ECE 431 Electric Machinery

Name: Solution

Test #1 February 26, 2020

NetID: ______________

You may use one 2-sided sheet of your own hand-written notes as reference. Calculators are allowed. Please do all work on this test. Label any solutions that are written on the backs of pages or on any spare sheets.

Q1. (30)

i. An 60Hz induction motor is rated to operate at 1120 rpm. Based on your judgment, what is:

a) the synchronous speed of this motor?

$W_s = 1200$ rpm

$1200 \times \frac{6}{2} = 60 \cdot 2\pi \cdot \frac{60}{2\pi}$

b) the number of poles?

$P = 6$

c) the rated slip?

$$S = \frac{1200 - 1120}{1200} = 6.67\%$$

d) the frequency of the rotor currents at rated speed?

$f_r = s f_s = 6.67\% \times 60 = 4\ Hz$

ii. You need an induction motor to drive a load whose torque profile is given by:

$$T_{load} = 120 + 0.015\omega_m^2$$

A 3-phase, 4 pole, line-line voltage 480 V, 60 Hz induction motor has the following parameters:

$R_1 = R_2' = 0.2\ \Omega$, $X_1 = X_2' = 0.6\ \Omega$, $X_m = 100\ \Omega$, $R_c = 200\ \Omega$

Can this induction motor start when the load is applied? (approximation is acceptable)

$$T_{start} = \frac{3 V_\phi^2 R_2'}{\frac{W_e}{P/2}\left[(R_1 + R_2')^2 + (X_1 + X_2')^2\right]} = \frac{3\left(\frac{480}{\sqrt{3}}\right)^2 (0.2)}{\frac{60 \times 2\pi}{4/2}\left[(0.2+0.2)^2 + (0.6+0.6)^2\right]} = 152.8\ Nm$$

$T_{load}(@\ W_m = 0) = 120\ Nm$

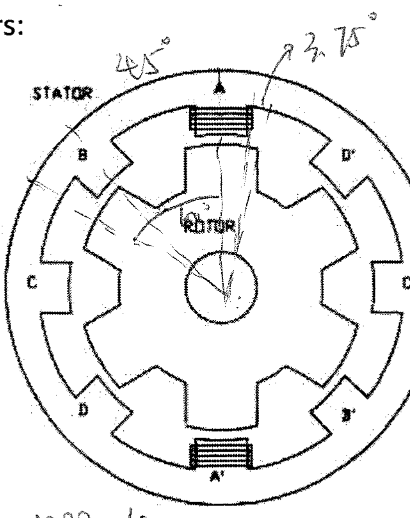
$T_{start} > T_{load}$ $\therefore$ the motor can start.

Q2. (30)

The 8/6 reluctance machine shown has the following parameters:

Rotor pole angle = $\pi/6$ rad

Stator pole angle = $\pi/8$ rad



a. What should the sequence of excitation be to obtain a half step counter clockwise rotation?

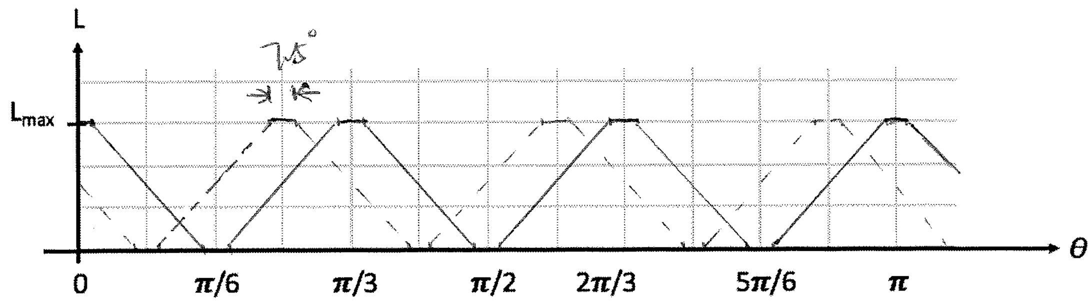
A AD D DC C CB B BA

b. How fast would the rotor spin (in rpm) if excitation is applied at a frequency of one pulse per millisecond?

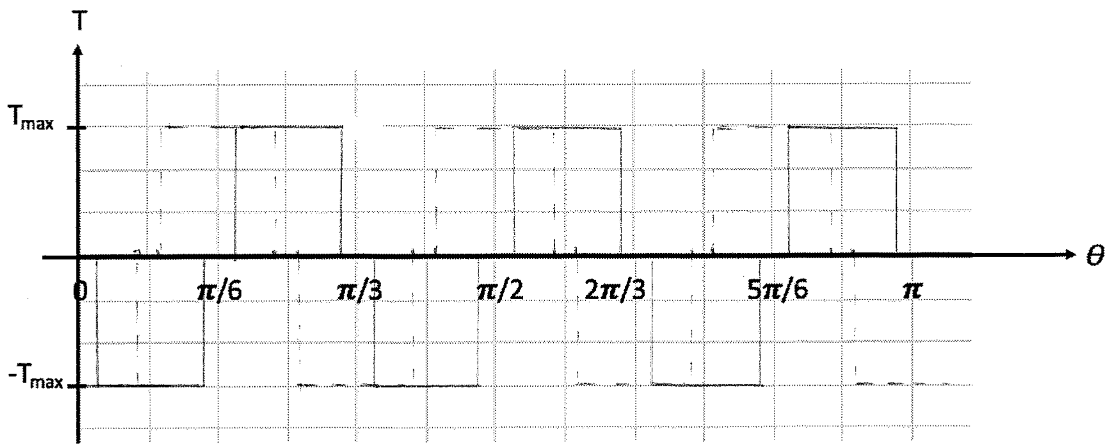
assume full step: $f = 1/ms = 1000$ Hz

$S = m N_r = 4 \times 6 = 24$ step/rev $\quad n = \frac{f}{S} 60 = \frac{1000 \cdot 60}{24} = 2500$ rpm

c. Plot the variation of phase A inductance versus rotor position, θ, measured counter clockwise starting from the position shown, from 0 to π radians. (Assume L_{max} is known). Overlay in dashed lines, the phase B inductance.



d. Plot the variation of torque versus rotor position, θ, with constant current in Phase A. (Assume T_{max} is known). Overlay in dashed lines, the variation of torque with constant current in Phase B.



→ assume half step. $n = 1250$ rpm.

(both are correct)

Q3. (20)

A single phase transformer is rated at 40KVA, 60Hz, 4160/480 V. The nameplate shows 5% series impedance. Assume low magnetizing current and negligible series resistance.

a. What is the high-side voltage magnitude needed to supply rated power to a unity power factor load at rated voltage connected to the low voltage side?

$$V_{H,pu} = V_{L pu} + I_{pu} (Z_{pu})$$

$$= 1 + 1 (j0.05)$$

$$= 1.00125 \angle 2.86^{\circ} \text{ pu}$$

$$|V_H| = V_{H pu} \cdot V_{Base} = 1.00125 \times 4160 = 4165 \text{ V}$$

b. Compute the load regulation.

$$\% \text{ reg} = \frac{V_{noload} - V_{load}}{V_{load}} = 0.125 \%$$

Q4. (20)

A balanced, 3-phase, 60 Hz, wye connected source has a line-line voltage of 4160 V-rms. It is connected to a balanced three-phase wye-connected load whose impedance is 20+j5 Ω/phase.

a. If the two –wattmeter method is used, what would each of those meters read? (voltage, current, and power)

$|V_{LL}| = 4160 \quad I_\phi = \frac{4160/\sqrt{3}}{20+j5} = 116.5 \angle -14.04^\circ \text{ A}$

$P_1 = |\bar{V}_{AB}| \cdot |\bar{I}_A| \cos(\angle \bar{V}_{AB} - \angle \bar{I}_A) = 4160 \times 116.5 \cos(30^\circ - (-14.06^\circ))$

$= 348.4 \text{ kW}$

$P_2 = |\bar{V}_{CB}||\bar{I}_c| \cos(\angle \bar{V}_{CB} - \angle \bar{I}_c) = 4160 \times 116.5 \cos(90^\circ - (120 + 14.06^\circ))$

$= 466.0 \text{ kW}.$

b. If unity power factor is wanted, should capacitors or inductors be added to the system? How much reactive power compensation should be added per phase

Capacitors should be added

$Q_{3\phi} = \sqrt{3}(P_2 - P_1) = \sqrt{3}(466 - 348.4) = 203.6 \text{ KVAR}.$

$Q_\phi = \frac{Q_{3\phi}}{3} = 67.88 \text{ KVAR}.$