10–15. Explain the operation of a stepper motor.

10–16. What is the difference between a permanent-magnet type of stepper motor and a reluctance-type stepper motor?

10–17. What is the optimal spacing between phases for a reluctance-type stepper motor? Why?

10–18. What are the advantages and disadvantages of brushless dc motors compared to ordinary brush dc motors?

PROBLEMS

10–1. A 120-V, ⅓-hp, 60-Hz, four-pole, split-phase induction motor has the following impedances:

$$R_1 = 1.80\ \Omega \qquad X_1 = 2.40\ \Omega \qquad X_M = 60\ \Omega$$
$$R_2 = 2.50\ \Omega \qquad X_2 = 2.40\ \Omega$$

At a slip of 0.05, the motor's rotational losses are 51 W. The rotational losses may be assumed constant over the normal operating range of the motor. If the slip is 0.05, find the following quantities for this motor:

(a) Input power
(b) Air-gap power
(c) P_{conv}
(d) P_{out}
(e) τ_{ind}
(f) τ_{load}
(g) Overall motor efficiency
(h) Stator power factor

10–2. Repeat Problem 10–1 for a rotor slip of 0.025.

10–3. Suppose that the motor in Problem 10–1 is started and the auxiliary winding fails open while the rotor is accelerating through 400 r/min. How much induced torque will the motor be able to produce on its main winding alone? Assuming that the rotational losses are still 51 W, will this motor continue accelerating or will it slow down again? Prove your answer.

10–4. Use MATLAB to calculate and plot the torque–speed characteristic of the motor in Problem 10–1, ignoring the starting winding.

10–5. A 220-V, 1.5-hp, 50-Hz, two-pole, capacitor-start induction motor has the following main-winding impedances:

$$R_1 = 1.40\ \Omega \qquad X_1 = 1.90\ \Omega \qquad X_M = 100\ \Omega$$
$$R_2 = 1.50\ \Omega \qquad X_2 = 1.90\ \Omega$$

At a slip of 0.05, the motor's rotational losses are 291 W. The rotational losses may be assumed constant over the normal operating range of the motor. Find the following quantities for this motor at 5 percent slip:

(a) Stator current
(b) Stator power factor
(c) Input power
(d) P_{AG}
(e) P_{conv}

(*f*) P_{out}
(*g*) τ_{ind}
(*h*) τ_{load}
(*i*) Efficiency

10–6. Find the induced torque in the motor in Problem 10–5 if it is operating at 5 percent slip and its terminal voltage is (*a*) 190 V, (*b*) 208 V, (*c*) 230 V.

10–7. What type of motor would you select to perform each of the following jobs? Why?
(*a*) Vacuum cleaner
(*b*) Refrigerator
(*c*) Air conditioner compressor
(*d*) Air conditioner fan
(*e*) Variable-speed sewing machine
(*f*) Clock
(*g*) Electric drill

10–8. For a particular application, a three-phase stepper motor must be capable of stepping in 10° increments. How many poles must it have?

10–9. How many pulses per second must be supplied to the control unit of the motor in Problem 10–8 to achieve a rotational speed of 600 r/min?

10–10. Construct a table showing step size versus number of poles for three-phase and four-phase stepper motors.

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