ECE 431 Electric Machinery NAME: Solution

Test #1 February 17, 2016

You may use one 1-sided sheet of *your own* hand-written notes as reference.

Please do all work on this test. Label any solutions that are written on backs of pages or on this spare sheet.

Q1: _____

Q2: _____

Q3: _____

Q4: _____

Q1. (25 points):

A wye connected load is tested using the two-wattmeter method yielding the following:

Meter #1: Voltage 480 V, Power 960 W.

Meter #2: Voltage 480 V, Power 1200 W.

Assume the load is balanced, and can be represented as a series combination of resistance and reactance.

a) Compute the total three-phase real power consumed by the load.

6

$$P_{tot} = P_1 + P_2 = 960\,W + 1200\,W$$

$$= \boxed{2160\,W}$$

b) Compute the total three-phase reactive power consumed by the load.

6

$$Q_{tot} = \sqrt{3}(P_2 - P_1) = \boxed{415.69\,VAR_c}$$

c) Find the per phase resistance and reactance of the load.

7

$$R_\phi = \frac{V_{LL}^2}{P_{3\phi}} = \boxed{106.7\,\Omega}$$

$$X_\phi = \frac{V_{LL}^2}{Q_{3\phi}} = \boxed{550.26\,\Omega}$$

d) A capacitor bank is used to correct the load power factor to unity. Re-compute the Wattmeter readings.

6

Power factor unity

$$P_1 = P_2 = \frac{P_{tot}}{2} = \boxed{1080\,W}$$

Q2. (25 points):

A 400 turn coil is wound around a magnetic core with a cross-sectional area of $2cm^2$ and a mean length of 10cm. To stay below saturation limits in the core, a maximum flux density of 1.2T is selected. The permeability of the unsaturated core material is approximately 400 μ_0.

a) Calculate the inductance of the coil when the core is not saturated.

5

$$L = \frac{N^2}{\mathcal{R}} = \frac{N^2 \mu_c A_c}{l_c} = \boxed{160.85\,mH}$$

5 b) What is the maximum current the inductor can be run at to stay below saturation?

$$NI = H l_c \rightarrow I = \frac{B l_c}{\mu_c N}$$

$$I_{max} = \frac{B_{sat} l_c}{\mu_c N} = \boxed{0.59A}$$

5 c) How much energy is stored in the inductor for this maximum current?

$$W = \frac{1}{2} L I_{max}^2 = \boxed{0.029\,J}$$

10 d) How would your answer in (c) change:

(i) if the number of turns is doubled

Doesn't Change

(ii) if the core cross-section is doubled

Doubled

Q3. (25 points):

(a) A three phase transformer bank is made with three single phase transformers rated 60Hz, 50kVA transformer with voltage rating 4160/270 Volts.

3 (i) What would the rating of the transformer be if it is connected as a delta-delta transformer? Provide power and voltage ratings.

Rated S = **150 KVA**

Rated V = **4160/270v**

3 (ii) What would the rating be if the above transformer bank is operated as an open-delta, with one of the transformers taken out?

$58\% S_{rated}$ = **87 kVA**

4 (iii) What rating would you recommend if the above three phase, delta-delta transformer is installed in a 50Hz grid?

Want to keep λ constant $\rightarrow \frac{V}{f}$.

$V_{new} = \frac{50}{60} V_{old}$ = **3467/225V**

$S_{new} = \frac{50}{60} S_{old}$ = **125kVA**

b) A single-phase transformer is rated at 25kVA, 13800V/480V. The nameplate shows 5% series impedance. Assume low magnetizing current and negligible resistances.

10 (i) What is the high-side voltage magnitude needed to supply rated power to a unity power factor load at rated voltage connected to the LV side?

$$V_H = 1_{pu} + 1_{pu}(j0.05) = 1.00125 \angle 2.86^\circ \quad (pu)$$

$$\therefore |V_H| = 13800 \cdot 1.00125 = \boxed{13817\ V}$$

5 (ii) Compute the load regulation for this case.

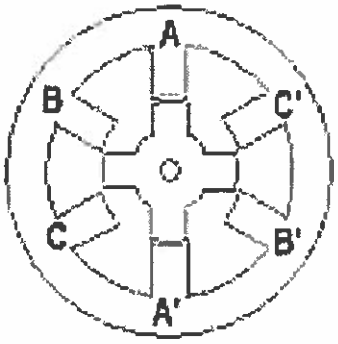
$$\% \text{ reg} = \frac{V_{noload} - V_{load}}{V_{load}} = \boxed{0.123\%}$$

Q4. (25 points)

A reluctance machine has a three-phase 6-4 configuration, shown, and has the following properties:

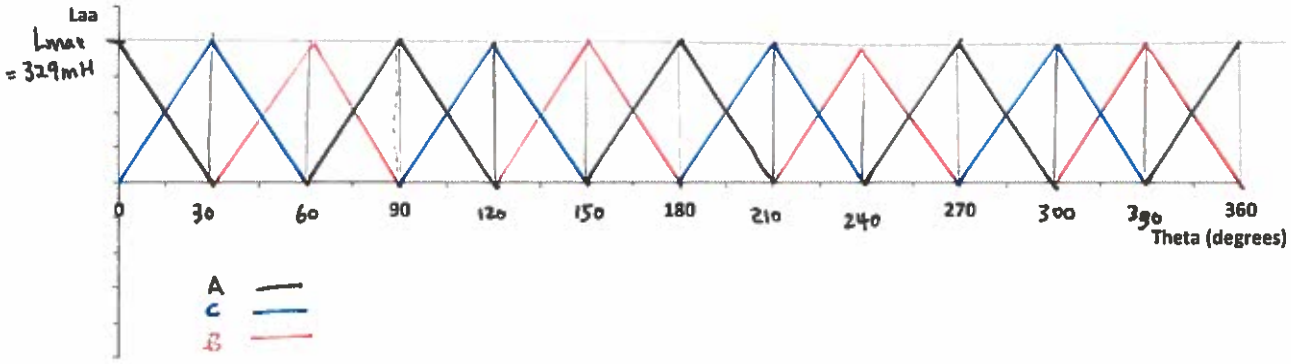
- Stator pole angle 30^0
- Stator turns 100 turns per pole
- (200 turns per phase)
- Rotor pole angle 30^0
- Air gap 0.2 mm
- Rotor outer radius 5 cm
- Length 10 cm

Assume permeability of the core and rotor parts to be extremely high.



a) Plot the self inductance of phase 'A' as a function of rotor position, theta, starting in the position shown and rotated counter-clockwise. Superimpose with dashed lines and label the self inductance of phases 'B' and 'C'.

7



b) Assuming only one phase is excited at a time, how many steps per revolution do you get?

4

$$S = mN_r = \boxed{12 \text{ steps/rev}}$$

c) Starting from the position shown, what should the sequence of excitation be to obtain a clockwise rotation?

4

$$B \rightarrow C \rightarrow A$$

d) What is the maximum torque you can obtain with a 10A current limit?

10

$$T_{max} = \frac{1}{2} I^2 \left(\frac{\partial L_{max}}{\partial \theta}\right) = \frac{1}{2} I^2 \frac{L_{max}}{\pi/6} = \boxed{31.4 \text{Nm}}$$

where $L_{max} = \frac{N^2}{\mathcal{R}} = \frac{N^2 \mu_0 [\alpha D L]}{2g} = 0.329\text{H}$