machine, kg.

h = Specific heat, Joules per kg per °C.

A = Cooling surface, m^2.

d = Coefficient of heat transfer or specific heat dissipation, joules/sec/m^2/°C.

θ = Mean temperature rise, °C.

(2 marks)

During a time increment dt, let the machine temperature rise be dθ. Since,

Heat absorbed (or stored) in the machine = (Heat developed inside the machine − Heat dissipated to the surrounding cooling medium)

$$Whd\theta = p_1 dt - p_2 dt \tag{4.1}$$

$$p_2 = \theta dA \tag{4.2}$$

Substituting in Eq. (4.1) and rearranging the terms

$$C\frac{d\theta}{dt} = p_1 - D\theta \tag{4.3}$$

$$C = Wh \tag{4.4}$$

$$D = dA \tag{4.5}$$

C is the thermal capacity of the machine, watts/°C, and D the heat dissipation constant, watts/°C. Heat dissipation mainly occurs through convection. Typical values of d are in the range of 40 of 600 W/m^2/°C. The first order differential equation (4.3) has a solution

$$\theta = \theta_{ss} + Ke^{-t/\tau} \tag{4.6}$$

$$\theta_{ss} = \frac{p_1}{D} \tag{4.7}$$

$$\tau = \frac{C}{D} \tag{4.8}$$

(4 marks)

(4 marks)

b.

a.

(4 marks)

(4 marks)

b.

a.

(4 marks)

(4 marks)

b.

(2 marks)

c.

(2 marks)

(2 marks)

c.

(4 marks)

a.

b.

(4 marks)

b.

(4 marks)

(4 marks)

(4 marks)

a.

(4 marks)

(4 marks)

b.

(4 marks)

(4 marks)

a.

(4 marks)

(4 marks)

b.

(4 marks)

(4 marks)

a.

(4 marks)

(4 marks)

(4 marks)

9.

(4 marks)

(2 marks)

(4 MARKS)

a.

(2 marks)

(4 marks)

b.

(3 marks)

(3 marks)

c.

(4 marks)