University of KwaZulu-Natal

School of Electrical, Electronic and Computer Engineering

Examinations: November 2015

Subject, Course & Code: ELECTRICAL MACHINES 2 – ENEL3MBH2

DURATION: 2 HOURS TOTAL MARKS: 100

Examiners: Dr. R. Pillay Carpanen (Internal)

Dr. R. Tiako (Moderator)

Instructions: Answer ALL Questions. **Start answering each question on a fresh page of the answer booklet.**

The use of scientific calculators is permitted but their memories must be cleared.

QUESTION 1 [36 Marks]

A 100 kVA, 3000 V, 50 Hz, three-phase, round-rotor, star-connected synchronous generator has a stator resistance of 0.2 Ω per phase. A field current of 40 A produces a short-circuit current of 200 A and an open-circuit voltage of 1040 V (line value).

(a) Determine the true value of the synchronous reactance per phase. [3]

(b) If the generator is delivering rated load at 0.8 lagging power factor at rated voltage, determine the induced voltage $\bar{E}_0$ using the generator phasor diagram. [11]

(c) Determine the voltage regulation for the conditions in part (b). [2]

(d) If the generator is delivering rated load at 0.8 leading power factor at rated voltage, determine the induced voltage $\bar{E}_0$ using the generator phasor diagram. [8]

(e) Determine the voltage regulation for the conditions in part (d). [2]

(f) If the generator is delivering rated load at unity power factor at rated voltage, determine the induced voltage $\bar{E}_0$ using the generator phasor diagram. [8]

(g) Determine the voltage regulation for the conditions in part (f). [2]

QUESTION 2 [28 Marks]

A 2300 V, 298.4 kW, 60 Hz, 8 pole three-phase, star-connected synchronous motor has a rated power factor of 0.85 leading. At full load, this machine has an efficiency of 85 percent. The machine has a stator resistance of 0.4 Ω and a synchronous reactance of 4.4 Ω per phase. Determine the following:

(a) The total output torque at full load. [3]

(b) The total input power at full load. [2]

(c) The armature current $\bar{I}$ and the excitation voltage $\bar{E}_0$ per phase when the machine is operating at rated load with a leading power factor of 0.85 using the synchronous motor's phasor diagram. [10]

(d) The total power that is transmitted to the rotor for the conditions in part (c). [4]

(e) The armature current $\bar{I}$ and the excitation voltage $\bar{E}_0$ per phase when the machine is operating at rated load with at unity power factor using the synchronous motor's phasor diagram. [9]

QUESTION 3 [36 Marks]

A four-pole, single-phase, 120 V, 60 Hz induction motor gave the following locked-rotor impedances when tested at rated frequency:

Main winding: $\mathbf{Z_s = 2.5 + j4.5\ \Omega}$

Auxiliary winding: $\mathbf{Z_a = 5.0 + j8.0\ \Omega}$

(a) Determine the value of the external resistance to be inserted in series with the auxiliary winding to obtain maximum starting torque as a resistance split-phase motor. [2]

(b) Determine the value of the capacitor to be inserted in series with the auxiliary winding to obtain maximum starting torque as a capacitor-start motor. [3]

(c) Determine the value of the capacitor to be inserted in series with the auxiliary winding to obtain maximum starting torque per ampere of starting current as a capacitor-start motor. [3]

(d) Compare the starting torque and starting current in part (c) with the case of the split-phase motor having no external element in the auxiliary circuit when operated at 120V, 60Hz. The stator torques and starting currents must be expressed in per unit of the starting torque and starting current without any external element in the auxiliary circuit and draw the phasor diagram in each case. [28]

Design Equation for Resistance split phase motors

For Maximum starting torque: $R_a + R_{ext} = \frac{X_a}{X_s}(R_s + |Z_s|)$

Design Equations for Capacitor start split phase motors

For Maximum starting torque: $X_c = X_a + \frac{R_a R_s}{|Z_s| + X_s}$

For Maximum starting torque per Ampere of starting current:

$$X_c = X_a + \frac{-X_s R_a + |Z_s|\sqrt{R_a(R_a + R_s)}}{R_s}$$