UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: Aug/Sep 2018

Module Number: ME 5302 **Module Name: Electrical power and machines**

[Three Hours]

[Answer **all questions**, each question carries **twelve** marks]

Q1 a) The following Figure Q1 shows a part of an electromechanical actuator (not in scale) in which the direction of flux is FA direction as shown. The coil wound around FA link has 6500 turns. The mean length of AB, BC and BE sections are 15 cm, 20 cm and 25 cm respectively. The magnetic core has uniform cross sectional area of 3 cm^2. The relative permeability of the material used is 1000 and the permeability of free space is $\mu_0 = 4\pi \times 10^{-7} Hm^{-1}$.

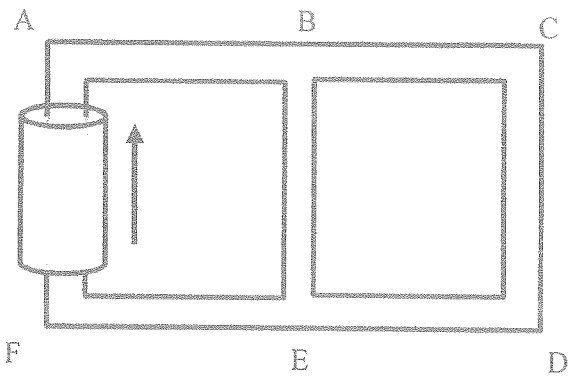

Figure Q1

I) Copy the Figure 1 to your answer script and show the direction of current in the coil and direction of flux in BE and CD branches.

[1.0 Mark]

II) Calculate the reluctance of BE and BCDE sections.

[1.0 Mark]

III) If a magnetic flux of 12 mWb is observed in the BCDE section, Calculate the flux density in AF section.

[3.0 Marks]

IV) Calculate the current in the coil when the flux in BCDE link is 12 mWb.

[2.0 Marks]

V) State any assumptions you made for above calculations.

[1.0 Mark]

b) You are assigned to develop a propulsion system of a vertical takeoff and landing capable unmanned aircraft having a total lift off weight of 5kg. The design team decided to use four motors to drive four rotors (fans) mounted on wing tips. Propose suitable motor and controller types for this application? Explain reasons for your selection and mention four merits of the types you selected compared to other types.

[4.0 Marks]

Q2 a) A Δ/Y connected three-phase step down transformer is rated as 180/33 kV, 50 Hz and 15 MVA. Primary and secondary resistance per phase is 5 Ω and 0.07 Ω respectively. The percentage voltage drop due to impedance is 1%.

I) Calculate full load secondary current.

[1.0 Mark]

II) Calculate the equivalent resistance per phase referred to secondary.

[1.0 Mark]

III) Calculate the equivalent reactance per phase referred to secondary.

[2.0 Marks]

IV) Calculate the secondary line voltage at full load when power factor is 0.8 lagging.

[1.0 Mark]

V) Calculate percentage voltage regulation.

[1.0 Mark]

b) A single-phase transformer on full load has a drop of 26 V due to impedance and drop of 6 V due to resistance. Calculate the power factor of this transformer when the voltage regulation is zero and state whether the obtained power factor is lagging or leading.

[3.0 Marks]

c) Briefly explain two tests used to identify the values for the parameters of a transformer. What are the major losses that can be identified during each test? In your answer explain why the stated test is suitable to identify stated loss, how each test is performed and the equipment used.

[3.0 Marks]

Q3 a) A shunt DC motor has rated no load speed of 1800 rpm. The rated supply voltage is 96 V. This motor operates at 1200 rpm at full load, while having full field and reduced armature voltage of Vr (i.e. Motor was operated at a voltage lower than 96 V). When the load reduced to 50% of its full load torque while having full field (i.e. field flux was not changed) and reduced armature voltage of Vr, the speed increased to 1240 rpm. Neglecting the effect of armature reaction,

I) Calculate no load, full load and, 50% full load back emf of the motor.

[2.0 Marks]

II) Calculate armature voltage drop at the full load torque.

[4.0 Marks]

b) A DC series motor has 1.2 Ω terminal resistance and runs at 3000 rpm at 48 V while drawing 3 A current.

I) Calculate the back emf.

[1.0 Mark]

Q3. is continued to next page

II) The motor was connected to a 2.4 Ω external resister in series. If the supply voltage and current remained unchanged, calculate the new speed of the motor.

[2.0 Marks]

III) If the load torque is 0.52 Nm when operated with series resistor, calculate efficiency of the motor.

[1.0 Mark]

c) Briefly explain regenerative braking mode of a DC motor. Using suitable sketches show the direction of currents and the voltages.

[2.0 Marks]

Q4 a) An induction motor has following data indicated in its name tag.
Rated power 100 kW,
3-phase, 50 Hz,
12 poles,
Rotor impedance is $0.05 + 0.4j$ at stand still (locked rotor condition)
If the full load torque is obtained at 450 rpm, calculate,

I) the ratio of maximum to full load torque.

[2.0 Marks]

II) speed at which the maximum torque can be obtained.

[1.0 Mark]

III) the resistance to be added to the rotor to get maximum starting torque.

[1.0 Mark]

b) Specifications of an induction motor are 100 kW, 380 V, 3-phase, 60Hz, Star-Connected stator and rotor, 6 poles, stator to rotor phase voltage ratio is 2:1. The stator impedance per phase is 0.2+0.5j Ω and the rotor impedance per phase is 0.04+0.12j Ω. If an external resister of 1.5 Ω are inserted to each phase of the rotor to start the motor, calculate,

I) the synchronous speed of the motor.

[1.0 Mark]

II) the total motor impedance per phase after inserting the external resistor referred to the rotor.

[1.0 Mark]

III) the rotor current.

[2.0 Marks]

IV) the total rotor circuit copper loss for all 3 phases while inserted resisters are still in place.

[1.0 Mark]

c) Explain how the maximum torque of a 3-phase induction motor can be increased during the motor design. Explain two limitations of such measures.

[3.0 Marks]

Q5. is in next page

Q5 a) A star connected synchronous generator is rated as 30 kVA, 380V, 3-phase, and 60Hz. The effective armature resistance per phase is 0.2 Ω, the synchronous reactance per phase is 2.8 Ω and the leakage reactance per phase is 0.4 Ω. The machine is operating at rated load and unity power factor.

I) Draw the per phase equivalent circuit and indicate all the parameters of the circuit.

[1.0 Mark]

II) Draw the phasor diagram corresponding to the generator which is operating at rated load and unity power factor.

[2.0 Marks]

III) Calculate the internal EMF per phase. (i.e. the EMF excluding the drop due to the armature reactance)

[2.0 Marks]

IV) Calculate no-load EMF per phase and no-load line EMF.

[2.0 Marks]

V) Calculate percentage voltage regulation on full load.

[2.0 Marks]

b) Briefly describe two major types of construction of synchronous generators. Include their applications, features and properties in your answer.

[3.0 Marks]