Professional Engineers Ontario

Electromagnetic Energy Conversion Exam: 98-Elec-A6

Spring 2005

Notes:

1. This exam consists of two parts: Part 1 consists of 30 multiple choice questions, and Part 2 consists of problems. For Part 1, please use the answer sheet provided at the back of the exam. For Part 2, you have a choice of questions - do ***only*** 2 of the 4 questions given. If you attempt more than two questions, clearly indicate which questions should be marked; otherwise, the first two questions found in the answer booklet will be the only ones marked.

2. You may use one of the approved Casio or Sharp calculators.

3. This is a closed book exam. Formulae sheets are attached. Candidates are allowed to bring ONE aid sheet 8.5" x 11" hand-written on both sides containing notes and formulae. Note, no example or solution problems and no figures allowed. The aid sheet must be submitted with the written exam paper.

4. All ac voltages and currents are rms values unless noted otherwise. For three-phase circuits, all voltages are line-to-line voltages unless noted otherwise.

5. You may use pencil for this exam.

If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.

Part 1 - Multiple Choice

1. The power waveform in an ac circuit is a sine wave at double the source frequency.

   a. True.
   b. False, because the average power is greater than zero.
   c. True, but only with a resistive load.
   d. False, because the power waveform has the same frequency as the source.

2. In a transformer, the secondary voltage can rise above its rated voltage when the load is:

   a. resistive.
   b. capacitive.
   c. inductive.
   d. none of the above.

3. The short-circuit secondary current in a transformer is 2 A. What is the primary current if the transformer turns ratio is 2 : 5?

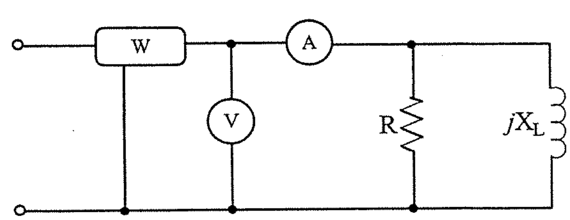
   a. 2 A
   b. 5 A
   c. 2.5 A
   d. 0.8 A

4. An ideal 400 Hz transformer is to be used in a 60 Hz system. Which of the following statements is correct if the maximum permissible flux is not to be exceeded?

   a. The maximum voltage that should be applied in this case is the same as it was for 400 Hz.
   b. The maximum voltage that should be applied is 667% of the rated voltage in the 400 Hz system.
   c. The maximum voltage that should be applied is 15% of the rated voltage in the 400 Hz system.
   d. A transformer can only be used at the frequency for which it was designed.

5. For the circuit shown below, the instrument readings are as follows: Wattmeter: 400 W; Voltmeter: 100 V; and, Ammeter: 5.0 A. The values of R and X_L are:

   a. 16 Ω and 12 Ω, respectively
   b. 25 Ω and 22.37 Ω, respectively
   c. 20 Ω and 22.37 Ω, respectively
   d. 20 Ω and 12 Ω, respectively



6. The apparent power rating of a 10:1 autotransformer is 450 VA. This means that the apparent rating of the secondary is

   a. 45 VA.
   b. 4500 VA.
   c. 450 VA.
   d. None of the above.

7. The line voltage at the secondary of a three-phase transformer connected Δ-Y is 208 V. What is the line voltage at the primary if the turns ratio is 10:1?

   a. 2080 V.
   b. 1200 V.
   c. 3600 V.
   d. 3280 V.

8. A DC motor turns at a speed of 1460 rpm and produces an output torque of 23.5 N-m (208 in-lbf). The DC voltage applied to the motor is 280 V and a current of 14.1 A flows through the motor. What is the efficiency of the motor?

   a. 94%
   b. 91%
   c. 79%
   d. 86%

9. What are the two main categories of losses for rotating machines?

   a. Copper and iron losses.
   b. Electrical and copper losses.
   c. Mechanical and iron losses.
   d. Electrical and mechanical losses.

10. The motor of a water pump produces an output torque of 10 N-m (88.5 in-lbf) at a speed of 3000 rpm. How much work is done by the pump motor if it turns for 10 minutes?

   a. 31.4 kW
   b. 3.14 kJ
   c. 1.88 MJ
   d. 31.4 kJ

11. If the armature connections to a universal motor are reversed, the

   a. armature current will decrease
   b. direction of rotation will reverse
   c. motor will stop rotating
   d. motor speed will become unstable

12. The direction of rotation of a DC series motor or a universal motor connected to a DC power source

    a. depends on the polarities of the armature and field currents
    b. depends exclusively on the polarity of the armature current
    c. depends exclusively on the polarity of the field current
    d. depends on the connection of the compensating winding

13. Does the speed of a squirrel-cage induction motor increase or decrease when the motor load increases?

    a. It increases.
    b. It decreases.
    c. Neither - it stays the same.
    d. The speed oscillates around the original value.

14. A squirrel-cage induction motor always requires

    a. reactive power to maintain the rotating magnetic field.
    b. active power to create the rotating magnetic field.
    c. a source of DC power to operate correctly.
    d. a prime mover to help it start.

15. What will be the output voltage of an asynchronous generator turning at its synchronous speed if the generator is not connected to an ac source?

    a. It will be zero except for a small voltage variation due to residual magnetism.
    b. It will depend on the direction of rotation.
    c. It will equal the nominal voltage rating of the generator.
    d. It will be much higher than if the generator were connected to an ac source.

16. How is motor torque affected when the motor voltage is decreased for a three-phase induction motor?

    a. It increases.
    b. It decreases.
    c. It does not change.
    d. It depends on the speed of the motor.

17. When the strength of the stator electromagnet is increased, the torque produced by a squirrel-cage induction motor

    a. does not change.
    b. decreases.
    c. increases.
    d. Torque only depends on the motor input voltage.

18. The current in the stator winding of a squirrel-cage induction motor greatly increases when the nominal winding voltage is exceeded because

    a. the motor develops a large torque.
    b. saturation occurs in the motor.
    c. squirrel-cage reaction occurs in the motor.
    d. reactive power is consumed in the motor.

19. What advantage is obtained by reducing the voltage applied to a squirrel-cage induction motor?

    a. The line current is reduced during starting.
    b. The motor brushes suffer less damage and wear.
    c. The starting torque is increased.
    d. The danger of motor runaway is avoided.

20. The direction of rotation of a three-phase squirrel-cage induction motor depends on the

    a. residual magnetism in the squirrel-cage rotor.
    b. interaction of the stator and rotor magnetic fields.
    c. design of the induction motor.
    d. phase sequence of the voltage applied to the motor stator windings.

21. When a synchronous motor without load is connected to a three-phase ac power network, the resulting power factor depends on

    a. the speed of the motor.
    b. the active power consumed by the motor.
    c. the amount of the field current.
    d. the line current.

22. A squirrel cage in a synchronous motor with a rotor of the electromagnet type

    a. allows the motor to start when ac power is applied to the stator windings.
    b. prevents saturation of the rotor electromagnet.
    c. minimizes the line current.
    d. makes the motor operate as a synchronous condenser.

23. When the load torque in a synchronous motor is increased, the pull-out torque

    a. decreases.
    b. increases.
    c. does not change
    d. increases momentarily until the speed stabilizes.

24. The output voltage of a synchronous generator is a function of the

    a. speed of rotation and polarity of the field current.
    b. speed of rotation and strength of the field electromagnet.
    c. speed of rotation and input torque.
    d. speed of rotation only.

25. For a synchronous generator to deliver a constant output voltage at a fixed frequency,

    a. both its speed and field current must be controlled.
    b. only its speed must be controlled.
    c. only its excitation current must be controlled.
    d. the load must be only resistive.

26. Active power to overcome the rotation friction of a synchronous generator that is "floating" on the ac power network comes from

    a. the network.
    b. the ac power supply.
    c. the prime mover turning the generator.
    d. the field current.

27. A three-phase synchronous generator with thirty pairs of poles per stator winding produces voltages at a frequency of 60 Hz when it rotates at the nominal speed. What is the nominal speed of the generator?

    a. 120 rpm.
    b. 360 rpm.
    c. 1800 rpm.
    d. 3600 rpm.

28. When a synchronous generator supplies power to either a resistive or an inductive load, the output voltage

    a. decreases as the output current increases.
    b. increases as the output current increases.
    c. remains constant as the output current varies.
    d. decreases as the field current increases.

29. When a single synchronous generator supplies power to a load that fluctuates, the voltage and frequency can be maintained constant by continually adjusting the

a. generator speed only.
b. position of the stator windings.
c. speed and field current of the generator.
d. field current only.

30. When a synchronous generator is synchronized with an ac power network, increasing the torque applied to the generator's shaft

a. increases the reactive power the generator delivers.
b. increases the active power the generator delivers.
c. decreases the reactive power the generator delivers.
d. increases the generator's speed.

Part 2 - Problems - Do *ONLY* 2 of these 4 questions. Each question is worth 20 marks.

1. A 208V/120 V, 60 Hz, 1800 VA transformer has the following parameters:

$R_C = 416\ \Omega$ (HV side) $\quad$ $R_{eq} = 0.21\ \Omega$ (LV side)

$X_m = 172\ \Omega$ (HV side) $\quad$ $X_{eq} = 0.98\ \Omega$ (LV side)

(Note: HV = high voltage side; LV = low voltage side)

The transformer is to be used as a step-down transformer.

a. If an open-circuit and short-circuit test were performed on this transformer, what would be the wattmeter reading for each test condition? You may place the measuring instruments in either winding.

b. Determine the efficiency and percent voltage regulation if a 1200 W load with a power factor of 0.67 lagging connected to the low voltage side, and the voltage across the load is the rated voltage, i.e., 120 V.

c. Repeat part (b) if the load is changed to a capacitive impedance of 12 Ω.

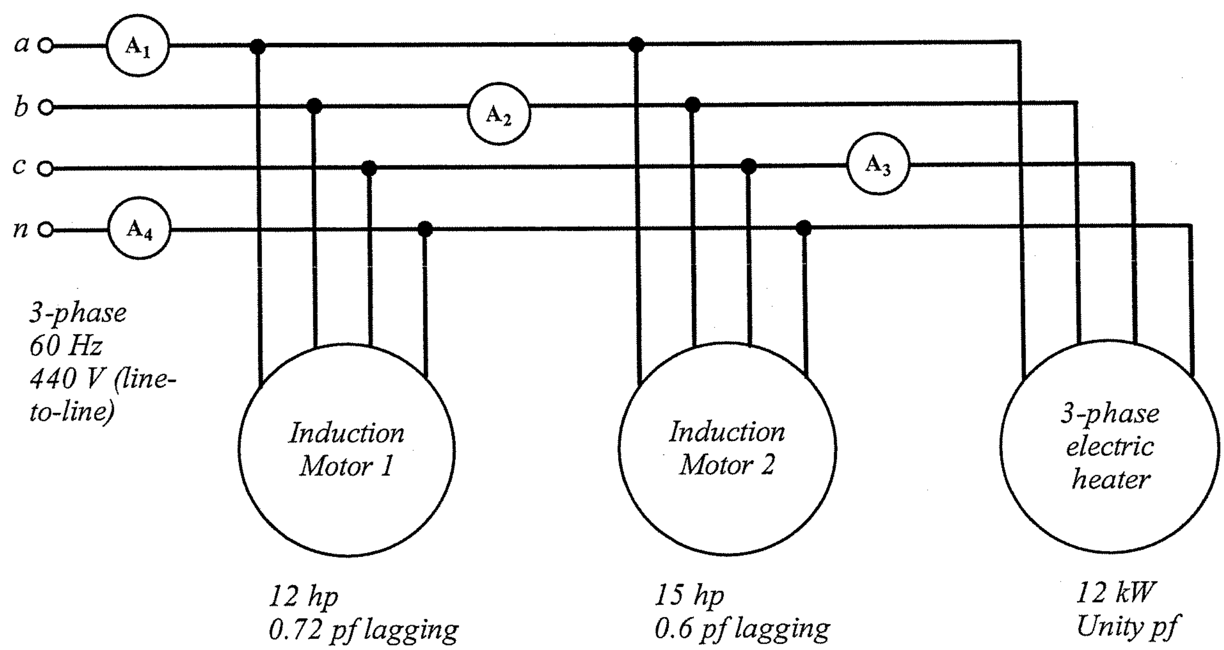
2. The circuit below shows the power distribution circuit for part of a small factory. The loads consist of a three-phase induction motor driving a constant speed pump, a second induction motor driving a constant speed fan, and a three-phase electric heater. Each load can be considered to be a balanced three-phase load.

   a. Determine the readings of the 4 ammeters indicated (recall that ammeters read only rms magnitudes).

   b. If all loads are on 24 hours per day, and energy costs are 9.4¢ per kWh, determine the daily energy costs.

   c. Determine the overall power factor for this circuit.

   d. If Induction Motor 2 were to be replaced with a synchronous motor that can supply the same output power, but at a leading power factor of 0.8, determine the new daily energy costs and the new overall power factor.



3. For a terminal voltage of 220 V DC, a DC shunt motor has a rated armature current of 50 A and a field current of 1.5 A, and a speed of 1000 rpm. No-load tests indicate the rotational losses at this speed are 1100 W. The armature resistance is 0.4 Ω. Determine:

   a. the no-load speed;

   b. the output power and torque under rated conditions;

   c. the full-load efficiency; and,

   d. the resistance that must be inserted in the armature winding during start up to limit the current to twice the rated value.

4. A three-phase, 60 Hz, 4-pole induction motor provides the following per-phase readings:

	Voltage	**Current**	**Power**
No-load test	254 V	13.7 A	900 W
Blocked rotor test	91.8 V	45 A	810 W

   a. Determine the parameters of the per-phase equivalent circuit for this motor.

   b. Determine the output torque developed by this motor for 5% slip.

END OF THE EXAM

Useful formulae

$$P = VI\cos\theta = \frac{V_R^2}{R} = I^2 R = Re[\mathbf{VI}^*]$$

$$Q = VI\sin\theta = \frac{V_X^2}{X} = I^2 X = Im[\mathbf{VI}^*]$$

$$\mathbf{S} = \mathbf{VI}^*$$

$$|\mathbf{S}| = \sqrt{P^2 + Q^2} = VI = I^2 Z = \frac{V^2}{Z}$$

$$p.f. = \cos\theta = \frac{R}{Z} = \frac{P}{S}$$

$$P_T = \sqrt{3}\,V_L I_L \cos\theta = 3P_P \qquad P_P = V_P I_P \cos\theta$$

$$Q_T = \sqrt{3}\,V_L I_L \sin\theta = 3Q_P \qquad Q_P = V_P I_P \sin\theta$$

$$S_T = \sqrt{3}\,V_L I_L \qquad S_P = V_P I_P$$

$$B = \frac{\Phi}{A} = \mu H = \mu\frac{\mathscr{F}}{l} = \mu\frac{Ni}{l} \qquad \left[\frac{Wb}{m^2} = T\right]$$

$$H = \frac{NI}{l} = \frac{B}{\mu} = \frac{\Phi/A}{\mu} \qquad \left[\frac{A-t}{m}\right]$$

$$\mathscr{F} = Ni = \Phi\frac{l}{\mu A} = \Re\Phi \qquad [A-t]$$

$$\Re = \frac{l}{\mu A} \qquad \left[\frac{A-t}{Wb}\right]$$

$$\mu_0 = 4\pi \ x \ 10^{-7} \ \frac{Wb}{A-t-m} \qquad \mu = \mu_0\mu_r$$

$$P_e = K_e f^2 B^2_{\max} V_{vol} \qquad P_h = K_h f B^x_{\max} V_{vol}$$

$$L = \frac{N^2}{\Re}$$

$$I_L = I_f + I_a$$

$$V_t = E_a + I_a R_a$$

$$E_a = K_a \Phi \omega$$

$$T = K_a \Phi I_a$$

$$P_{input} = V_t I_L$$

$$P_{dev} = E_a I_a = T_{dev} \omega_m$$

$$P_{out} = P_{dev} - P_{rot} = T_{out} \omega_m$$

$$P_{rot} = \text{No load } P_{dev}$$

$$n_s = 120 \frac{f}{p}$$

$$s = \frac{n_s - n_m}{n_s}$$

$$P_{input} = 3 V_1 I_1 \cos\theta$$

$$P_{gap} = P_{input} - 3 I_1^2 R_1 = 3 I_2'^2 \frac{R_2'}{s} = T_{dev} \omega_s$$

$$3 I_2'^2 R_2' = s P_{gap}$$

$$P_{dev} = P_{gap} - 3 I_2'^2 R_2' = (1 - s) P_{gap}$$

$$P_{out} = P_{dev} - P_{rot} = T_{out} \omega_m$$

$$\mathbf{E_f} = \mathbf{V_t} + \mathbf{I_a}(R_a + jX_s)$$

$$P = \frac{3 V_t E_f}{X_s} \sin\delta$$