Professional Engineers Ontario

Exam

07-Elec-A6 Power Systems and Machines

Fall 2014

Notes:

1) There are two parts to this exam. You <u>must</u> complete Part A (Question 1), which consists of 20 multiple choice questions. For Part B, you have a choice of questions - do **<u>only</u>** 4 of the 5 questions given. If you attempt more than 4 questions, clearly indicate which questions should be marked; otherwise, the first 4 questions found in the answer booklet will be the only ones marked. **FIVE (5)** questions constitute a complete exam paper. All questions are of equal value

2) ***<u>IMPORTANT!!</u>*** Start each question on a new page, and clearly indicate the question number. Only work written on the right hand pages of the answer booklets will be marked. Use the pages on the left side for rough work only - ***<u>work presented on pages the left hand side will NOT be marked</u>***.

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

4) This is a closed book exam. Formula sheets are attached.

5) 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, and power is total power unless noted otherwise.

6) You are strongly encouraged to use a pencil and eraser 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 A. Multiple choice questions.

You **must** answer these questions. Provide your answers to these questions on the answer sheet attached as the last page of the exam. Include the answer sheet with the exam booklet.

Marking. Note that there is one mark per multiple-choice question; no marks for an answer left blank; and a loss of half a mark for a wrong answer.

1) In two wattmeter method of power measurement, one of the wattmeters will show a negative reading when the load power factor angle is:
   a) greater than 60°;
   b) less than 60°;
   c) greater than 30°; or,
   d) less than 30°.

2) Three identical impedances are connected in delta to a 3-phase supply of 400 V. The line-current is 34.65 A and the total power drawn is 14.4 kW. The resistance of the load in each phase (in ohms) is:
   a) 4 Ω;
   b) 16 Ω;
   c) 12 Ω; or,
   d) 10 Ω.

3) Three equal impedances are first connected in delta across a 3-phase balanced supply. If the same impedances are then reconnected in Y across the same supply,
   a) the phase currents will be one-third;
   b) the line currents will be one-third;
   c) the power consumed will be one-third; or
   d) none of the above.

4) An air gap is usually inserted in magnetic circuits to:
   a) increase the mmf;
   b) increase the flux;
   c) prevent saturation; or,
   d) none of the above.

5) In the analogy of a magnetic equivalent circuit being similar to that of an electric circuit, the flux of the magnetic circuit can be compared with which parameter of the electrical circuit?
   a) Emf;
   b) Current;
   c) Current density; or,
   d) Conductivity.

6) Both the number of turns and the core length of an inductive coil are doubled. Its self-inductance will be:
   a) unaffected;
   b) doubled;
   c) halved; or,
   d) quadrupled.

7) Laminated cores in electrical machines are used to reduce:
   a) copper loss;
   b) eddy current loss;
   c) hysteresis loss; or,
   d) all of the above.

8) The full-load copper loss of a transformer is 1600 W. At half load the copper loss will be
   a) 6400 W;
   b) 1600 W;
   c) 800 W; or
   d) 400 W.

9) The wires of which transformer winding have the smallest cross-sectional area?
   a) Primary winding;
   b) Secondary winding;
   c) Low voltage winding; or,
   d) High voltage winding

10) During a short-circuit test on a transformer, iron/core losses are negligible because:

a) the current on the secondary side is negligible;
b) the voltage on the secondary side does not vary;
c) the voltage applied on the primary side is low; or,
d) the full-load current is not supplied to the transformer.

11) A transformer can have regulation close to zero when:

a) supplying full-load power;
b) the transformer is overloaded;
c) if the load power factor is leading; or,
d) if the load power factor is zero.

12) The slip of a 3-phase 440 V, 50 Hz induction motor is 4%. The frequency of the rotor emf will be:

a) 0.2 Hz;
b) 2 Hz;
c) 50 Hz; or,
d) 200 Hz.

13) The starting torque of a squirrel-cage induction motor is:

a) zero;
b) low;
c) the same as the full-load torque; or,
d) slightly more than the full-load torque.

14) The speed of a squirrel-cage induction motor can be controlled by all of the following methods, with the exception of :

a) changing the supply frequency;
b) changing the winding resistance;
c) changing the number of poles; or,
d) reducing the supply voltage.

15) In three-phase induction motors, copper bars can be placed deep in the rotor to:

a) improve the starting torque;
b) reduce copper losses;
c) improve the motor's efficiency; or,
d) improve the motor's power factor.

16) Which of the following statement is not valid when a squirrel-cage induction motor operates under no-load?

a) the induced emf in the rotor is low;
b) the rotor current is low;
c) the power factor is low; or,
d) the slip is low.

17) The no-load speed of which of the following DC motors is the highest?

a) shunt motor;
b) series motor;
c) cumulative compound motor; or,
d) differential compound motor.

18) If the field of a DC shunt motor is lost while motor is running,

a) the speed of the motor will be reduced;
b) the armature current will be reduced;
c) the motor will speed up; or,
d) the motor will continue to run at constant speed.

19) In DC shunt motors, as the load is reduced:

a) the speed will increase;
b) the speed will increase in proportion to reduction in load;
c) the speed will remain almost constant; or,
d) the speed will reduce.

20) The direction of rotation of a DC series motor can be changed by:

a) interchanging the polarity of the supply terminals;

b) interchanging the polarity of the field terminals;

c) either of (a) and (b) above; or,

d) none of the above.

Part B. Problems to be solved in the answer booklet.

Answer <u>only</u> 4 of the 5 following questions. If you answer all 5 questions, clearly indicate which questions should be marked; if not, the first 4 questions as they appear in order in the answer book will be the only ones marked.

2) <u>Induction motors.</u> A four-pole, three-phase, Y-connected, 60 Hz induction motor has the following equivalent circuit parameters, all referred to the stator side:

$R_1 = 0.641\ \Omega$ $R_2 = 0.300\ \Omega$
$X_1 = 0.750\ \Omega$ $X_2 = 0.500\ \Omega$ $X_m = 26.3\ \Omega$

Iron/core losses are 455 W. The motor is connected to a 460 V (line-to-line) 60 Hz voltage source. Draw the equivalent circuit showing the above circuit values, and then determine, for a slip of 3%:

a) the stator current;
b) the shaft speed;
c) the output power;
d) the output torque; and,
e) the efficiency.

3) <u>Transformers.</u> A single-phase step-down transformer has a turns ratio of 3. The resistance and reactance of the primary winding are 1.2 Ω and 6 Ω, respectively, and those of the secondary winding are 0.05 Ω and 0.3 Ω, respectively, with all impedance values referred to their own windings. If the high voltage winding is supplied at 230 V, 60 Hz with the low voltage winding short circuited, find:

a) the current in the low voltage winding;

b) the copper loss in the transformer; and,

c) the power factor.

4) Three-phase power. A balanced three-phase 4.16 kV (line-to-line), 60 Hz, Y-connected system is shown below in Figure 1. The per-phase load impedance, $\mathbf{Z}_\phi$, is $50 + j30\ \Omega$. Line impedances are negligible. Using V_{an} as the 0° phase reference and assuming positive phase rotation, draw the single-line diagram for this circuit, and then find the following quantities:

   a) the magnitude of line current;
   b) the six line and phase voltages (magnitude and phase), making clear which are line and which are phase;
   c) the six labeled currents (magnitude and phase), making it clear which are line and which are phase;
   d) find the power absorbed by the three-phase load;
   e) the per-phase capacitance in kVAR which when placed across each phase of the load will bring the power factor to 0.93 lagging; and,
   f) the magnitude of the line current after the capacitors are connected.

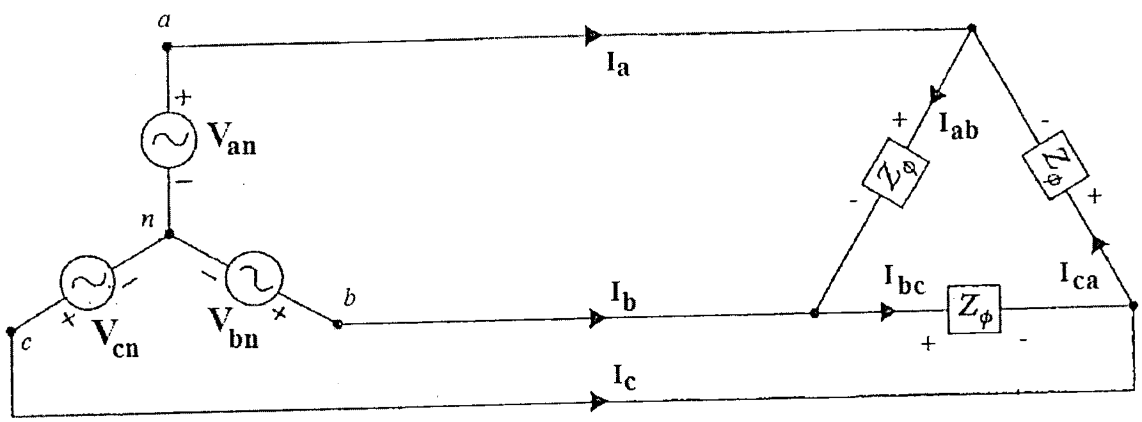

Figure 1

5) Synchronous machines. A three-phase, round-rotor synchronous generator is rated at 10 kV and 50 MVA. It has an armature resistance of 0.1 per unit and a synchronous reactance of 1.65 per unit, bases on its rating. The generator is connected to an infinite bus having a voltage of 10 kV, where it delivers 2000 A at 0.9 power factor leading.

   a) Determine the internal voltage and the power angle of the machine.
   b) Draw a well-labelled phasor diagram for the above operating conditions.
   c) What is the open-circuit voltage of the generator at the same level of excitation?
   d) Determine the steady-state short-circuit current at the same level of excitation.

6) DC motors.
   a) What does Ea represent in the equivalent circuit of a DC motor?
   b) A 30 hp, 240 V, 1150 rpm DC shunt motor, operating at rated conditions, has an efficiency of 88.5 percent. The armature resistance is 0.064 Ω and the field resistance is 93.6 Ω. Draw an equivalent circuit for the motor, and determine:
      i) what percentage of the total losses are rotational losses;
      ii) the external resistance needed in series with the armature circuit to limit the starting current to 175 percent of rated armature current on start-up; and,
      iii) the new speed if the flux is reduced by 10 percent and the shaft load is adjusted to maintain rated armature current.

END OF THE EXAM

Potentially useful formulae

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

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

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

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

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

$$P_T = \sqrt{3}V_LI_L\cos\theta = 3P_P \qquad P_P = V_PI_P\cos\theta$$

$$Q_T = \sqrt{3}V_LI_L\sin\theta = 3Q_P \qquad Q_P = V_PI_P\sin\theta$$

$$S_T = \sqrt{3}V_LI_L \qquad S_P = V_PI_P$$

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

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

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

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

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

$$P_e = K_ef^2B^2_{\max}V_{vol} \qquad P_h = K_hfB^x_{\max}V_{vol}$$

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

$$I_L = I_f + I_a$$

$$V_t = E_a + I_a R_a$$

$$E_a = K_a \Phi \omega$$

$$T = K_a \Phi I_a$$

$$P_{input} = V_t I_L$$

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

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

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

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

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

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

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

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

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

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

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

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

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Multiple Choice Answer Sheet

Candidate's Name ____

Separate this page from the exam and submit it with the exam booklet.

Please ensure you provide only one answer choice for each question - two or more answers will be deemed incorrect. The marking scheme is as follows (maximum 20 marks):

Correct answer:	1 mark
No answer:	0 marks
Incorrect answer:	-0.5 mark (although you cannot get a negative total mark, i.e., less than zero, for this question)

You should use pencil for this part of the exam, and ensure you completely erase any answers you wish to change.

1.	[a]	[b]	[c]	[d]	11.	[a]	[b]	[c]	[d]
2.	[a]	[b]	[c]	[d]	12.	[a]	[b]	[c]	[d]
3.	[a]	[b]	[c]	[d]	13.	[a]	[b]	[c]	[d]
4.	[a]	[b]	[c]	[d]	14.	[a]	[b]	[c]	[d]
5.	[a]	[b]	[c]	[d]	15.	[a]	[b]	[c]	[d]
6.	[a]	[b]	[c]	[d]	16.	[a]	[b]	[c]	[d]
7.	[a]	[b]	[c]	[d]	17.	[a]	[b]	[c]	[d]
8.	[a]	[b]	[c]	[d]	18.	[a]	[b]	[c]	[d]
9.	[a]	[b]	[c]	[d]	19.	[a]	[b]	[c]	[d]
10.	[a]	[b]	[c]	[d]	20.	[a]	[b]	[c]	[d]

Mark obtained = ______________ - ______________/2 = ________
correct   # incorrect   20