B.E. (EE) Part-II 4th Semester Examination, 2010

Electrical Machines-II
(EE-402)

Time : 3 hours Full Marks : 70

Use separate answerscript for each half.
Answer SIX questions, taking THREE from each half.
Two marks are reserved for neatness in each half.
Graph papers must be supplied.

FIRST HALF

1. a) Explain how an induction machine may be made to operate as an induction generator while remaining connected to the utility mains. Establish, with proper diagrams, why an induction generator can never feed a lagging power factor load.

b) A 3-phase Y-connected 415 V. 50 Hz. 4-poIe induction machine has the following parameter values per phase (referred to stator):

r. = 0.25 0, .r;' = 0.35 0. x< = '.03O., y.₂'=!.03O, x_m = 13.25 *Q*.

The machine is to be run as an induction generator with a negative slip of 2%. the total friction, windage and core losses may be assumed to be constant at 41OW and is independent of load. Compute (i) the shaft speed, (ii) the shaft mechanical input power and (iii) the shunt capacitor 'C to be connected per phase if the machine is required to feed a 51cW load at 0.8 p.f. lagging at 50 Hz as an induction generator. Draw the phasor diagram under this condition.

[3+(6+2)l

2. The following test data relate to a 3-phase Y- connected 15 hp. 415 V. 3-phase. 50 Hz. 4-pole squirrel cage induction motor :

No-load test: 415V, 6.0 A, 525 W

Blocked rotor test: 115 V, 20 A, 950 W

The dc stator resistance measured between two stator terminals under hot condition is 0.9 ohms.

Draw the circle diagram and evaluate the following: (1) input current, (ii) p.f. (iii) slip and (iv) efficiency at rated load. Also find (v) the maximum power, (vi) the slip for maximum power, (vii) the maximum torque and (viii) the slip for maximum torque. Separate marks are reserved for neat drawing of the circle diagram and proper extraction of key technical information from test data. 17+4]

3. a) Starting from expressions of rotor power (assuming constant air-gap emf) derive, in brief, the expression for torque developed in an induction machine in terms of peak torque, slip at peak torque and the operating slip.

   b) A wound rotor induction motor develops, at rated voltage, a maximum torque of 2.25 times it full load torque at a slip of 0.16 when its slip rings are shorted. Estimate, at rated voltage, the slip at full-load and its starting torque (as percent of the full load torque). How much extra resistance must be inserted per phase (as pert cent of its per-phase rotor resistance) if it has to develop maximum torque at starting?

   c) Find the expressions for slip when an induction motor develops maximum mechanical power and the corresponding mechanical power. Show that the slip for maximum mechanical power is less than the slip for maximum torque.

   r

   d) What is brake horse-power*? (3+4+3+1]

4. a) The winding particulars of a 3-phase A-connected <u>15 hp. 415 V. 3-phase. 50 Hz. 4-pole</u> squirrel cage induction motor are as below:

   (i) total no. of slots = 18

   (ii) winding arrangement: double layer

   (iii) coil pitch: short pitch of slot

   (iv) no. of filaments per coil side = 8.

   Calculate the space fundamental component of the overall armature mmf at full load. The efficiency and power factor at full load may be taken as 88% and 0.87 respectively. Derive expressions for breadth factor and pitch factor of the winding used in the calculation above.

   b) Explain the concept of a sinusoidal current sheet and derive expressions for armature mmf from the same. Why is short-pitching done windings of ac machines? |7+4]

5. a) Fora2-pole, 16 slot, UOV, 10 A dc machine armature having a double-layer winding configuration, draw (preferably on a graph paper) the slot ampere conductor distribution and derive the stepped mmf wave-pattern utilizing basic concepts of magnetic circuits and mechanical symmetry as applicable to electrical machines. Next introduce the concept of uniform current sheet and from there analytically derive the idealized mmf wave-pattern (after evaluating the transverse current density of the uniform sheet). Superpose the same on the previous figure. Show that the peak value of mmf is equal in both cases.

b) Starting from basic principles of electromechanical energy conversion, show that torque developed in a d.c. machine is given by,

$T = k_t$ (pp. l_a, where symbols have their usual significance. J7+4J

SECOND HALF

6. Justify the validity of the following statements with reasons :
   a) The stator power factor increases while the rotor power factor decreases as the load on a three-phase induction motor is increased.
   b) Welding transformers are made to have a relatively large reactance.
   c) The rotor slots of a double-cage induction motor have a narrow constriction between the space for upper and lower bars.
   d) The rotor of a three-phase induction motor can never attain synchronous speed.
   e) To run a slip-ring induction motor, it is not required to short circuit the rotor windings if they are delta-connected. (3+2+2+2+2J

7. a) What will be the effect on the torque developed by an induction motor when both the applied voltage and frequency are reduced to half?
   b) A 230 V, 20 hp, 60 Hz, 6-pole, three-phase induction motor driving a constant torque load at rated frequency, rated voltage and rated horse-power, has a speed of 1175 r.p.m. and an efficiency of 92.1%. Determine the new operating speed if a system disturbance causes 10% drop in voltage and 6% drop in frequency. Assume that the friction, windage and stray power losses remain constant.
   c) Why usually transformer tappings are provided on the high voltage side? Describe a typical resistor-type on-load tap changer. |2+4+(2+3)l

8. a) How is it possible to obtain a high starting torque and good running performance with a double-cage induction motor? Explain with the help of torque-slip curves. Compare a double-cage induction motor with a deep bar induction motor.
   b) The Hopkinson's test on two d.c. shunt machines gave the following results for full load :
   Line voltage = 240 V; Line current = 40 A; Armature current of motor = 240 A; Field currents are 5A and 6A. The armature resistance of each machine is 0.014 O. Calculate the efficiency of each machine assuming a brush contact drop of 1 V per brush.
   c) What do you mean by NEMA Type I and Type 4 enclosures? |(3+2)+4+21

9. a) Explain how the parameters of a three-winding transformer can be determined experimentally. What are the applications of a three-winding transformer?

   b) A 11/33 kV, delta/star tap-changer transformer supplies a star-connected load of 1200 kW at 0.8 p.f. (lag). Per-phase leakage impedances for l.v. and h.v. windings are respectively 0.5+j 5Q and 2+j *\5C1,* Each line conductor has impedance of 2+J5CJ. If l.v. winding is energised at 11 kV, find the tap-changer setting to give load terminal voltage of 33 kV.

   c) The ratio of resistance to standstill leakage reactance is 3 for the top-cage and 0.3 for the bottom-cage of a double-cage induction motor. At standstill, the top-cage current is twice the bottom-cage current. For a full-load slip of 5%, determine the relative magnitudes of (i) bar currents and (ii) the electromagnetic torques. |(3+l)+3+4|

10. a) What are the common schemes for conversion from three-phase to twelve-phase supply? Draw phasor diagrams for each connection.

   b) A 100 kVA, 2000/400 V, single-phase two-winding transformer is to be used as an auto-transformer for stepping up the voltage from 2000 V to 2400 V. At rated load, the two-winding transformer has 2.4% loss, 3.4% voltage regulation and 4.2% impedance. Calculate the following for the auto-transformer : (i) kVA rating, (ii) Efficiency, (iii) Regulation, (iv) Short circuit current on each side.

   c) Discuss the limitations of circle diagram of a three-phase induction motor.

14+4+3)