National University of Singapore

Department of Electrical & Computer Engineering

EE-4502:Electric Drives and Control

Tutorial - 1 (Fundamentals of Electric Drives)

Year 2021-22

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

As $t \to \infty$, $e^{-\alpha} \to 0$, only the term within the bracket must be there.

where N is the speed in rpm.

When the hoist is loaded, the net load torque $T_l = 120$ N.m and when it is unloaded, the net load torque is $T_l = -100$ N.m.

1. Sketch and dimension the corresponding motor and load torque-speed characteristics on the torque-speed plane.
2. Obtain the equilibrium speeds for operation in all the four quadrants.
3. Examine the stability of the equilibrium points.

(Ans. 266.7 rpm, 1000 rpm, - 333.33 rpm and -1066.7 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 torques.

(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 small permanent magnet based 100 V DC motor drives a constant torque-load at 1000 r/min and draws an input power of 250 W from the electrical source. The armature resistance is 10 Ω. The motor is to be reversed by a solid-state contactor which can be assumed to apply the full reverse voltage instantaneously.

The inertia of the motor together with the load is 0.05 $kg.m^2$. Assume that electrical time constant is negligible in comparison with the electro-mechanical time constant of the drive system. Also assume that frictional and windage torque is negligible. Determine the time taken by the electric motor to reach the steady-state speed in the reverse direction. You may assume that the motor speed is considered to have reached the steady-state speed once it reaches 98% of the final steady-state speed.

(Ans. 4.25 sec)

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 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 $v_a(t) = 45.83t + 5.25\,V$)

— END —

Question 4:

Given that $V = 100$, $N = 1000$ rpm, $R_a = 10.0\ \Omega$, $P_{in} = 250W$

$\therefore P_{in} = (V) \times (I)$

$250 = (100)(I_a)$

$\therefore I_a = 2.5\ A$

since $E_a = V_a - (I_a)(R_a)$

$= 100 - (2.5)(10)$

$= 75V$

$E_a = k\varphi\ (\omega_m)\quad (2\pi)(N)(\frac{1}{5})$

$= (k\varphi)(\frac{2\pi}{60})(1000)$

$75 = (k\varphi)(\frac{2\pi}{60})(1000)$

$\therefore k\varphi = 0.71619 \approx 0.72$

$\therefore T_s = T_{em} = (0.72)(I_a) = (0.72)(2.5)$

$= 1.8$

During speed reversal the armature voltage will be reversed from 100 to -100 V.

$\therefore$ the motor has now shifted to QUADRANT II !

In Quadrant II,

$T_{em} = T_L + (J_{eq})(\frac{d\omega_m}{dt})$