[ESS33]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) ELECTRICAL & ELECTRONIC ENGINEERING

SEMESTER ONE EXAMINATION 2019/2020

ELECTRICAL MACHINES & POWER ELECTRONIC DRIVES

MODULE NO: EEE6011

Date: Monday 13th January 2020 **Time: 14:00 – 16:00**

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).**

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Question 1

(a) Explain with drawings why a DC machine armature produces cross- and demagnetizing- armature reactions. How do we overcome these two components of armature reaction in a practical DC machine? **[8 marks]**

(b) 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; **[4 marks]**

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

(iii) The mechanical power and torque developed by the motor; **[4 marks]**

(iv) The starting current and the starting resistance required to limit this current to 30 A. ;and **[4 marks]**

(v) the efficiency. **[2 marks]**

Total 25 marks

Question 2

a) 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. **[12 marks]**

(ii) Calculate transformer efficiency **[6 marks]** and voltage regulation at 50% full load with 0.85 power factor lagging **[7 marks]**.

Total 25 marks

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Question 3

(a) Draw the voltage, current and flux phasor diagram of a 3-phase synchronous generator loaded with inductive load indicating the different voltage drops and fluxes. Explain the effect of armature reaction on the field flux.

[8 marks]

(b) 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 **[3 marks]**

(iii) Efficiency when operating at full load with an excitation equivalent to 400-line volts **[6 marks]**

Total 25 marks

Question 4

a) Explain how the rotating field can be developed in a 3-phase induction motor and its effect on the motor rotor? **[9 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 %. You may use the simplified equivalent circuit. Determine:
   (i) stator input current and power factor; **[7 marks]**
   (ii) the full-load electromagnet torque; and **[3 marks]**
   (iii) Efficiency. **[6 marks]**

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

Total 25 marks

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Question 5

(a) Explain briefly how a capacitor added in series with the auxiliary winding of a split-phase single-phase induction motor can improve the starting torque.

[8 marks]

(b) A 200 W, 110 V, 50 Hz, 4-pole, capacitor-start motor has the following equivalent circuit parameter values (in ohms) and losses:

$R_{1,main} = 2.02, X_{1,main} = 2.79 , R_{2,main} = 4.12 , X_{2,main} = 2.12, X_{m,,main} = 66.8$

Core loss=30 W, Friction and windage loss=18 W.

When this motor is running as a single-phase motor at rated voltage and frequency with its starting winding open and for a slip of 0.05, determine:

(i) The stator current and power factor; **[8 marks]**

(ii) Power output, speed, and torque and **[7 marks]**

(iii) Efficiency **[2 marks]**

Total 25 marks

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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

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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: $R_2' = (\frac{N_1}{N_2})^2 R_2$, $X_2' = (\frac{N_1}{N_2})^2 X_2$,

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

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

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

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

$$Z_f = R_f + jX_f = \frac{jX_m\left(R'_2/s + jX'_2\right)}{jX_m + \left(R'_2/s + jX'_2\right)}$$

$$Z_b = R_b + jX_b = \frac{jX_m\left(R'_2/(2-s) + jX'_2\right)}{jX_m + \left(R'_2/(2-s) + jX'_2\right)}$$

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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

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

$P=\sqrt{3}V_LI_Lcos\theta$

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

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

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

END OF FORMULA SHEET