[ENG16]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) ELECTRICAL & ELECTRONIC ENGINEERING

SEMESTER ONE EXAMINATION 2021/2022

ELECTRICAL MACHINES & POWER ELECTRONIC DRIVES

MODULE NO: EEE6011

Date: Monday 10th January 2022 **Time: 14:00 – 16:30**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

CANDIDATES REQUIRE: **Formula Sheet (attached from page 7).**

Question 1

(a) classify DC machines in terms of its field excitation method **[5 marks]** and briefly explain the characteristics of a differential compound DC generator **[3 marks]**.

(b) Explain with drawings DC machine armature reaction and show its cross and demagnetizing components. How do we overcome the demagnetising and cross magnetising effects of armature reaction? **[5 marks]**

(c) A shunt DC motor has the following parameters:

Supply voltage=120 V., speed=1500 RPM, line current=51 A., shunt-field resistance=120 Ω, armature resistance=0.1 Ω. Calculate the following:

(i) The current in the armature. **[3 marks]**

(ii) The armature back EMF. **[3 marks]**

(iii) The mechanical power, efficiency and torque developed by the motor [**6 marks]**

Total 25 marks

Question 2

(a) Answer the following questions detailing the reasons:

I. Is it true that open-circuit power-factor angle is greater than short-circuit power-factor angle of good transformer? **[3 marks]**

II. Is it true that open-circuit power-factor angle is close to 90 degrees of a good transformer? **[3 marks]**

III. Copper losses are equal to iron losses at maximum efficiency. **[3 marks]**

(b) A 200-kVA single-phase transformer with a voltage ratio 6350/660 V has the following test results:

No load test: 6350 V., 0.86 A. at a power factor of 0.263 lagging.

Short-circuit test: 50 V, 8.8 A., and 240 W.

(i) Calculate the equivalent-circuit parameters referred to the high-voltage winding.

[7 marks]

(ii) Calculate transformer efficiency **[4 marks]** and voltage regulation at 50% full load with 0.85 power factor lagging **[5 marks]**.

Total 25 marks

Question 3

(a) For a 3-phase synchronous generator connected to a large power system bus with voltage V, prove that its active power injected to the bus is:

$P = \frac{EV}{X_S} \sin \delta$ Where E is the internal induced voltage, X_s is the synchronous reactance and δ is the load angle. Assume the armature resistance $R_A \ll X_S$ that can be neglected. **[6 marks]**

(b) Draw the voltage, current and flux phasor diagram of a 3-phase synchronous generator loaded with inductive load. Explain the effect of armature reaction on the field flux. **[4 marks]**

(c) A 3-phase, 100-hp, 440-V, star-connected synchronous motor has a synchronous impedance per phase of 0.1 +j1.0 ohm. The excitation and torque losses are 4 kW and may be assumed constant. Calculate:

(i) The line current; **[8 marks]**

(ii) Power factor and; **[2 marks]**

(iii) Efficiency when operating at full load with an excitation equivalent to 400 line volts. **[5 marks]**

Total 25 marks

Question 4

(a) Explain how a 3-phase induction motor develops a rotating magnetic flux and rotation? **[10 marks]**

(b) A 500-V, 3-phase, 50 Hz, 8-pole, star-connected induction motor has the following equivalent-circuit parameters: R_1=0.13, R_2=0.32, X_1=0.6, X_2= 1.48 (all in ohms), magnetising branch admittance Ym = 0.004-j0.05 Ω^{-1} referred to primary side. The full-load slip is 5 %. Using the exact equivalent circuit determine:

(i) the full-load electromagnet torque; **[7 marks]**

(ii) stator input current and power factor; and **[3 marks]**

(iii) Efficiency. **[5 marks]**

The effective stator/rotor turns ratio per phase is 1/1.57. Neglect mechanical loss.

Total 25 marks

Question 5

(a) Explain briefly how a single-phase induction motor can produce a revolving flux and rotation. **[10 marks]**

(b) A 2.5 kW, 120 V, 60 Hz, capacitor-start motor has the following impedances for the main and auxiliary windings (at starting):

$\mathbf{Z}_{main}$=4.5+j3.7 Ohms, $\mathbf{Z}_{auxiliary}$=9.5+j3.5 Ohms

i. Find the value of starting capacitance that will place the main and auxiliary currents in quadrature at starting. **[10 marks]**

ii. Draw the circuit diagram of this motor and its phasor diagram showing the voltage and currents of this motor. **[5 marks]**

Total 25 marks

Question 6

(a) Explain with drawings how a separately excited DC motor speed can be controlled by changing the magnetic field and using power electronic drives.

[12 marks]

(b) Explain with drawings how the speed of a 3-phase induction motor can be controlled by changing the voltage and frequency at the same time using power electronic drives. **[13 marks]**

Total 25 marks

END OF QUESTIONS

Formula sheets follow over the page….

Formula sheet

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

DC Machines

$E=V+I_A.R_A$ (Generator voltage equation)

$E=V- I_A.R_A$ (Motor voltage equation)

$K_e=K_t=(2pCN/a)$, $E=K_e.\omega.\Phi$, $T=K_t.I_A.\Phi$

$P_{conv} = E.I_A = \omega.T$

Transformers and Induction motors

Transformer voltage ratio: $\frac{E_1}{E_2} = \frac{N_1}{N_2}$, V.R=$\frac{I.R_{eq} \mp I.X_{eq}}{E}$X100%, $\eta = \frac{P_o}{P_{in}} X100\%$

Secondary parameters referred to primary side: $R_2' = (\frac{N_1}{N_2})^2 R_2$, $X_2' = (\frac{N_1}{N_2})^2 X_2$,

$I_2' = \frac{N_2}{N_1} I_2$, $V_2' = \frac{N_1}{N_2} V_2$, $P = \sqrt{3} V_L I_L \cos\theta$, $Q = \sqrt{3} V_L I_L \sin\theta$

$slip\ \ s = \frac{n_s - n_r}{n_s}$, $\boxed{P_{AG} = 3I_2^2 \frac{R_2}{s}}$, $\boxed{P_{conv} = 3I_2^2 R_2\left(\frac{1-s}{s}\right)}$, $\boxed{P_{core} = 3E_1^2 G_C}$,

$\tau_{ind} = \frac{(1-s)P_{AG}}{(1-s)\omega_{sync}}$

$\boxed{\tau_{ind} = \frac{P_{AG}}{\omega_{sync}}}$

Synchronous machines

Voltage vector equation: E =V + I.Z

Power equations: P= $\frac{EV}{Z}\cos(\psi - \delta) - \frac{V^2}{Z}\cos(\psi)$, Q= $\frac{EV}{Z}\sin(\psi - \delta) - \frac{V^2}{Z}\sin(\psi)$

For generator

$P_{in} = \tau_{app}\omega_m$, $P_{conv} = \tau_{ind}\omega_m = 3E_A I_A \cos\gamma$,

$P = \sqrt{3} V_L I_L cos\theta$

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For motor the above equations will be used in the reversed order.

Motor Drives

The rotor terminals ac voltage with the open-circuit rotor voltage at standstill, $E = sE_{oc}$

The rectified output voltage $E_d = 1.35\ E$

$$s = \frac{E_2}{1.35 E_{OC}}$$

DC Voltage developed by the inverter $E_2 = 1.35\ E_T cos\alpha$

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