OCD069

UNIVERSITY OF BOLTON

WESTERN INTERNATIONAL COLLEGE FZE

BENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING

SEMESTER TWO EXAMINATION 2018/2019

ELECTRICAL MACHINES AND POWER ELECTRONIC DRIVES

MODULE NO: EEE6011

Date: Thursday 30th May 2019 **Time: 10:00am – 12:30pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer any FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Q1

(a) The open circuit and short circuit tests on a 10 KVA, 125/250 V, 50 Hz, single phase transformer shows the following results:

O.C. test: 125 V, 0.6 A, 50 W (on Low Voltage side)
S.C. test: 15 V, 30 A, 100 W (on High Voltage side)

(i) Draw the equivalent circuit of the transformer referred to both Low Voltage and High Voltage sides

(6 marks)

(ii) Calculate copper loss on full load, full load efficiency at 0.8 leading power factor (P.F.), half load efficiency at 0.8 leading P.F. and full load regulation at 0.9 leading P.F.

(4 marks)

(b) A 5kVA, 200 V/ 100 V, 50 Hz, single phase ideal two winding transformer is connected as an autotransformer to step up a voltage of 200 V to 300 V.

(i) Show the connection diagram to achieve this.

(2 marks)

(ii) Calculate the maximum kVA that can be handled by the autotransformer (without over loading any of the HV and LV coil).

(2 marks)

(iii) Analyse kVA that is transferred magnetically and transferred by electrical conduction.

(2 marks)

(c) Analyse the term “All Day Efficiency” and critically evaluate the various losses in a transformer

(9 marks)

Total 25 marks

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Q2

(a) A 220 V DC Shunt motor has armature and field resistances of 0.2 Ω and 220 Ω respectively. The motor is running at 1000 rpm drawing 10 A current from the supply. Making use of appropriate equivalent circuits and neglecting armature reaction & saturation, determine the new speed and armature current for the following cases.

(i) An external armature resistance of value 5 Ω is inserted in the armature circuit. Assume constant load torque.

(10 marks)

(ii) An external armature resistance of value 5 Ω is inserted in the armature circuit and motor is driving load torque, $T_L \propto n^2$.

(4 marks)

(iii) The field resistance is increased by 5%. Assume constant load torque.

(4 marks)

(b) Analyse the effect of armature flux on main field flux for a dc machine with the help of necessary diagrams.

(7 marks)

Total 25 marks

Q3

(a) A 2-pole, 120V, 60 Hz, single-phase induction motor is running at 3420 rpm. The equivalent circuit parameters are: $R_1 = 3.5\Omega$, $R_2 = 3.2\Omega$, $X_1 = 4.1\Omega$, $X_2 = 4.1\Omega$, $X_m = 80\Omega$, $P_{rot} = 42.5W$. Calculate,

(i) slip, input current, input power, power factor

(4 marks)

(ii) Output power and efficiency.

(2 marks)

(b) The data given below are taken from a no-load, blocked rotor, and DC tests of a 3-phase, wye connected, 440 V, 50 Hz, 4 Pole induction motor. Assume motor is NEMA Design A.

- No-load test: Line voltage = 440 V, Line current = 1.5 A and Input power = 600 W (of which 200 W is windage and friction loss)
- Blocked-rotor test: Line voltage = 70 V, Line current = 7.5 A and Input power = 600 W
- DC Test: Per Phase stator resistance = 2 Ω

(i) Calculate the motor parameters and draw the approximate equivalent circuit.

(8 marks)

(ii) Analyse the total current drawn by the motor if the slip is 0.05.

(3 marks)

(c) Single phase induction motors are not self-starting, justify the statement and analyse any three methods used to make it self-starting.

(8 marks)

Total 25 marks

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Q4

A 40 KVA, 600 V, 3 phase, star connected synchronous machine having a synchronous reactance of 8 Ω when excited to a phase voltage of 600 V, carry an armature current of 40 A. Analyse the power factor, power input and draw phasor diagrams when the machine is operating as

(i) Generator

(3 marks)

(ii) Motor

(3 marks)

(b) A 10 KVA, 400 V, 4-pole 50 Hz, 3-phase star-connected synchronous alternator has negligible armature resistance and synchronous reactance of 16 Ω/phase.

(i) Determine the per phase excitation voltage and power angle when the machine is delivering rated KVA at 0.8 lagging PF.

(4 marks)

(ii) Analyse stator current, power factor and power angle if machine excitation is increased by 20% while supplying same real power as in (i).

(4 marks)

(iii) The load on machine is increased till the steady state limit is reached (90^0) with field current fixed as in (i). Calculate the maximum power delivered by the machine, stator current and power factor. Draw the phasor diagrams.

(4 marks)

(c) Analyse construction, principle of operation and applications of Stepper motor.

(7 marks)

Total 25 marks

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Q5

(a) A 3φ full converter is used to control the speed of a 100 HP, 600 V, 1800 rpm, separately excited DC motor. The converter is operated from a 3φ, 480 V, 60 Hz star-connected supply. The motor parameters are Ra = 0.1 Ω, La =5 mH, KΦ = 0.3V/rpm (E_a =KΦN). The rated armature current is 130 A and width 120^0.

(i) Determine the firing angle and supply power factor when the machine is operated as a rectifier (or motor) that draws rated current and runs at 1500 rpm. Assume that motor current is ripple-free. (5 marks)

(ii) Calculate the firing angle, power factor and power fed back to the supply if the dc machine is operated in regenerative breaking mode drawing rated motor current and running at 1000 rpm. (4 marks)

(b) A 220V, 20A 1500 RPM separately excited dc motor has an armature resistance of 0.75Ω and inductance of 50 mH. The motor is supplied from a single phase fully controlled converter operating from a 230 V, 50 Hz, single phase supply. Assume continuous conduction and ripple free armature current.

(i) If the firing angle α is 30°, analyse at what speed the motor will supply full load torque. (3 marks)

(ii) If the speed of the dc motor is controlled by varying the firing angle of the converter while the load torque is maintained constant at the rated value, determine the “power factor” of the converter as a function of the motor speed. (3 marks)

(c) Analyse the following operational circuits and provide appropriate figures

(i) Controlled rectifier (5 marks)

(ii) Inverters (5 marks)

Total 25 marks

END OF QUESTIONS

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University of Bolton
Western International College FZE
BEng (Hons) Electrical & Electronic Engineering
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EQUATION SHEET

TRANSFORMERS:

$\cos \phi_0 = W_0 / (V_1 I_0)$

Active component, $I_w = I_0 \cos \phi_0$

Reactive component, $I_m = I_0 \sin \phi_0$

Parallel branch parameters - Low Voltage side (O.C. test) : $R_{op} = V_1/I_w$, $X_{op} = V_1/ I_m$

Series branch parameters - High voltage side (S.C. test): $R_{02} = W_{sc}/ I_{sc}^2$, $Z_{02} = V_{sc}/I_{sc}$,

$X_{02} = \sqrt{(Z_{02}^2 - R_{02}^2)}$

$K = V_2 / V_1$

Series branch parameters - Low Voltage side: $R_{01} = R_{02} / K^2$, $X_{01} = X_{02}/ K^2$

Parallel branch parameters - High Voltage side: $R_{os} = R_{op} \times K^2$, $X_{os} = X_{op} \times K^2$

Efficiency, $\eta = V_2 I_2 \cos\phi / (V_2 I_2 \cos\phi + P_{core} + P_{copper})$

% regulation = $(I_2 R_2 \cos\phi - I_2 X_2 \cos\phi)/V_2$

DC MACHINES:

DC Shunt Motor :

$V_{sh} = I_{sh} R_{sh}$

Torque, $T = K_t I_{sh} I_a$

Back Emf, $E_b = K_b I_{sh} N$, $E_b = V - I_a R_a$

INDUCTION MOTOR:

Synchronous Speed, $N_s = 120f/p$

Slip, $S = (N_{sync} - N_{motor})/N_{Sync}$

Equation sheet continued over page

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Equation sheet continued

$$Z_{in} = Z_1 + \left(\frac{Z_f + F_b}{2}\right)$$

$$Z_1 = R_1 + jX_1$$

$$Z_f = \frac{jX_m\left(\frac{R_2}{s} + jX_2\right)}{\frac{R_2}{s} + j(X_2 + X_m)}$$

$$Z_f = R_f + jX_f$$

$$Z_b = \frac{jX_m\left(\frac{R_2}{(2-s} + jX_2\right)}{\frac{R_2}{(2-s)} + j(X_2 + X_m)}$$

$$Z_b = R_b + jX_b$$

$$I_1 = \frac{V_1}{Z_{in}}$$

$$P_{in} = V_1 I_1 \,\mathrm{pf}$$

$$P_{conv} = \frac{1}{2} I_1^2 (1-s)(R_f - R_b)$$

$$P_{out} = P_{conv} - P_{rotational}$$

$$\eta = \frac{P_{out}}{P_{in}}$$

IEEE Equivalent Circuit: Single Phase Induction Motor

$I_{in} = V_{in} / Z_{in}$

From No-load test: $R_{NL} = P_{NL}/I^2_{NL}$, $Z_{NL} = V_{NL}/I_{NL}$, $X_{NL} = \sqrt{(Z^2_{NL} - R^2_{NL})}$, $X_{NL} = X_1 + X_m$

From blocked rotor test: $R_{BR15} = P_{BR15}/I^2_{BR15}$, $Z_{BR15} = V_{BR15}/I_{BR15}$, $X_{BR15} = \sqrt{(Z^2_{BR15} - R^2_{BR15})}$

$X_{BR60} = X_{BR15} * (60/15)$, $R_{BR15} = R_1 + R_2$, $X_{BR60} = X_1 + X_2$

R_1 is the stator resistance obtained from DC test.

Design Type	A, D	B	C	Wound Rotor
X_1	$0.5 \cdot X_{BR60}$	$0.4 \cdot X_{BR60}$	$0.3 \cdot X_{BR60}$	$0.5 \cdot X_{BR60}$
X_2	$0.5 \cdot X_{BR60}$	$0.6 \cdot X_{BR60}$	$0.7 \cdot X_{BR60}$	$0.5 \cdot X_{BR60}$

SYNCHRONOUS MACHINES:

Generator, $E_f = V_t + I_a jX_s$

Motor, $E_b = V_t - I_a jX_s$

Input Power, $P_{in} = 3\, V_{ph} I_{ph} \cos\phi$

$P_e = E_f V_t \sin\delta / X_s$

$P_{e,max} = 3\, E_f V_t / X_s$

Equation sheet continued over page

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Equation sheet continued

POWER ELECTRONIC DEVICES:

Star Connection: $V_{phase} = V_L/\sqrt{3}$, $I_{phase} = I_L$

Motor , $V = E_b + I_a R_a$

$I_A = (I^2 * \text{width in radians}/\ \pi)^{1/2}$

Supply Volt Amperes, $S = 3\ V\ I_A$

Power from supply, $P = VI$

Supply Power Factor = Power from supply/Supply Volt Amperes

Three phase full converter $V_0 = \frac{3\sqrt{6}}{\pi} V_p \cos\alpha$

Single phase full converter, $V_0 = \frac{2\sqrt{2}}{\pi} V_i \cos\alpha$

$$V_a = r_a\ I_a\big|_{rated} + E_b\big|_{rated} \frac{N}{N_{rated}}$$

$$pf = \frac{2\sqrt{2}}{\pi} \cos\alpha$$

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