Data Provided: None

The University of Sheffield

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2005-2006 (2 hours)

Modelling of Electrical Machines 4

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 equations (you may leave all rotational terms in their G coefficient forms) **(5)**

b. A high-speed tool is manufactured using a 2-pole series connected universal motor which has a total self inductance measured at the terminals of 0.14H and a total resistance measured at the terminals of 10Ω.

When connected to a 200V DC voltage supply, the motor rotates at 16,000rpm, drawing an input power of 600W. The same machine 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 200V DC supply.

Calculate the following:

The efficiency of the machine when connected to the 200V DC supply

Rotational speed achieved when connected to the AC mains supply

The power factor of the motor when connected to the AC mains supply

The ratio of the starting torques produced on the DC and the AC supplies **(12)**

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

2. **a.** Starting from the Kron primitive equivalent of a non-salient three-phase, squirrel cage induction motor, derive the voltage equations and a corresponding exact equivalent circuit for steady-state operation with a sinusoidal AC supply. Discuss the assumptions which allow this exact equivalent circuit to be simplified when certain conditions are satisfied. **(12)**

b. A four-pole, non-salient, star-connected three phase induction motor for 400V(rms line voltage) 50Hz mains operation has the following equivalent circuit parameters:

Stator resistance= 0.2Ω

Referred rotor resistance = 0.1Ω

Stator leakage reactance = 0.5Ω

Referred rotor leakage reactance = 0.2Ω

Magnetising reactance = 20Ω

The total mechanical loss in the machine at 1462rpm is 750W. For this particular operating speed, calculate the following performance features noting any assumptions that you make:

i) Magnitude of the input current

ii) Power factor of the machine

iii) Net output power supplied to its mechanical load

iv) The machine copper losses

v) Overall efficiency

(8)

3. Figure 3 shows the measured variation of coil flux linkage with phase current for one phase of a three-phase switched reluctance rotating machine. The characteristics are measured at equal increments of angular displacement between the fully un-aligned and fully aligned positions. This machine has 6 stator teeth (each equipped with a concentrated coil having 127 turns) and 4 rotor teeth. The coils of a given phase are connected in series. The stator and rotor cores are manufactured from Silicon Iron

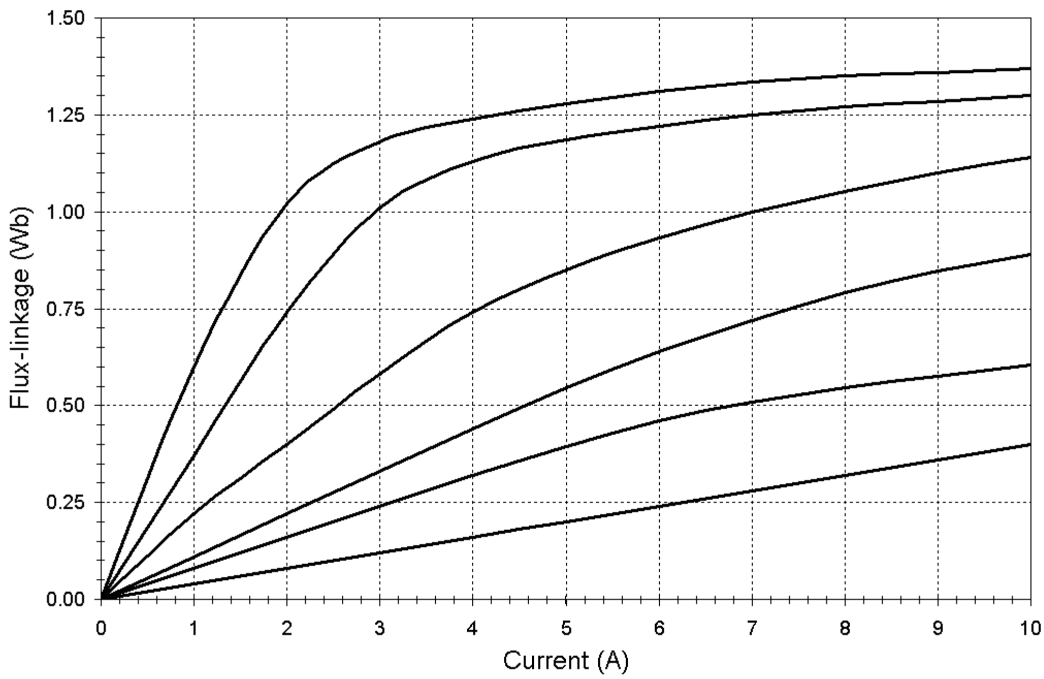

Figure 3 Measured Ψ-I characteristics for an SR machine

a. Estimate the average torque produced per phase in moving from the un-aligned to the aligned position for a phase current of 5A **(5)**

b. The stator and rotor core materials saturate at a flux density of approximately 1.6T. Using the flux-linkage versus current characteristic for the fully aligned position, estimate the length of the airgap. **(4)**

c. By plotting a corresponding flux-linkage versus rotor angular displacement characteristic, estimate the magnitude of the instantaneous induced phase emf at a rotor angular displacement midway between the un-aligned and aligned positions for a current of 3A and a rotational speed of 200 rpm. **(6)**

d. By reference to the flux-linkage versus current characteristics of the machine, describe two design changes that could be made to the machine to enhance its torque capability. In each case, ***sketch*** representative flux-linkage characteristics in the un-aligned and aligned positions for the original design and the improved design, taking care to label any significant features. **(5)**

4. Figure 4 shows the measured variation of flux-linkage of one phase of a non-salient, three-phase permanent magnet brushless machine for various levels of current between 0A and 100A. This machine has 6 stator teeth and 4 rotor poles

a. Calculate the phase inductance of the machine at rotor angles of 0^o and 90^o and currents of 25A and 100A (i.e. four values of inductance in total) and comment on any differences between the calculated inductances you calculate **(3)**

b. Calculate the peak magnitude of the open-circuit emf when the machine is rotating at 3000 rpm. **(4)**

c. By plotting appropriate flux-linkage versus current characteristics using the graph paper provided, estimate the average torque produced by the machine over the full angular excursion of -90^o to $+90^o$ for currents of 25A and 100A. **(6)**

d. The mechanical airgap in this machine is 1.0mm and the rotor magnets have a thickness in the direction of magnetisation of 6.0mm. Listing assumptions that you make, estimate the number of turns in each phase given that the stator core starts to saturate at a flux density of 1.6T (You may assume that the relative permeability of the magnet is 1.0) **(7)**

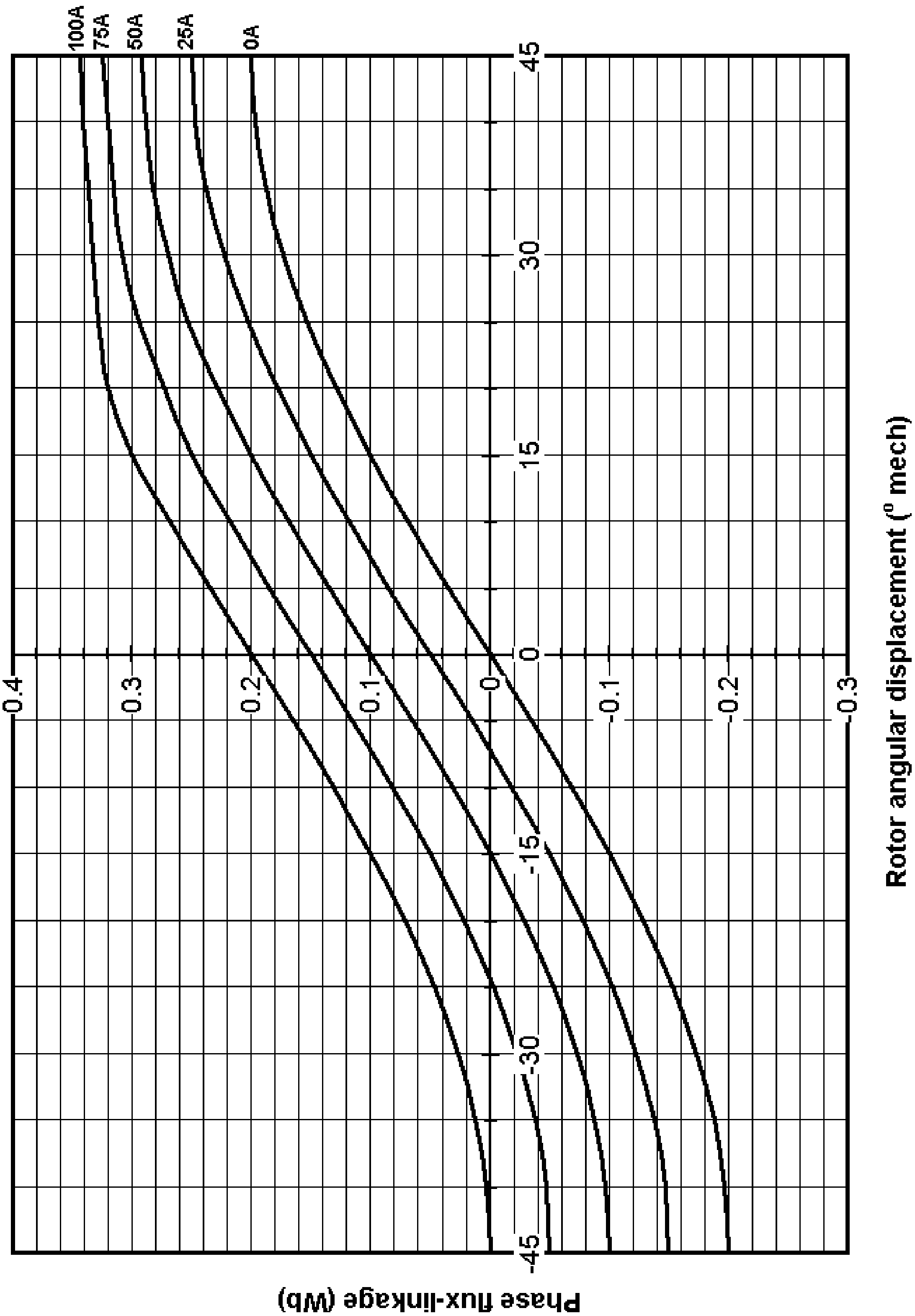

Figure 4 Measured variation of flux-linkage of one phase of a non-salient, three-phase permanent magnet brushless machine

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