First Mid-term examination

Subject → Electric Drives and Their Control

Q (1)(a) Derive fundamental torque equations.

(b) A motor drives two loads, one has rotational motion. It is coupled to the motor through a reduction gear with $\alpha = 0.1$ and efficiency of 90% The load has a moment of inertia of 10 kg m^2 and a torque of 10 N-m. Other load has translational motion and consists of 1000 kg weight to be lifted up at an uniform speed of 1.5 m/s. Coupling between this load and the motor has an efficiency of 85%. Motor has an inertia of 0.2 kg-m^2 and runs at a constant speed of 1420 rpm. Determine equivalent inertia referred to the motor shaft and power developed by the motor.

Q (2)

(a) Explain Regenerative Breaking of Series motor.

(b) A 220 V, 200 A, 800 rpm d c separately excited motor has an armature resistance of 0.06 Ω. The motor armature is fed from a variable voltage source with an internal resistance of 0.04 Ω. Calculate internal voltage of the variable voltage source when the motor is operating in regenerative braking at 80% of the rated motor torque and 600 rpm.

Q①
(a): **Fundamental Torque Equations ⇒**
ans:

(machines) A motor generally drives a load through some transmission system. While motor always rotates, the load may rotate or undergo a translational motion. Load speed may be different from that of motor, and if the load has many parts, their speed may be different and while some parts may not rotate others may go through a translational motion. Equivalent rotational system of motor and load is shown in figure.

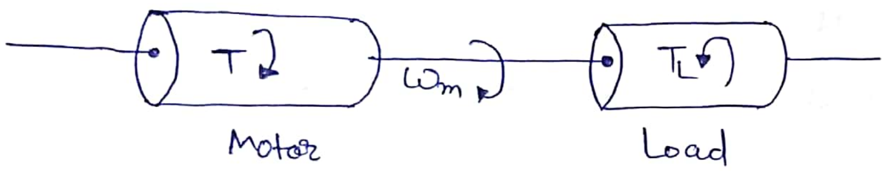

figure ⇒ Equivalent motor load system

Notations Used:

J = Polar moment of inertia of motor load system referred to the motor shaft, kg-m².

ω_m = Instantaneous angular velocity of motor shaft, rad/sec.

T = Instantaneous value of developed motor torque, N-m.

T_L = Instantaneous value of load torque, referred to the motor shaft, N-m.

Load torque includes friction and windage torque of motor. Motor-load system shown in figure. Can be described by the following fundamental torque equation

$$T - T_L = \frac{d}{dt}(J\omega_m) = J\frac{d\omega_m}{dt} + \omega_m \frac{dJ}{dt} \quad \text{——— (1)}$$

Equation ① is applicable to variable inertia drives such as mi winders, reel drives, industrial robots. for drives with Constant inertia $\frac{dJ}{dt} = 0$

$$\therefore \boxed{T = T_L + J\frac{d\omega_m}{dt}} \quad \text{———} \quad (2)$$

from the above equations, it is possible to determine the different states at which an electric drive causing rotational motion can remain following.

(i) $T > T_L$, i.e., $\frac{d\omega_m}{dt} > 0$

i.e, the drive will be ~~de~~-accelerating, imparticular picking up speed to reach rated speed.

(ii) $T < T_L$, i.e., $\frac{d\omega_m}{dt} < 0$

i.e., the drive will be de-accelerating and particularly, coming to rest speed.

(iii) $T = T_L$, i.e., $\frac{d\omega_m}{dt} = 0$

i.e, the motor will continue to run at the same speed, if it were running, else will continue to be at rest, if it were not running.

Statement (i), (ii) and (iii) are valid only when T_L happenes to be a passive Load. The reverse may occur with active loads.

Eqns ② shows that torque developed by motor is counter balanced by load torque T_L and a dynamic torque $\left[J\frac{d\omega_m}{dt}\right]$.
Torque component $\left[J\frac{d\omega_m}{dt}\right]$ is called dynamic torque because it is present only during the transient operations.

Drive accelerates or decelerates depending on whether T is greater or less than T_L. During acceleration motor should supply not only the load torque but an additional torque ponent $J\left(\frac{d\omega_m}{dt}\right)$ in order to overcome the drive inertia. In drive with large inertia, such as electric trains, motor torque must exceed the load torque by a large amount in order to get adequate acceleration. In drives requiring fast transient response, motor torque should be maintaining at the highest value and motor load system should be designed with a lowest possible inertia. Energy associated with dynamic torque $\left[J\frac{d\omega_m}{dt}\right]$ is stored in the form of kinetic energy given by $\frac{d\omega_m^2}{2}$.

During deceleration, dynamic torque $J\frac{d\omega_m}{dt}$ has a negative sign. Therefore, it assist the motor developed torque T and maintains drive motion by extracting energy from stored kinetic energy

(b)

Ans:

The total moment of inertia referred to the motor shaft.

from eq^n

$$J = J_0 + \alpha_1^2 J_1 + M_1\left[\frac{V_1}{\omega_m}\right]^2 \quad \text{———} \quad (1)$$

Here,
$$J_0 = 0.2\ kg\text{-}m^2$$
$$\alpha_1 = 0.1$$
$$J_1 = 10\ kg\text{-}m^2$$
$$v = 1.5\ m/s$$

and $\omega_m = \frac{(1420 \times \pi)}{30} = 148.7\ rad/sec$

these above values substituting in eq^n (1) we have -

$$J = 0.2 + (0.1)^2 \times 10 + 1000 \left[\frac{1.5}{148.7}\right]^2 = 0.4 \text{ Kg-m}^2$$

∵ We know that -

$$T_L = \frac{\alpha_1 T_{L1}}{\eta_1} + \frac{f_1}{\eta_1'}\left[\frac{v_1}{\omega_m}\right] \qquad \text{——— (2)}$$

Here,

$\eta_1 = 0.9$

$\alpha_1 = 0.1$

$T_{L1} = 10 \text{ N-m}$

$\eta_{1}' = 0.85$

$F_1 = 1000 \times 9.81 \text{ N}$

$V_1 = 1.5 \text{ m/s}$

and $\omega_m = 148.7$ rad/sec

these values substituting in eqn (2),

we have

$$T_L = \frac{0.1 \times 10}{0.9} + \frac{1000 \times 9.81}{0.85}\left[\frac{1.5}{148.7}\right]$$

$$= 117.53 \text{ N-m}$$

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Q ②
(a)
ans:

Regenerative Braking of a Series motor ⇒

With chopper control, regenerative braking of series motor Can also be obtained. Power circuit of is employed. During regenerative braking, series motor functions as a self-excited series generator. For self-excitation, current flowing through field winding should assist residual magnetism. Therefor, when changing from motoring to braking Connection, while direction of armature current should reverse, field current should flow in the same direction. This is achived by reversing the field with respect to armature when changing from motoring to braking operation. Waveforms Va and Ia will be same

$$\boxed{W_m = \frac{\delta V + I_a R_a}{K_a}} \qquad \text{——— (1)}$$

$$\boxed{T = -k_a I_a} \qquad \text{——— (2)}$$

for a chosen value of Ia, ka is obtained from magnetization characteristic. Then T and Wm are obtained from eqⁿ ② and ①, respectively. The nature of speed-torque characterstics ~~is~~ Such as Characterstics give unstable operation with most loads. Consequently, regenerative braking of the series motor is difficult.

(b)

Ans: Since torque is proportional to the armature current, motor armature current when regenerating.

$$I_{a2} = 0.8 \times 200 = 160 A$$

$$E_1 = 220 - 200 \times 0.06$$

$$E_1 = 208 V$$

$$E_2 = \frac{N_2}{N_1} E_1$$

$$= \frac{600}{800} \times 208$$

$$\boxed{E_2 = 156 V}$$

Internal voltage of the variable voltage source

$$= 156 - 160(0.06 + 0.04) = 140 V$$