UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: August 2015

Module Number: ME 5302 **Module Name: Electrical Power and Machines**

[Three Hours]

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

Q1. a) Apply Ampere's law to derive the expression for reluctance of the magnetic core shown in Figure Q1(a). State all the assumptions used.

[4.0 Marks]

b) A core with three legs is shown in Figure Q1(b) with the necessary dimensions. What current is required to produce a flux density of 0.1 T in the left leg of the core? The relative permeability of the core is 1500 and is assumed to be constant. Assume a five percent increase in the effective area of the air gaps due to fringing effects.

[4.0 Marks]

c) Explain how regenerative braking helps electric or hybrid vehicles be more efficient.

[4.0 Marks]

Q2. A 400 V, 25-kW, 50-Hz, 4-pole, Y-connected three phase induction motor has the following impedances in ohms per phase referred to the stator circuit as shown in Figure Q2: $R_1 = 0.1\ \Omega$, $R_2 = 0.05\ \Omega$, $Rc = 100\ \Omega$, $X_1 = 0.15\ \Omega$, $X_2 = 0.2\ \Omega$, and $X_M = 7\ \Omega$. Above impedances were measured at the rated frequency of 50 Hz. The total rotational losses were estimated to be 1.0 kW and are assumed to be constant. The rated slip of the motor is 2.0%. The motor is driven by a variable frequency drive (VFD) which maintains its output voltage to frequency ratio a constant of 8 V/Hz.

a) Calculate the frequency of the VFD that gives 1000 RPM at 2.0% slip. What is the VFD output phase voltage at this frequency?

[3.0 Marks]

b) Calculate the load torque output in N.m at 1000 RPM with 2.0% of slip when the motor is driven by the VFD with the frequency calculated in (a).

[3.0 Marks]

c) Calculate the approximate value of motor speed in RPM, when the load torque is two times the value in (b) and the VFD setting is unchanged. State your assumption(s).

[3.0 Marks]

d) Give two advantages of using a VFD to drive an induction motor.

[3.0 Marks]

Q3. A 30-kVA 6350-V/230-V stepdown transformer, whose equivalent circuit is shown in Figure Q3, has an impedance referred to the primary of $R_{eq} = 80\ \Omega$ and $X_{eq} = 300\ \Omega$. The components of the excitation branch referred to the primary side are $R_c = 350\ k\Omega$ and $X_M = 70\ k\Omega$.

a) If the primary voltage is 10990 V and a load with impedance of $Z_L = 6.0 + j\ 2.5\ \Omega$ is connected, what is the secondary voltage of the transformer?

[4.0 Marks]

b) If a capacitor of -j15 Ω is connected in parallel with the load, what is the new secondary voltage of the transformer?

[4.0 Marks]

c) Describe the advantages of having a capacitor bank connected to an inductive load system supplied by the main power grid.

[4.0 Marks]

Q4. A separately excited DC generator is used to generate electricity from a water wheel turbine and charge a battery as shown in Figure Q4(a). The circuit of the generator and the battery is shown in Figure Q4(b). The ratio of the generator shaft speed to the water wheel shaft speed is 100 and the gear unit has negligible losses. The generator is rated to produces a no load terminal voltage of 90 V at the generator shaft speed of 1500 RPM for a field current of 20 A. The armature reaction is negligible.

a) Find the no load terminal voltage of the generator for a field current of 20 A when the water wheel turns at 10 RPM.

[2.0 Marks]

b) For a field current of 20 A, calculate the armature current I_a that would apply a torque of 7500 N.m on the water wheel shaft.

[3.0 Marks]

c) Calculate the generator terminal voltage $V_{terminal}$ for the condition in part (b) above, if the water wheel turns at 10 RPM.

[3.0 Marks]

d) Calculate the value of R_{adj} that would set the terminal voltage $V_{terminal}$ to 36 V when the water wheel produces 7500 N.m at 10 RPM. Clearly state your assumptions.

[4.0 Marks]

Q5. a) Briefly explain two starting methods used in single phase induction motors. What is your choice for a low cost application that does NOT require large starting torque?

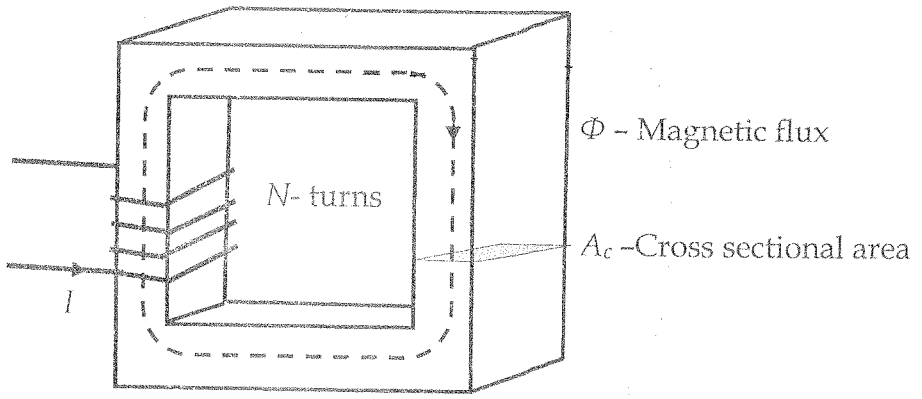
[4.0 Marks]

b) Briefly describe the DC shunt motor and the DC series motor by drawing their equivalent circuits. What is your choice for an application requiring a very large starting torque?

[4.0 Marks]

c) A synchronous generator with no-load frequency of 51.0 Hz and a slope of 0.5 MW/Hz is connected to a load consuming 2 MW of real power. After a second load consuming real power of 1 MW is connected to the generator, a change in frequency was noticed. What value of no load frequency setting would restore the system frequency?

[4.0 Marks]



l_c – Mean magnetic path length μ_r – Relative permeability of core

Figure: Q1(a)

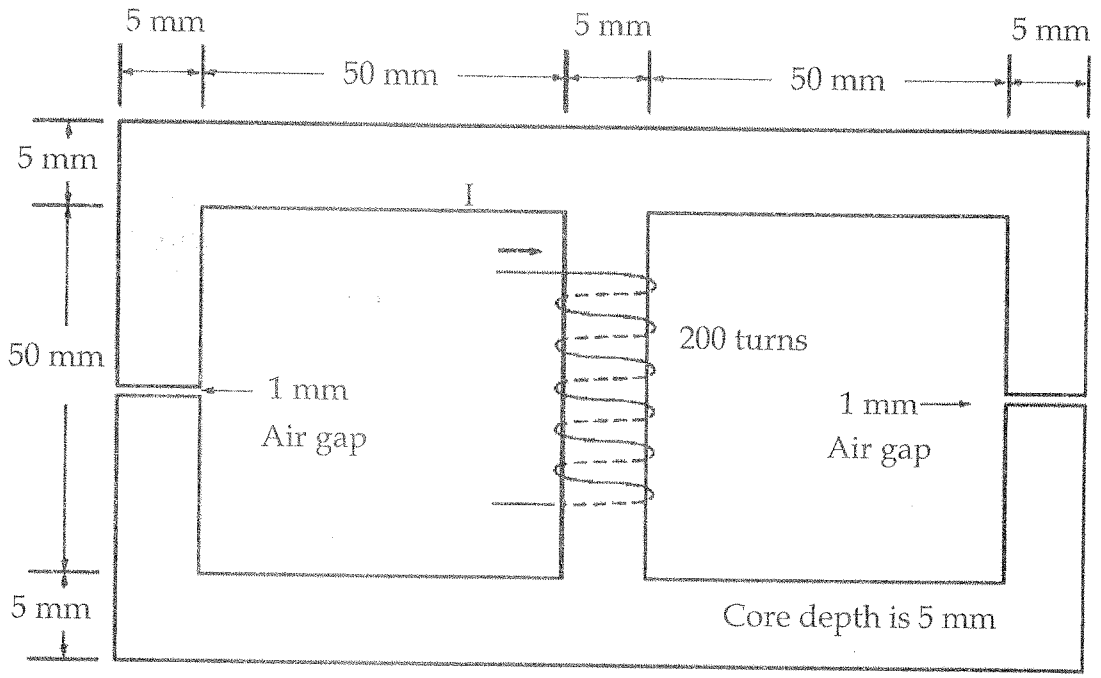


Figure: Q1(b)

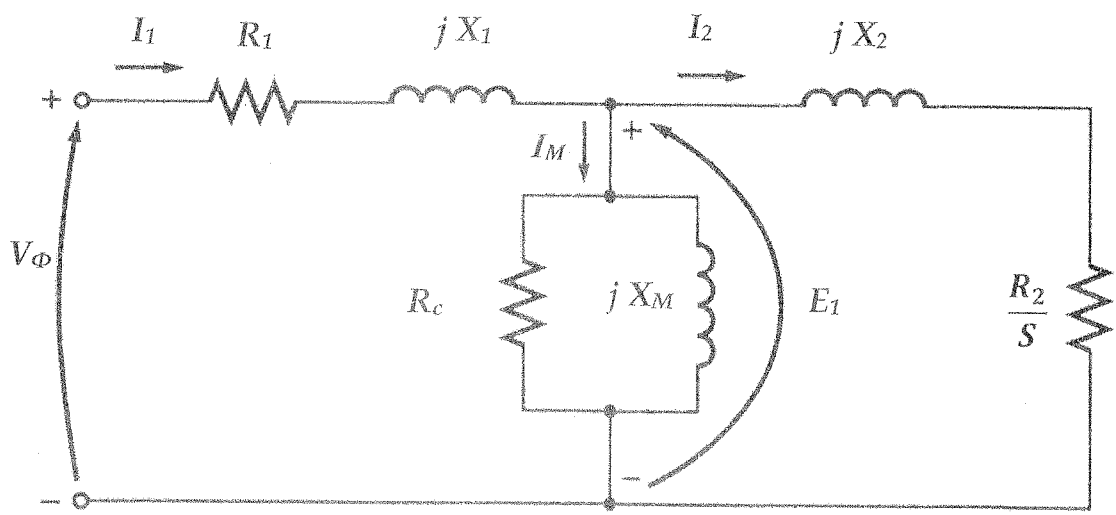


Figure: Q2

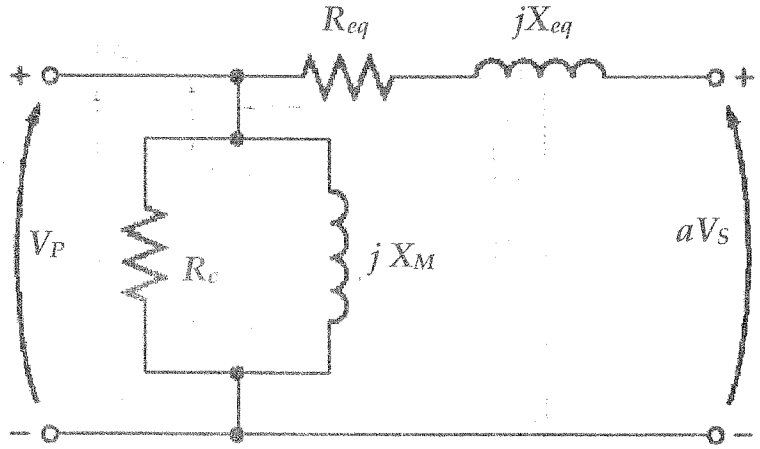


Figure: Q3

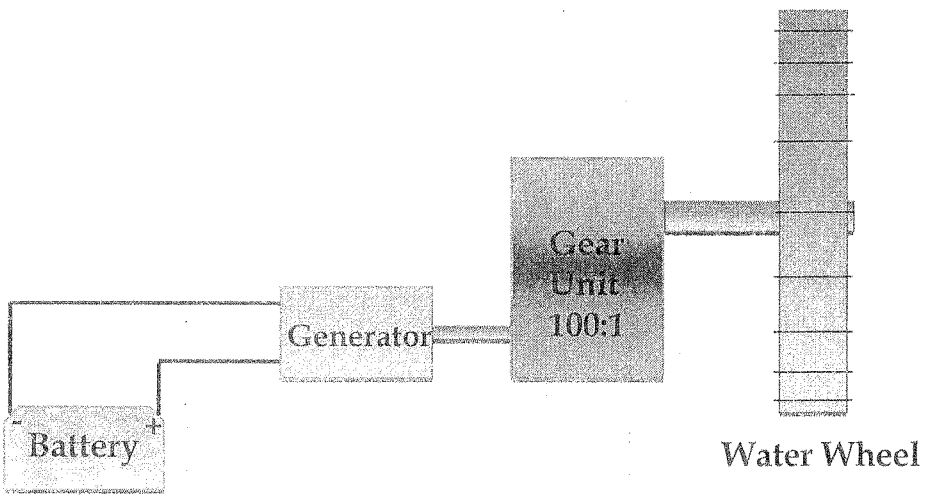


Figure: Q4(a)

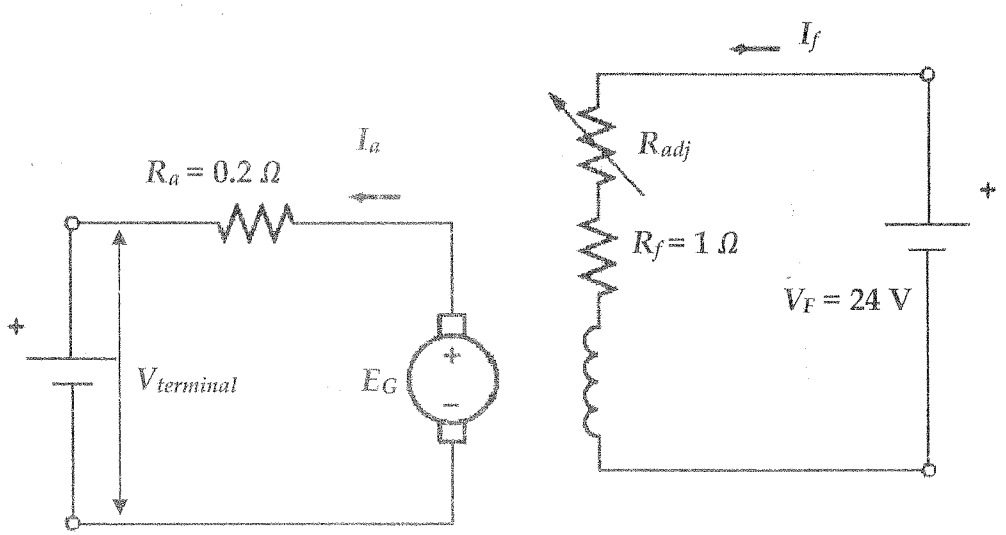


Figure: Q4(b)