University of KwaZulu-Natal

School of Electrical, Electronic and Computer Engineering

Examinations: November 2013

Subject, Course & Code: ELECTRICAL MACHINES 2 – ENEL3MBH2

DURATION: 2 HOURS TOTAL MARKS: 100

Examiners: Dr. R. Pillay Carpanen (Internal)

Prof. E. J. Odendal (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 [33 Marks]

A three-phase, 480 V, 60 Hz, delta-connected, 4-pole synchronous generator has no-load saturation curve shown in Fig. 1 where is open circuit terminal voltage is measured line to line. This generator has a synchronous reactance of 0.1 Ω and an armature resistance of 0.01 Ω. At full load, the machine supplies 1100 A at a lagging power factor of 82%. Under full-load conditions, the friction and windage losses are 35 kW, and the core losses are 30 kW. Any field circuit losses can be assumed to be negligible.

(a) Determine the speed of rotation of this generator. [1]

(b) Determine the field current required by the generator to set the terminal voltage at its rated value of 480 V at no load condition. [2]

(c) If the generator is connected to a load that draws a line current of 1100 A at a lagging power factor of 82%, determine the field current that will be required to maintain the terminal voltage its rated value of 480V using the generator phasor diagram. [8]

(d) Determine the generator output power (kW), the input power (kW) and the overall machine efficiency under its current loading condition. [8]

(e) If the generator's load were suddenly disconnected from the line, explain what would happen to the generator's terminal voltage and why? [2]

(f) If the generator was instead delivering a line current of 1100 A at a leading power factor of 82 %, determine the field current that will be required to maintain the terminal voltage at its rated value of 480 V using the generator phasor diagram. [8]

(g) If the generator speed was reduced to 1260 rpm, determine the new value of the excitation voltage assuming that the field current was kept constant. [2]

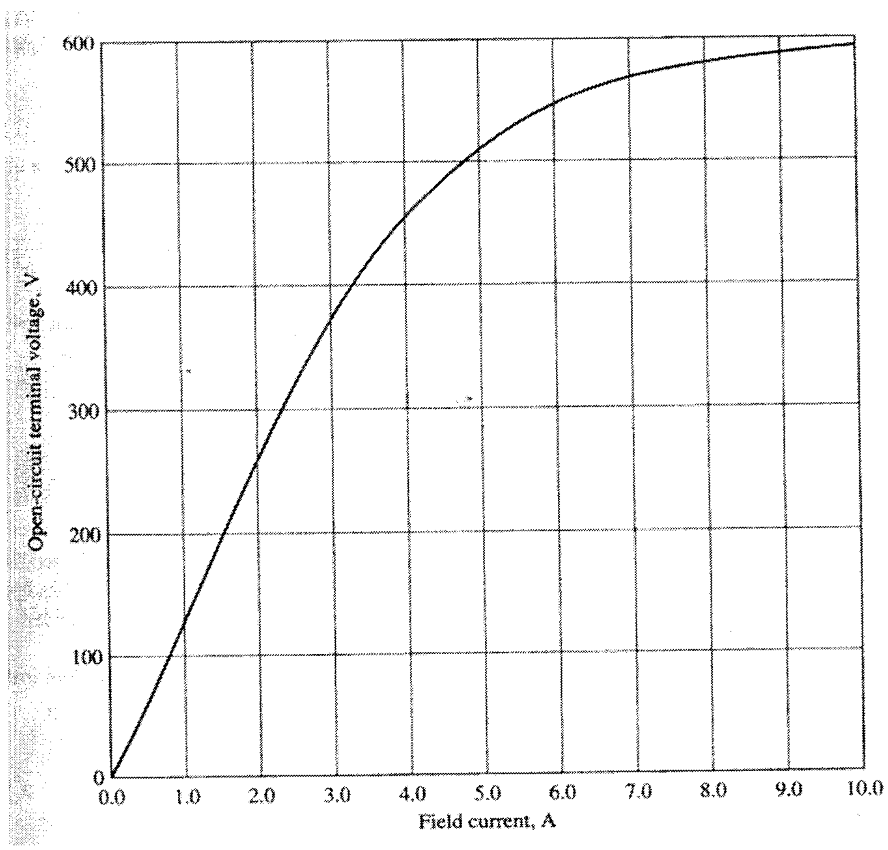

Figure 1

QUESTION 2 [37 Marks]

A 74.6 kW, three-phase, star-connected, 60 Hz, 460 V, 4-pole, synchronous motor is operating at rated conditions and 80 percent power factor leading. The efficiency, excluding field and stator losses is 96 percent, and the synchronous reactance is 2.72 Ω per phase. Determine the following:

(a) The mechanical torque developed by the motor. [4]

(b) The armature current I. [4]

(c) The excitation voltage $\bar{E}_0$ per phase using the motor phasor diagram. [6]

(d) The torque angle. [2]

(e) The total pull-out torque. [4]

(f) Assuming that the shaft load is now reduced to 50 kW with no change in the excitation current, determine the new excitation voltage $\bar{E}_0$ per phase. [4]

(g) Determine the new armature current $\bar{I}$ per phase using the motor phasor diagram for the new operating condition in part (f). [8]

(h) Determine the new power factor for the new operating condition in part (f). [2]

(i) If the mechanical load is suddenly disconnected, determine the new line current $\bar{I}$ using the motor phasor diagram. [3]

QUESTION 3 [30 Marks]

The main and auxiliary windings of a 110 V, 60 Hz split-phase motor have the following locked-rotor parameters:

$$\mathbf{R_s = 2.50\ \Omega \quad X_s = 4.00\ \Omega}$$

$$\mathbf{R_a = 9.00\ \Omega \quad X_a = 8.00\ \Omega}$$

If the motor is connected to a 110 V, 60 Hz system, determine the following:

(a) The locked-rotor current in each winding $\bar{I}_a$ and $\bar{I}_s$; [6]

(b) The phase-displacement angle α between the two currents; [2]

(c) The locked-rotor torque in terms of the machine constant; [2]

(d) The external resistance required in series with the auxiliary winding in order to obtain a 30° phase displacement between the currents in the windings (Z_{ext} is purely resistive); [4]

(e) The locked-rotor torque for the conditions in (d); [4]

(f) The percentage increase in the locked-rotor torque due to the addition of external resistance. [2]

(g) The external capacitance required in series with the auxiliary winding in order to obtain a 90° phase displacement between the currents in the windings (Z_{ext} is purely capacitive); [4]

(h) The locked-rotor torque for the conditions in (g); [4]

(i) The percentage increase in the locked-rotor torque due to the addition of external capacitance. [2]