The University Of Sheffield.

Data Provided: Linear-Linear Graph Paper, Figure 3.1 and Figure 4.2 (both in many body of questions)

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2011-12 (2.0 hours)

EEE6120 Modelling of Electrical Machines

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. a. Draw the general form of an unconnected Kron primitive machine and derive the general form of its voltage matrix equation (you may leave all rotational terms in their G coefficient forms) **(4)**

b. A power tool is manufactured using a 2-pole series connected universal motor which has a total self inductance measured at the terminals of 0.14H.

When connected to a 230V DC voltage supply, the motor draws a DC current of 3.5A and rotates at 18,000rpm. The motor has an efficiency of 84% at this operating point (you may neglect core losses in terms of their effect on efficiency).

The same motor is then connected to a 230V (rms), 50Hz sinusoidal AC supply and provides the same torque to the mechanical load as that produced on the 230V DC supply.

Calculate the following:

i) The resistance of the motor at its terminals

ii) The torque produced by the machine when connected to the 230V DC supply running at 18,000rpm.

iii) Rotational speed achieved when connected to the AC mains supply.

iv) The power factor of the motor when connected to the AC mains supply running at 18,000rpm.

v) The ratio of the starting torques produced on the DC and the AC supplies. **(13)**

c. Draw the Kron primitive equivalent of an inductively compensated universal motor and ***sketch*** representative phasor diagrams for both an uncompensated and an inductively compensated universal motor when connected to the AC mains supply. **(3)**

2. **a.** Starting from the Kron primitive equivalent of a single-phase induction motor, derive the steady-state terminal voltage equations for operation with a sinusoidal AC supply. **(8)**

b. A four-pole single-phase induction motor is connected to a 230Vrms, 50Hz sinusoidal AC supply has the following equivalent circuit parameters (all rotor values are already referred to the stator):

Magnetising reactance X_m: j300Ω

Stator resistance: 11Ω

Rotor resistance: 45Ω

Stator leakage reactance: j10Ω

Rotor leakage reactance: j10Ω

The machine is operating at 13% slip. For this operating condition, calculate the following aspects of performance:

i) The rms magnitude and phase of the input current

ii) The power factor of the motor

iii) The input power to the motor

iv) The mechanical output power

v) The mechanical torque produced by the motor **(12)**

3. A 3-phase switched reluctance machine has 12 stator teeth and 8 rotor teeth. Each phase consists of 4 series connected coils. The measured variation in the flux-linkage of one phase with rotor angular displacement is shown in Figure 3.1 for a range of phase currents from 1A to 8A in 1A increments (Note: An angular displacement of 22.5° corresponds to a rotor tooth being fully-aligned with the phase).

a. Estimate from Figure 3.1 the combination of rotor angular displacement and current at which the maximum induced emf in one phase occurs, and hence calculate the value of this maximum induced emf at a rotational speed of 4000rpm **(3)**

b. Calculate the number of normal torque strokes per mechanical revolution for this combination of phase number, stator teeth and rotor teeth. **(2)**

c. Using the information in Figure 3.1 and the graph paper provided, plot flux-linkage versus current characteristics for the angular displacements which correspond to the start and fully-aligned rotor angular positions of a normal torque stroke, and hence calculate the average torque per stroke produced by this machine for currents of 2A and 4A. **(9)**

d. Estimate from your flux-linkage characteristic the current at which the maximum value of phase self inductance occurs in the fully-aligned position, and hence calculate this maximum value of inductance. **(2)**

e. The airgap between the rotor and stator when the rotor is in the fully-aligned position is 0.5mm. Using the flux-linkage versus current characteristic plotted in part (c), estimate the number of turns on each individual stator coil if the stator and rotor core material begin to magnetically saturate at ~1.5T. **(4)**

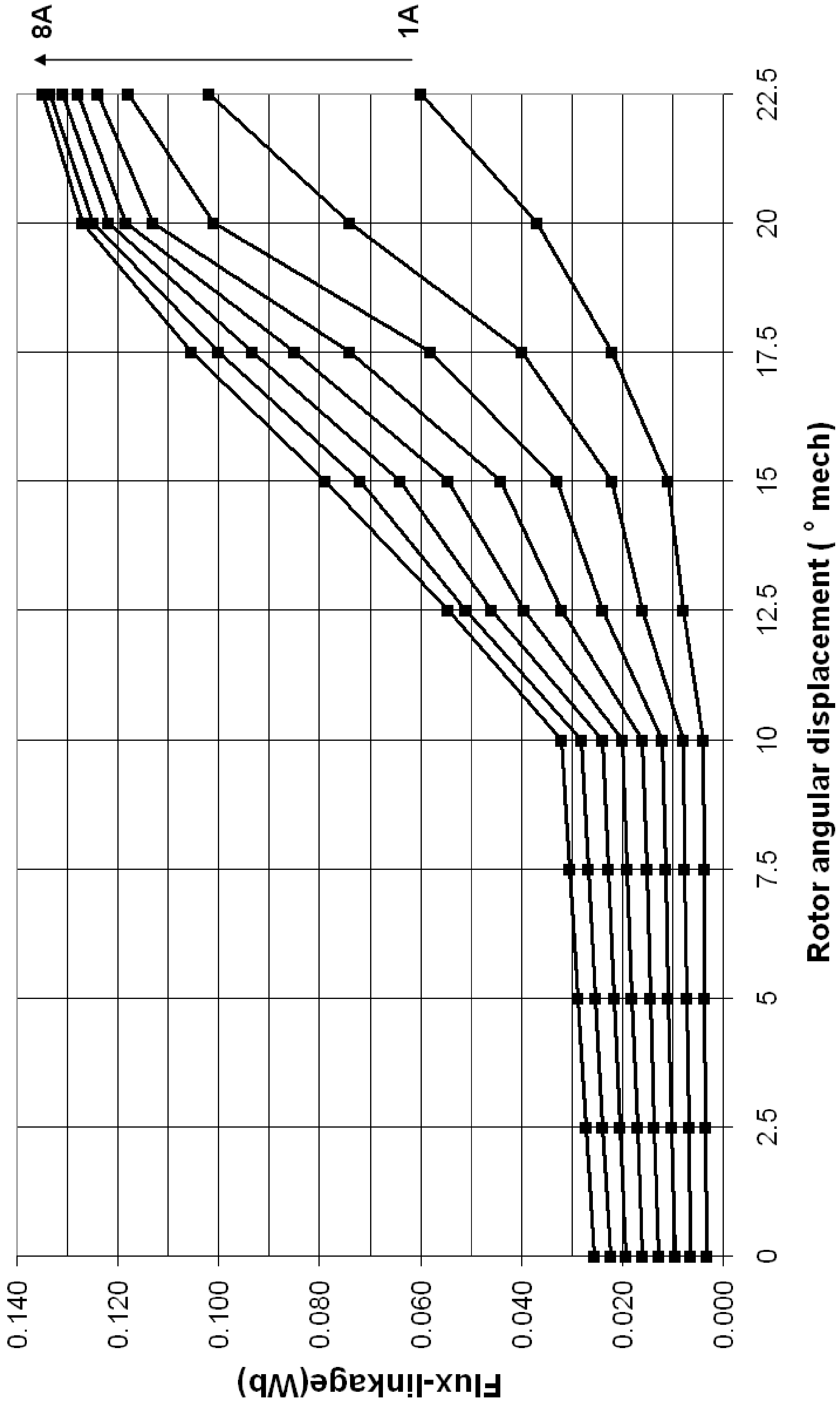

Figure 3.1 - Measured variations in the flux-linkage of one phase of a 12-8 switched reluctance machine with rotor angular displacement for a range of phase currents

4. Figure 4.1 shows a schematic of a single-phase, 2-pole brushless permanent magnet motor. The machine is driven from a power electronic converter. The rotor consists of a 2-pole magnet ring with a wall thickness of 2.5mm which is mounted on a cylindrical Silicon Iron core. The airgap between the outer surface of the magnet ring and the stator core is 0.5mm.

Under normal operating conditions, the motor is driven by a power electronic converter that produces a 180° (elec) wide square-wave current waveform of alternating polarity. The measured variation in the coil flux-linkage with rotor angular displacement for a series of different DC currents is shown in Figure 4.2.

a. Calculate the peak value of the open-circuit back-emf at 4500pm, stating any assumptions that you make. **(4)**

b. By plotting appropriate flux-linkage versus current characteristics on the graph paper provided, calculate the average torque per amp produced by the motor for currents of 0.5A and 1.0A, commenting on any differences in the values calculated. **(6)**

c. Given that the Silicon Iron cores begins to magnetically saturate at a flux density of 1.40T, estimate the number of turns on the stator coil (You may assume that the permanent magnet has a relative permeability of 1.0 and that the flux density in the core is the same as that in the airgap). **(6)**

d. From the variation in the open-circuit coil flux-linkage with rotor angular displacement calculate the remanence of the permanent magnet material used in the rotor. **(4)**

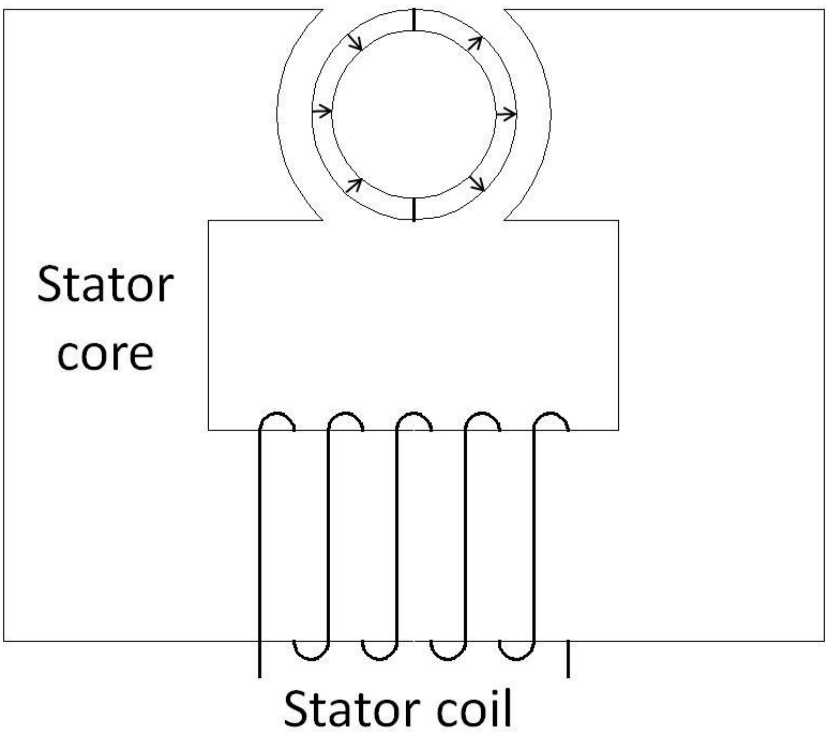

Figure 4.1 – Schematic of a single-phase permanent magnet brushless machine (shown at an angular displacement of 90°)

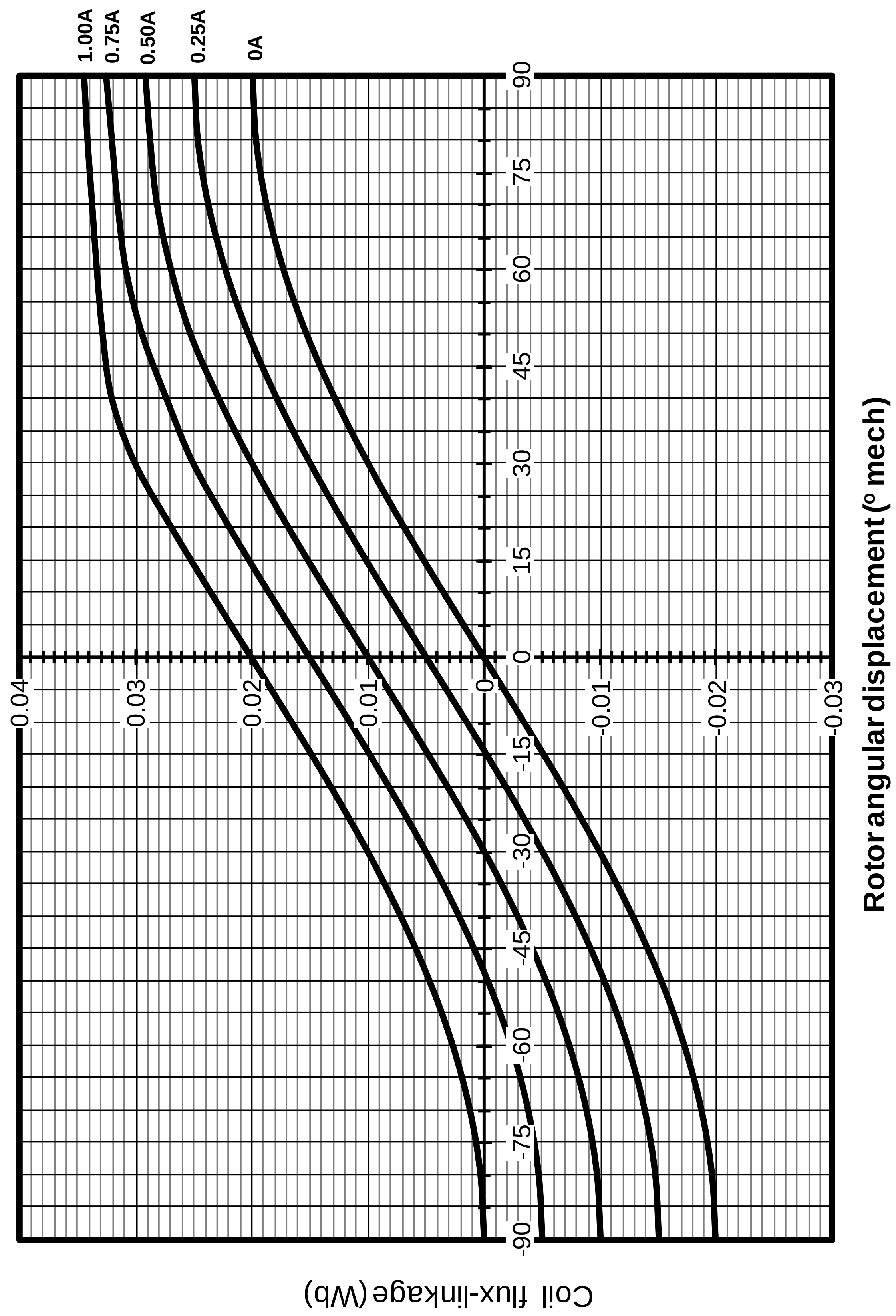

Figure 4.2 – Measured variation in coil flux-linkage with rotor angular dispalcement for the motor of Figure 4.1

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