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KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF ENGINEERING

B. Sc. (Engineering) End of Semester Examination, 2013

Second Year

EE 252 ELECTRICAL ENGINEERING MACHINES

AGRICULTURAL , MECHANINCAL AEROSPACE ENGINEERING

SEPTEMBER , 2013 **Duration**: **3 hours**

Answer ALL questions in **Section A** and **ONLY ONE** question in **Section B**

SECTION A

Shade the correct answer and circle the corresponding letter on the question paper.

1. A long shunt compound D.C. motor runs at full-load speed of 1000 rpm. If the current through its series field windings is caused to be zero, then its full-load speed
   a) becomes more than 1000 rpm
   c) remains 1000 rpm
   b) becomes less than 1000 rpm
   d) becomes 1100 rpm
2. In a d.c. series generator, the terminal voltage with increase in load
   a) Decreases
   c) remains unchanged
   b) increases
   d) varies with drooping characteristics
3. Armature winding is one in which working
   a) flux is produced by field current
   c) e.m.f. is produced by the working flux
   b) flux is produced by the working e.m.f.
   d) e.m.f. is produced by the leakage flux

The armature of a d.c machine has a resistance of 0.1 Ω and is connected to a 230 V supply.

Use the above information to answer questions 4 and 5.

4. Calculate the generated E.M.F when it is running as a generator giving 80A.
   a) 218V
   b) 265V
   c) 238V
   d) None of the above
5. Calculate the generated E.M.F when it is running as a motor taking 60A.
   a) 190V
   b) 245V
   c) 224V
   d) None of the above
6. A four pole motor is fed at 440V and takes an armature current of 50A .The resistance of the armature circuit is 0.28 Ω .The armature winding is wave –connected with 888 conductors and the useful flux per pole is 0.023Wb. Calculate the speed.
   a) 567rev/min
   b) 626rev/min
   c) 545 rev/min
   d) None of the above
7. A motor runs at 900rev/min off a 460 V supply. Calculate the approximate speed when the machine is connected across a 200V supply. Assume the new flux is to be 0.7 of the original flux
   a) 367rev/min
   b) 648 rev/min
   c) 559 rev/min
   d) None of the above
8. A D.C. shunt motor is running with a certain load. The effect of adding an external resistance in the field circuit is to
   a) reduce the motor speed
   c) reduce the armature current of the motor
   b) increase the motor speed
   d) stop the motor

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9. A three phase 50 Hz , 4-pole ,squirrel cage induction motor has its stator rewound for 6 poles without any alteration in the rotor .The motor will now run at the speed
   a) less than 1000 rpm.
   c) 1500 rpm
   b) less than 3000 rpm
   d) zero rpm
10. If a 3-phase, 4-pole slip ring induction motor runs at 1440 rpm, then the slip is
   a) 0.03
   b) 0.04
   c) 0.05
   d) None of the above

11. Which of the following explains why the armature current of a shunt motor decreases as the motor accelerates?
   a) The high speed of the motor will cause the flux in the motor to decrease.
   b) The supply voltage decreases because the back emf has increased.
   c) The current decreases because the motor cannot take up any load.
   d) The current decreases because the back emf has increased

A 3- phase , 4 pole , 440 -V , 50 HZ , star connected induction motor, operates at 1450 rev/min on full load and has the following parameters per phase: $R_1 = 0.05\ \Omega$, $X_1 = 0.12\Omega$, $R'_2 = 0.04\ \Omega$ *and* $X'_2 = 0.14\Omega$. *Neglect the magnetizing current.*
Use the above information to answer questions 15-22.

12. Calculate the synchronous speed in radians / second
   a) 150.0
   b) 163.3
   c) 157.1
   d) None of the above
13. Calculate the percentage slip at full load.
   a) 8%
   b) 5%
   c) 3%
   d) None of the above

14. Calculate the starting current of the motor.
    a) 811.06 A
    b) 766.26 A
    c) 991.08 A
    d) None of the above
15. Calculate the full load current of the motor.
    a) 234.69 A
    b) 166.46 A
    c) 180.94 A
    d) None of the above
16. Calculate the total power input to the rotor circuit at full load.
    a) 98.22kW
    b) 165.25kW
    c) 119.90kW
    d) None of the above
17. Calculate the full load torque of the motor.
    a) 939.54Nm
    b) 625.21 Nm
    c) 1051.80Nm
    d) None of the above
18. Calculate the percentage slip at which a maximum torque can occur in the motor.
    a) 18.7%
    b) 19.5%
    c) 16.3%
    d) None of the above
19. Calculate the starting torque of the motor.
    a) 628.09 Nm
    b) 560.62 Nm
    c) 750.29 Nm
    d) None of the above

20. The direction of rotation of a three phase induction motor can be changed by
    a) By connecting the winding in star.
    b) By completely changing the sequence of the leads to the windings of the motor.
    c) By interchanging any two of leads to the windings of the motor.
    d) By completely changing the sequence of the leads to the windings of the motor so that a delta connection is obtained.
21. A shunt motor supplied at 230 runs at 900rev/min when the armature current is 30A .The resistance of the armature circuit is 0.4 Ω. Calculate the resistance required in series with the armature to reduce the speed to 600rev/min, assuming that the armature is then 20A
    a) 6.35 Ω
    b) 4.90 Ω
    c) 3.84 Ω
    d) None of the above

A 100kW, 460-V shunt generator was run as a motor on no load at its rated voltage and speed. The total current was 9.8 A, including a shunt current of 2.7 A. The resistance of the armature circuit, at normal working temperature, was 0.11 Ω.

Use the above information to answer Q22 to Q27

22. Calculate the armature current at full load.
    a) 185 A
    b) 233.10A
    c) 220.09A
    d) None of the above
23. Calculate the armature copper loss at full load.
    a) 4,835.60W
    b) 5,433.56W
    c) 5,328.36W
    d) None of the above

24. Calculate the input power to the motor at no load.
    a) 3,266W
    b) 3,772W
    c) 3,122W
    d) None of the above

A 250 V d.c shunt machine has an armature resistance of 0.5Ω and a shunt field resistance of 125Ω, both values at working temperature. The iron, windage and frictional losses in the machine amount to 750 W. When the machine is running as a motor at full load, the current taken from the supply is 52A.

Use the above information to answer questions 25 to 28.

25. Calculate the power taken by the motor from the supply at full load.
    a) 15.7kW b)13.0 kW c) 11.9kW d) None of the above
26. Calculate the armature copper loss at full load.
    a) 1.25kW b)1.73 kW c) 1.81kW d) None of the above
27. Calculate the total losses in machine at full load.
    a) 2.50kW b)3.73 kW c) 2.81kW d) None of the above
28. Calculate the efficiency of the motor at full load.
    a) 83.80% b) 80.77% c) 95.50% d) None of the above
29. Which of the following is **not true** about a squirrel cage motor?
    a) It has a multiple phase rotor.
    b) The presence of external resistors in the rotor circuit gives rise to high starting torque.
    c) It is more efficient than the slip ring induction motor.
    d) It is more robust than the slip ring induction motor.
30. DC series motor should never be switched on at no load, because
    a) the field current is initially zero
    c) the speed becomes dangerously high
    b) the motor does not pick up
    d) it will take long to accelerate
31. The volt-ampere equation for a long shunt compound motor is given by
    a) $V_t = E_a + I_a r_a$
    c) $V_t = E_a - I_a r_a$

b) $V_t = E_a + I_a(r_a + r_s)$

d) $V_t = E_a + I_a r_a + I_L r_s$

32. The rotor of an induction motor cannot run at synchronous speed because if it does so then

a) rotor e.m.f will be zero

c) rotor current will be zero

b) rotor torque would be zero

d) all of the above

An eight –pole armature is wound with 480 conductors. The magnetic flux and speed are such that average emf generated in each conductor is 2.2V and each conductor is capable of carrying a full load current of 100A.

Use the above information to answer questions 33 to 36

33. Find the terminal voltage on no load in volts if the armature is lap-connected.

a. 162

b. 153

c. 132

d. None of the above

34. Find the output current on full load in amperes if the armature winding is lap-connected.

a. 800

b. 750

c. 700

d. None of the above

35. Find the terminal voltage on no load in volts if the armature winding is wave-connected.

a. 556

b. 544

c. 528

d. None of the above

36. Find the output current on full load in amperes if the armature is wave-connected.

a. 200

b. 180

c. 140

d. None of the above

A 11-kW, 3-phase, 6-pole, 50-Hz, 400-V induction motor runs at 960 rev/min on full load. If it takes 80 A on direct-on-line switching,:

37. Determine the full load current

38. Find the ratio of T_s and T_{fl} Direct-on-line starting

39. Star-delta starting
40. Autotransformer starting with 60 % tapping
41. Stator resistance starter limiting the starting current to 50 A

Take full-load power factor and efficiency to be 0.834 and 95.6 % respectively

Use the above information to answer questions 37 to 40

SECTION B

Answer only ONE of the three questions in this section.

a. With the aid of a diagram, describe the principle of operation of a d.c shunt motor.

b. A 230 V compound generator has armature, series-field and shunt –field resistances of 0.5Ω, 0.3Ω and 150 Ω respectively. If this generator supplies 20kW at rated voltage and runs at 1000rpm, find the emf generated in the armature when machine is connected

i. long shunt

ii. short shunt

c. If a diverter of 0.5 Ω is connected in parallel with the series-field winding, find the percentage decrease or increase in the series-field ampere turns.

d. Calculate the speed of the machine when it is running as a long-shunt motor and taking 20 kW from the supply.

QUESTION 2

a. Briefly describe the principle of operation of a three phase induction motor.

b. Draw the speed / torque characteristic of a slip ring induction motor.

A 415-V, 3-phase, 6-pole, 50-Hz, star-connected slip ring induction motor has the following parameters in ohms per phase $R_1 = 0.04$, $X_1 = 0.15$, $R_2' = 0.05$, $X_2' = 0.15$

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Determine

c . The stator current and the gross torque in Nm when the slip is 0.05 pu.

d . The maximum gross torque, the slip at which it occurs and the gross output power under these conditions

e. The value of external resistance to be inserted in the rotor circuit to produce the maximum torque at standstill or starting. Neglect the magnetizing branch.

Emmanuel Addo

FORMULA SHEET

$$I_2 = \frac{E_2}{\sqrt{R_2^{\,2} + X_2^{\,2}}}$$

$$I_2' = I_1 = \frac{V_{1ph}}{\sqrt{(R_1 + \frac{R_2'}{s})^2 + (X_1 + X_2^{'})^2}}$$

$$P_{rotor} = \frac{3I_2 R_2}{s} \quad = \frac{3I_2'^{\,2} R_2'}{s} = T\omega_s$$

$$T = \frac{3V_{1ph}^{\,2} R_2'}{s\omega_s[(R_1 + \frac{R_2'}{s})^2 + (X_1 + X'_2)^2]}$$

$$T_{\max} = \frac{3V_{1ph}^{\,2}}{2\omega_s(R_1 + \sqrt{(R_1^{\,2} + (X_1 + X_2')^2}}$$

$$s_{T\max} = \frac{R_2'}{\sqrt{(R_1^{\,2} + (X_1 + X_2')^2}}$$

$$\eta = \frac{n\,S\cos\theta}{n\,S\cos\theta + P_0 + n^2 P_{sc\ full\ load}}$$

$$V.R._{p.u} = \frac{V_{sc}\cos(\theta_{sc} \pm \theta_{pf})}{V_1}$$

$$V = E_{arm} - I_a R_a - I_L R_{ser} \qquad I_f = \frac{V_L + I_L R_{ser}}{R_f}$$

$$V = E_{arm} - I_a(R_a + R_{ser}) \qquad I_f = \frac{V_L}{R_f}$$

$$V = E_{arm} \pm I_a(R_a + R_{ser})$$

$$\eta = \frac{V_L I_L}{V_L I_L + I_a^{\,2} R_a + I_f V_f + I_{ser}^{\,2} R_{see} + coreloss + friction + windage}$$

All symbols have their usual meanings.