EEE202 – Answers 2007/2008

Qu 1.

a.) m.m.f = Reluctance × flux, Therefore: N.I = Reluctance of airgap × ϕ

$$\therefore N.I = \frac{x}{\mu_o dh} \times \phi$$

Therefore

$$\phi = \frac{N.I}{\frac{x}{\mu_o A}} = \frac{NI\mu_o dh}{x}$$

Hence, inductance,

$$L = \frac{\varphi}{I} = \frac{N\phi}{I}$$

so:

$$L = \frac{N^2 \mu_o dh}{x}$$

and the force on the iron core is given from:

$$F = \frac{1}{2} I^2 \frac{dl}{dx}$$

$$\therefore F = \frac{1}{2} I^2 \left(-\frac{N^2 \mu_o dh}{x^2} \right)$$

As requested:

$$\therefore F = -\frac{1}{2} \cdot \frac{I^2 N^2 \mu_o dh}{x^2}.$$

b) When locked, X=6mm, therefore current at this point, given the force needs to overcome a constant 2Nm torque, is: 3.4A

When Unlocked, X=3mm, therefore the current at this position is: 1.7A

c). The advantage of having different current levels to lock and unlock the system is that there will be some hysteresis in the current required to operate the system. Once the system starts to lock, for example, the current requirement will drop and the system will continue to lock, the current then has to be reduced significantly before the system then unlocks. There is therefore no uncertainty in the state of the lock.

Qu 2.

a) Examining the profile given, and assuming the application of paint has just finished at time t=0, the system then accelerates the component from standstill to 0.5ms^{-1} in 1 second, covering 0.25m of distance, and from t=1 to t=1.5 a further 0.25m of distance is covered leading to the component exiting the machine at position C. At the same time another component enters the machine at position A (at t=1.5sec) This component is then transported 0.25m at the same speed (0.5sec) until t=2sec, then the component is decelerated to standstill in a further second (covering a further 0.25m). This leaves the component at position B where it remains for 1 sec whilst it is painted. The cycle then repeats.

b) Total inertia of motor and load = 0.32kgm^2
Acceleration from t=0 to t=1 is 0.5ms^{-2}, and T=J.a

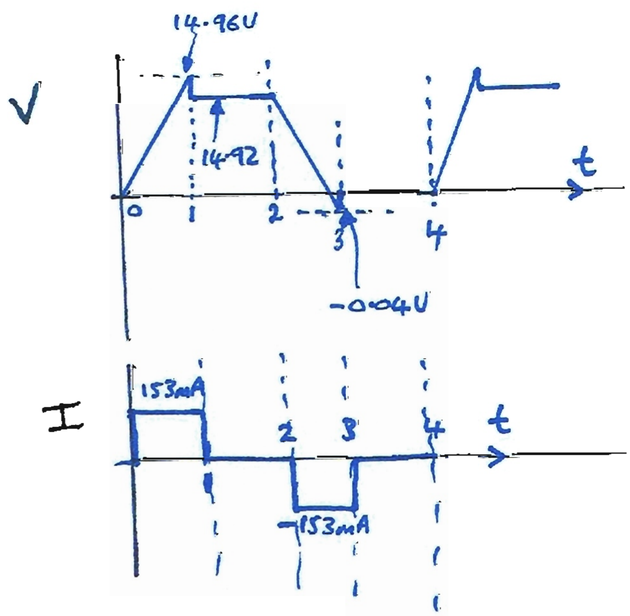
Therefore Torque required = 0.16Nm

Km = 100V / 1000rpm = 0.955V/rad or 0.955Nm/A

This gives a current requirement of 0.16 × 0.955 = 152.8mA.

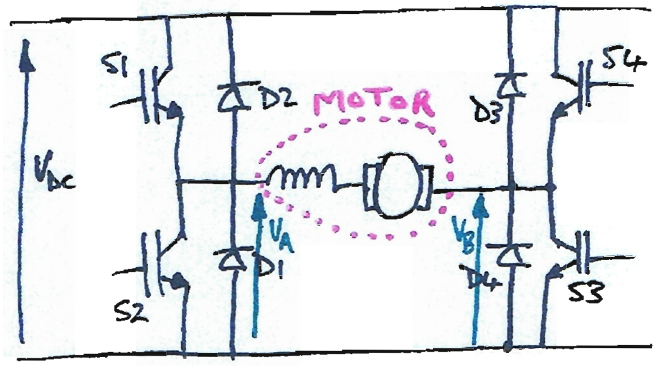
As v=rω, ω=0.5/0.032 = 15.63 rad/sec, which gives a back emf of 14.92V. The applied voltage should therefore be given by V=I×R+E, and be V= 14.92+0.1528×0.25, giving a voltage of: 14.96V

c)



The motor specified is adequate, if not a little over-specified.

d) A suitable power electronic servo amplifier would be a 4-quadrant chopper:



e) Continuous stall torque rating is a rating which is determined by the thermal ratings of the motor. The motor is capable of sustaining the losses correspondent to the continuous stall torque continuously. The maximum torque rating of the motor is the maximum short-term torque rating of the motor, and is usually specified by the demagnetisation withstand of the motor design. The motor cannot operate at this level continuously as it would overheat.

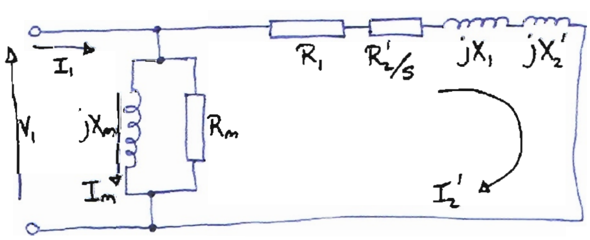
Qu 3.

a) As below:

R_1 = STATOR RESISTANCE PER PHASE
R_2' = REFERRED ROTOR RESISTANCE /ϕ
X_1 = STATOR LEAKAGE REACTANCE /ϕ
X_2' = REFERRED ROTOR LEAKAGE REACTANCE /ϕ
X_m = MAGNETIZING REACTANCE /ϕ
R_m = IRON LOSS RESISTANCE /ϕ (4)
V_1 = RMS SUPPLY PHASE VOLTAGE /ϕ
E_1 = INDUCED STATOR PHASE VOLTAGE
I_2' = REFERRED ROTOR CURRENT
I_m = MAGNETIZING CURRENT
I_1 = STATOR CURRENT.

APPROXIMATE EQUIVALENT CIRCUIT

ASSUME $E_1 = V_1$ ACCURACY 1-2%
FOR A TYPICAL MACHINE

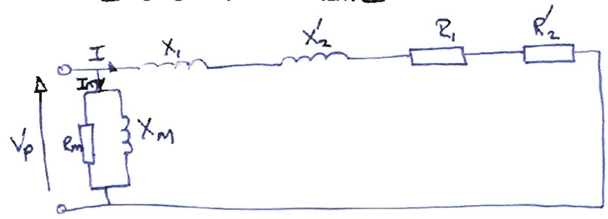


The locked rotor test is:

LOCKED ROTOR TEST

REDUCED VOLTAGE APPLIED TO INDUCTION MOTOR WITH ROTOR LOCKED TO PREVENT ROTATION.

MEASURE V_1 AT I_{RATED}



USUALLY $I_m \ll I$ as $Z_m \gg Z$

$\therefore$ IGNORE THE MAGNETIZING BRANCH

MEASURE INPUT POWER

$$\Rightarrow R_1 + R_2' = \frac{P_{LR}}{3I^2}$$

R_1 MEASURED

$\therefore R_2'$ CALCULATED

ALSO $\dfrac{V_P}{I} = \sqrt{X_T^2 + R_T^2}$ WHERE $R_T = (R_1 + R_2')$

MAY THEN FIND X_T', CAN THEN USE GIVEN EQUATIONS TO FIND MAX PULL-OUT TORQUE AT GIVEN VOLTAGE FOR MAX LOAD

b) As $V_L = 80V$, $I = 20A$, and $P=2kW$ with $R1=0.4\Omega$, then:

$R_2' = 1.27\Omega$,

Also, $X_T = 1.6\Omega$

From these values, the pull-out torque is

$$T_{PULL\text{-}OUT} = \frac{3pV_1^2}{2\pi f_1} \frac{\sqrt{R_1^2 + (X_1 + X_2')^2}}{\left(R_1 + \sqrt{R_1^2 + (X_1 + X_2')^2}\right)^2 + (X_1 + X_2')^2}$$

Therefore with a 25% reduction of supply voltage, the line voltage is 311.25V

Giving a pull-out torque of $T_{Pull\ out} = 537Nm$. If the torque is lower than this, the machine will not pull out under the worst case voltage of a 25% dip in line voltage.

Qu 4

a) Force on a wire in a magnetic field is $F=B\times I\times L$, The length of interaction of the coil and the field is $L=\pi D$, Thus, the total force is:

$$F = BI\pi DN$$

where N is the number of turns on the coil.

b) As the 'motor' constant is given by $F = (BN\pi D)I$

K_e = 10.05Nm/A, and if mechanics are dominated by the mass of coil and diaphragm, then the equivalent capacitance of this is C = M/K_e^2

This gives an equivalent capacitance of 59.7μF

The inductance of the winding is given as 172mH, therefore the resonance of the system is 49.8Hz or approximately 50Hz.

c) When the actuator is supplied by a 12V_{rms} voltage, then the current is governed in a series resonant circuit by the resistance at resonance, which is given as140Ω. This therefore gives a supply input current of 12/140 = 86mA rms.

d) The back emf of the actuator is the current across the equivalent capacitance in the equivalent circuit. As 50Hz with 86mA flowing in it, this is E = 4.6V_{rms} or 6.5V_p

$$Dist = \int_0^{10x10^{-3}} 0.65\sin(100\pi t)$$

$$= \left[\frac{0.65}{100\pi}\cos(100\pi t)\right]_0^{10x10^{-3}}$$

Therefore Dist = 4.1mm This is peak to peak displacement of the plunger. Given a plunger diameter of 50mm, the volume swept out per cycle is 8.05×10^{-6} m^3 Given 50 cycles per second, the total volume of air pumped per cycle becomes 4×10^{-4} m^3 per second. Given that 1Litre is 1000cm^3 and the volume pumped is 4×10^{2} cm^3, the volume of air pumped is 0.4L / sec which equates to 24 L/min.