National University of Singapore

Department of Electrical & Computer Engineering

EE-4502:Electric Drives and Control

Tutorial - 1 (Fundamentals of Electric Drives)

Year 2022-23

Q1. An electric motor is used to drive a hoist. A hoist consists of a rope wound on a drum and is coupled to the motor shaft. The other end of the rope is tied to a cage to transport people or material from one level to another.

The motor torque-speed characteristics are given by

Quadrants I, II and IV: $T_m = 200 - 0.3\,N$ N.m
Quadrants II, III and IV: $T_m = -200 - 0.3\,N$ N.m

where N is the speed in rpm.

When the hoist is loaded, the net load torque $T_l = 80$ N.m and when it is unloaded, the net load torque is $T_l = -100$ N.m. Sketch the corresponding motor and load torque-speed characteristics on the torque-speed plane. Obtain the equilibrium speeds for operation in all the four quadrants. Examine the stability of the equilibrium points.

(Ans. 400 rpm, 1000 rpm, - 333.33 rpm and -933.33 rpm.)

Q2. An electric motor is required to drive the take-up roll on a plastic strip line. The mandrel on which the strip is wound is 15 cm in diameter and the strip builds up to a roll of 25 cm in diameter. Strip tension is maintained constant at 1000 N. The strip moves at a uniform speed of 25 m/s. The motor is coupled to a mandrel by a reduction gear box with a gear-ratio of 0.5. The gear-box has an approximate efficiency of 87% at all speeds. Determine the power rating of the motor required for this application and hence determine the corresponding maximum and minimum speeds and torque.

(Ans. 28.73 kW, 666.6 and 400 rad/s and 43.1 and 71.8 $N.m$)

Q3. A weight of 500 kg put inside a carriage is being lifted up at a uniform speed of 1.5 m/s by a winch driven by a motor running at a speed of 1000 rpm. The moments of inertia of the motor and the winch are 0.5 and 0.3 $kg.m^2$ respectively. In the absence of any weight placed on the carriage, the motor develops a torque of 100 N.m when the motor runs at a speed of 1000 rpm. If the time taken by the drive to accelerate from zero speed to 1000 rpm is 12 sec then calculate the required motor torque.

(Ans. 178.1 N.m.)

Q.4 A permanent-magnet DC motor is to be started from rest. The motor parameters are: armature resistance, $R_a = 0.35\,\Omega$, back-emf constant, $k\phi = 0.5$ V/(rad/s), and motor inertia, $J_m = 0.02\,kg.m^2$. The motor is driving a load that has an inertia, $J_l = 0.04\,kg.m^2$ and a load torque, $T_L = 2$ N.m. The maximum motor current is limited to 15 A.

Write an expression for the armature voltage as a function of time, t that would be needed to bring the motor speed to a steady-state value of 300 rad/s as quickly as possible. Also derive the expression for the motor speed as a function of time, t and plot the corresponding armature voltage and motor speed as a function of time, t. The armature inductance, L_a is neglected.

(Ans. $\omega_m(t) = 91.67t$ and $v_a(t) = 45.83t + 5.25\,V$)

Note: **Practice problems not to be discussed in the class but for your own practice.**

Q.5 A shunt dc motor with a torque speed characteristics of

$$\omega_m = 100 - 0.053T_{em} \tag{1}$$

is used to drive a dc generator which feeds a resistive load such that the load (generator) torque speed characteristics is given by

$$T_l = \omega_m \tag{2}$$

It is assumed that the generator is directly coupled with the motor shaft. Determine the corresponding speed and torque for the steady-state operating point. Examine whether the operating point is stable or unstable.

(Ans.907 rpm and 95 N.m.))

Q.6 An induction motor driven by a variable frequency converter is used to drive the take-up roll in a wire drawing machine. The mandrel on which the wire strip is wound has a diameter of 650 mm and the wire strip builds up to a diameter of 1240 mm when the mandrel is full. The wire strip moves at a uniform speed of 12 m/s and the corresponding wire tension is maintained constant at 5800 N. The motor is coupled to the mandrel through a speed reduction gear-box with a gear-ratio of 1.0 : 7.1. The gear-box has an approximate efficiency of 98% at all speeds.

(a) Determine the corresponding torques and angular speeds of the load when the mandrel is empty and when it is full. Also determine the corresponding load power and comment on the nature of the load.

(b) Determine the corresponding torques and angular speeds reflected back at the motor shaft, when the mandrel is empty and when it is full.

(Ans. (a) 1886.2 N.m, 3597 N.m, 69.6 kW and (b) 271.1 N.m, 517 N.m)

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