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The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2014-2015 (2.0 hours)

EEE6203 Motion Control and Servo Drive Systems

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. a. Figure 1 shows the schematic of a servo drive system in which a purely inertia load is coupled to the motor via a lead-screw transmission. If the efficiency of the transmission is η, show that the required torque rating of the motor will be a minimum when the pitch s of the lead-screw is given by: **(8)**

$$s = 2\pi\sqrt{\frac{\eta(J_m + J_s)}{(m_T + m_w)}}$$

where J_m and J_s are moment of inertia of the motor and the lead-screw respectively, and m_T and m_w are mass of the table and work piece respectively.

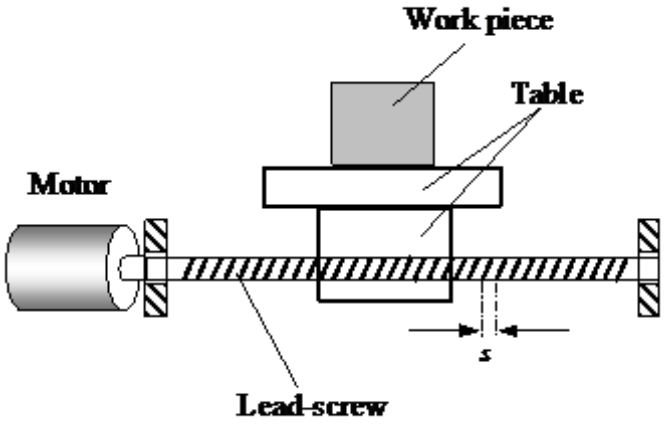

Figure 1

b. If the motor inertia is 1.2×10^{-3} kgm^2, the lead-screw inertia is 2.8×10^{-3} kgm^2, the transmission efficiency is 0.7 and the combined mass of the table and work piece is 500 kg, determine the pitch of the lead-screw at the optimal condition, and the equivalent inertia on the motor axis. **(2)**

c. If the torque constant and armature resistance of the motor are 0.9 Nm/A and 0.5 Ω, respectively, and the drive is required to move the work piece 1.0 m in 3 seconds via a trapezoidal velocity profile, determine the peak voltage and peak current ratings of the drive. Would the motor overheat if such a movement were executed repeatedly given the rms torque rating of the motor is 1.4 Nm? **(6)**

d. Would it be possible to perform the same movement continuously using a triangle velocity profile? Justify you answer. **(4)**

2. Figure 2 shows an H-bridge converter for a dc servo motor drive. The switches and diodes may be treated as ideal devices.

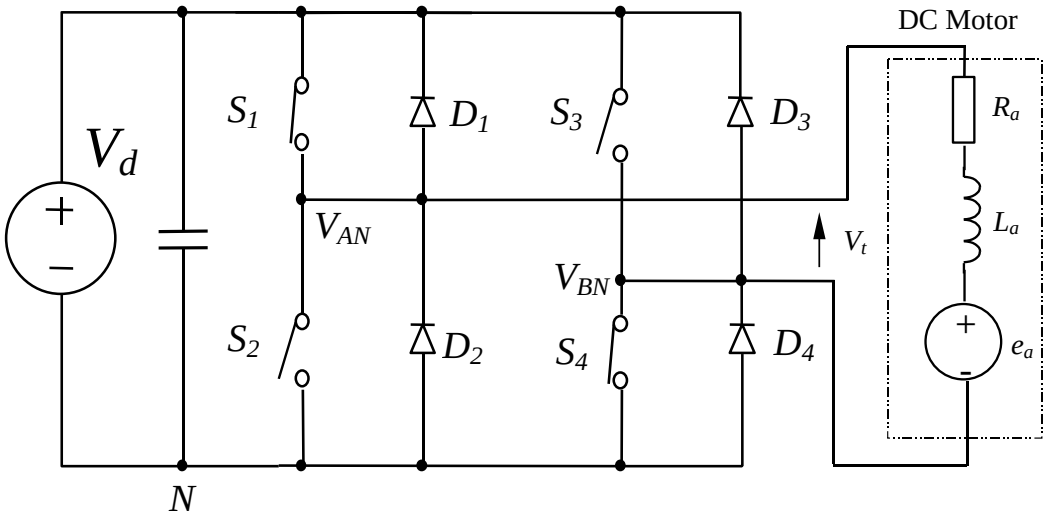

Figure 2

a. Describe, with the aid of appropriate waveforms, uni-polar operation of the converter. **(6)**

b. Derive an expression for the output voltage, V_t, as a function of duty ratio and show that the dc gain of the converter is given by V_d / V_{tp}, where V_d is the dc bus voltage, and V_{tp} is the peak value of a triangular carrier signal. **(3)**

c. Assuming that the ripple current is primarily determined by the armature inductance L_a and the armature resistance R_a has a negligible effect, show that the maximum current ripple of the uni-polar operation is given by: **(8)**

$$\Delta I_{pp} = \frac{V_d}{8 L_a f_c}$$

where f_c is the carrier frequency.

d. If the voltage source V_d in Figure 2 is replaced by a diode bridge rectifier, describe what could be a potential problem for servo-operation. **(3)**

3. A three-phase, 6-pole, star-connected synchronous permanent-magnet ac servomotor has a measured line-to-line open-circuit rms voltage of 190 V at a rotor speed of 2000 rpm. The phase resistance and synchronous inductance of the motor are 1.01 Ω and 5.7 mH, respectively.

a. Calculate the no-load peak flux-linkage and the torque constant of the motor, and sketch the phasor diagram for maximum torque per Ampere operation. **(4)**

b. If the motor is required to deliver 6 Nm torque at a speed of 1500 rpm, calculate the minimum rms phase current, rms phase voltage, and the power factor of the operation. **(6)**

c. If the motor is supplied by a three-phase inverter which is modulated using the Space Vector Modulation technique at a frequency of 10 kHz with a DC link voltage of 600V, determine the time duration for the two active vectors and zero vectors in order to achieve the required operation in 3(**b**) at a rotor position of 55 electrical degrees with respect to phase *a* axis, and sketch the per-cycle switching sequence waveforms. **(10)**

4. A three-phase, 4-pole star-connected induction motor has a rated speed of 1450 rpm, when operating from a 415V, 50Hz supply. The machine has the following parameters measured at 50Hz and referred to the stator:

Magnetising reactance	= 48.6 Ω
Stator resistance	= 0.35 Ω
Rotor resistance	= 0.55 Ω
Stator leakage reactance	= 1.20 Ω
Rotor leakage reactance	= 0.95 Ω

a. Sketch the equivalent circuit diagram and phasor diagram of the motor operation **(5)**

b. Show that the electromagnetic torque of the motor is given by: **(6)**

$$T_{em} = \frac{3p\Psi_{ag}}{\sqrt{2}} I_r \sin\delta$$

where p is the number of pole-pairs, Ψ_{ag} is the peak value of air-gap flux linkage, I_r is the rms rotor current, and δ is the angle between Ψ_{ag} and $I_{r.}$

c. If the motor operates at 50% rated torque, calculate the rotor speed, stator current, power factor, air-gap flux linkage, and efficiency. **(9)**

JBW/DG