EE4001 Study Questions – ED Chapter 11

Summer 2004
Problem 1

(a) A symmetrical, four-pole, three-phase, star-connected 70 hp induction motor is characterized as follows. The dc phase-to-phase resistance is measured to be 23.6 mΩ. A no-load test with an applied voltage of 195 V (line-line), 200 Hz, results in a phase current of 64.7 A, and a three-phase power of 1.093 kW. A locked-rotor test with an applied voltage of 35.6 V (line-line), 200 Hz, results in a phase current of 93 A, and a three-phase power of 641 W. Estimate the per-phase equivalent circuit parameters: R_S, L_{LS}, L_M, L_{LR}', and R_R'. Assume that $L_{LR}' = 0.8 \cdot L_{LS}$ for this class of machine.

[Ans. R_S = 11.8 mΩ, L_{LS} = 0.097 mH, L_M = 2.289 mH, L_{LR}'= 0.078 mH, and R_R' = 12.9 mΩ.]

(b) A four-pole, star-connected induction motor interfaces a mechanical load to the 400 V (line-line) 50 Hz power grid (via gearing, contactor and breaker). The machine has the following per-phase equivalent circuit parameters:
R_S = 20 mΩ, L_{LS} = 0.2 mH, L_M = 7.2 mH, L_{LR}' = 0.3 mH, and R_R' = 35 mΩ.

At full power, the induction motor requires a per-phase current of 225 A at a power factor of 0.89 and an overall system efficiency of 89.7 %. Calculate approximate values for the following: (i) the electrical input power, (ii) the airgap power, (iii) the per-phase magnetizing current, (iv) the per-phase rotor current, (v) the slip, and (vi) the core, friction and windage losses.

Calculate approximate values for the following when the mechanical load drops to 25 % of its value at full load: (i) the slip, (ii) the per-phase rotor current, (iii) the per-phase current, and (iv) the power factor.

[Ans.138.74 kW, 135.7 kW, 102.6 A, 200.25 A, 3.1 %, 7.04 kW; 0.9 %, 57.4 A, 117.2 A, 0.488]

Summer 2001
Problem 2

A symmetrical, four-pole, three-phase, wye-connected induction motor is characterized as follows. The dc phase-to-phase resistance is measured to be 1.1 Ω. A no-load test with an applied voltage of 208 V (line-line), 60 Hz, results in a phase current of 6.5 A, and a three-phase power of 175 W. A locked-rotor test with an applied voltage of 53 V (line-line), 60 Hz, results in a phase current of 18.2 A, and a three-phase power of 900 W. Estimate the per-phase equivalent circuit parameters: R_S, L_{LS}, L_M, L_{LR}', and R_R'. Assume that $L_{LR}' = \frac{3}{2} L_{LS}$ for this Class B machine.

[Ans: R_S = 0.55 Ω, L_{LS} = 1.5 mH, L_M = 47.4 mH, L_{LR}'= 2.25 mH, and R_R' = 0.356 Ω.]

Summer 2003
Problem 3

(a) A symmetrical, four-pole, three-phase, star-connected induction motor is characterized as follows. The dc phase-to-phase resistance is measured to be 3.54 Ω. A no-load test with an applied voltage of 400 V (line-line), 50 Hz, results in a phase current of 1.8 A, and a three-phase power of 120 W. A locked-rotor test with an applied voltage of 71 V (line-line), 50 Hz, results in a phase current of 4 A, and a three-phase power of 150 W. Estimate the per-phase equivalent circuit parameters: R_S, L_{LS}, L_M, L_{LR}', and R_R'. Assume that $L_{LR}' = \frac{3}{2} L_{LS}$ for this Class B machine.

[Ans. R_S = 1.77 Ω, L_{LS} = 12 mH, L_M = 395 mH, L_{LR}'= 19 mH, and R_R' = 1.36 Ω]

(b) A four-pole star-connected induction motor used in an electric vehicle application has the following per-phase equivalent circuit parameters:
R_S = 11.8 mΩ, L_{LS} = 0.0972 mH, L_M = 2.0 mH, L_{LR}' = 0.0772 mH, and R_R' = 12.9 mΩ.
When supplied by a current-controlled inverter outputting 93 A at 200 Hz, the motor generates an output torque of 40 Nm at 5945 rpm. Core, friction and windage losses are estimated at 2.3 kW at this speed.
Determine approximate values for the input per-phase voltage, power factor, and efficiency at this operating point.

[Ans.113.3 V, 0.869, 89.7 %]

Problem 4

The specification table for Westinghouse induction motors is provided as an attachment. Consider the 22 kW, four-pole machine with 400 V (line-line), 50 Hz applied in the delta configuration. What is the slope of the torque/slip curve in its linear region? Estimate the per-phase equivalent circuit parameters: L_M, R_R', R_S, P_{CFW}, L_{LS}, and L_{LR}'. Assume that $L_{LR}' = \frac{3}{2} L_{LS}$ for this class of machine.

[Ans. T/Hz = 245 Nm/Hz, L_M = 122 mH, R_R' = 0.44 Ω, R_S = 0.58 Ω, P_{CFW} = 671 W, L_{LS} = 2.9 mH, L_{LR}'= 4.3 mH]

Problem 5

Consider the 75 kW, four-pole machine with 400 V (line-line), 50 Hz applied in the delta configuration. What is the slope of the torque/slip curve in its linear region? Estimate the per-phase equivalent circuit parameters: L_M, R_R', R_S, P_{CFW}, L_{LS}, and L_{LR}'. Assume that $L_{LR}' = \frac{3}{2} L_{LS}$ for this class of machine.

[Ans. T/Hz = 1930 Nm/Hz, L_M = 35.6 mH, R_R' = 57 mΩ, R_S = 117 mΩ, P_{CFW} = 1861 W, L_{LS} = 0.9 mH, L_{LR}'= 1.4 mH]

Summer 2005

Problem 6

The specification table for Westinghouse induction motors is provided as an attachment (see page 6). Consider the 110 kW, four-pole machine with 400 V (line-line), 50 Hz applied in the delta configuration. Assume R_S = 58.3 mΩ.

(i) Determine the slope of the torque/speed (Nm/Hz) curve in its linear region?

(ii) Estimate the per-phase equivalent circuit parameters: L_M, R_R', and P_{CFW}.

(b) The four-pole, 22 kW induction motor in the tables is missing the power factor for the 50 % load point. Calculate an approximate value for the power factor based on the information provided at the 100 % load point.

(c) Given that the four-pole, 22kW motor has R_R' = 0.44 Ω and R_S = 0.58 Ω, determine the leakage inductances L_{LS} and L_{LR}'. Assume that $L_{LR}' = \frac{3}{2} L_{LS}$ for this class of machine.

[Ans. (a) T/Hz =2828 Nm/Hz, L_M = 24.3 mH, R_R' = 39.3 mΩ, P_{CFW} = 3169 W, (b) PF = 0.7, (c) L_{LS} = 2.9 mH, L_{LR}'= 4.3 mH]

Summer 2006

Problem 7

(a) The specification table for Westinghouse induction motors is provided as an attachment (see page 6). Consider the 22 kW, **eight**-pole machine with 400 V (line-line), 50 Hz applied in the delta configuration.
Estimate the per-phase equivalent circuit parameters:, R_R', P_{CFW}, L_{LS}, L_{LR}', and L_M.
Assume R_S = 0.432 Ω and L_{LS} equals L_{LR}' for this class of machine.

[Ans. R_R' = 0.49 Ω, P_{CFW} = 785 W, L_{LS} = 2.8 mH, L_{LR}'= 2.8 mH, L_M = 73 mH,]

(b) A four-pole star-connected induction motor used in an electric vehicle application has the following per-phase equivalent circuit parameters:
R_S = 11.8 mΩ, L_{LS} = 0.0972 mH, L_M = 2.0 mH, L_{LR}' = 0.0772 mH, and R_R' = 12.9 mΩ.
When supplied by a current-controlled inverter outputting 93 A at 200 Hz, the motor generates an output torque of 40 Nm at 5945 rpm. Core, friction and windage losses are estimated at 2.3 kW at this speed. Determine approximate values for the input per-phase voltage, power factor, and efficiency at this operating point.

[Ans.113.3 V, 0.869, 89.7 %]