THE UNIVERSITY of EDINBURGH

SCHOOL OF ENGINEERING

POWER ENGINEERING 2

SCEE08008

Exam Date: **17/05/2019** From and To: **14:30-16:00** Exam Diet: **May 2019**

Please read full instructions before commencing writing

Exam paper information

- This paper consists of TWO sections.
- Candidates should attempt THREE questions, chosen as follows:
- Section A: ONE question. Attempt the whole section.
- Section B: Attempt TWO out of the THREE questions.

Special instructions

- Students should assume reasonable values for any data not given in a question nor available on a datasheet, and should make any such assumptions clear on their script.
- Students in any doubt as to the interpretation of the wording of a question, should make their own decision, and should state it clearly on their script.
- Please write your name in the space indicated at the right hand side on the front cover of the answer book. Also enter your examination number in the appropriate space on the front cover.
- Write **ONLY** your examination number on any extra sheets or worksheets used and firmly attach these to the answer book(s).
- This examination will be marked anonymously.

Special items

- Data sheet (1 page)

Convenor of Board of Examiners: **Professor R Cheung**
External Examiner: **Professor J Morrow and Dr Z Durrani**

SECTION A

Question A1

a) For stable operation in a large power system, the total power generated should exactly equal the total power demand plus system losses. If a power station suddenly develops a fault and trips out, there is a power supply deficit. Explain:

(i) Where the extra energy comes from to meet demand in the seconds immediately following the fault; **(2)**

(ii) Why a large increase in the amount of wind and solar sources in the network makes this more difficult. **(2)**

b) A three-phase, 20 pole synchronous generator driven by a hydro turbine supplies power into the 50 Hz electricity network.

Explain the process that the operator needs to follow to start the system from rest, connect to the 18 kV network, and control the power and power factor supplied to the network. **(6)**

c) In a house wiring system, should the fuses be placed in the live, the neutral, or both wires? Give reasons for your answer. **(3)**

d) Why do birds sitting on a high voltage power line not receive an electric shock? **(1)**

e) In Figure A1, the three phase, delta-connected load is supplied from a balanced, star connected supply where the phase voltages E_a, E_b and E_c are 230 V.

(i) If $Z_{ab} = Z_{bc} = Z_{ca} = 8 + j6\ \Omega$, calculate the magnitude of the line currents I_a, I_b and I_c. **(4)**

(ii) Calculate the total active power dissipated in the load. **(2)**

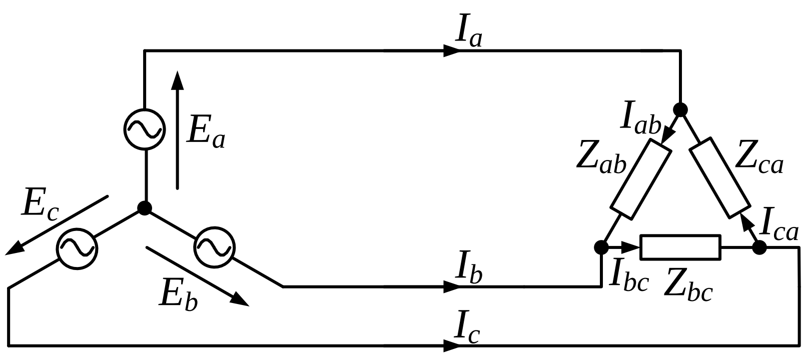

Figure A1

SECTION B

Question B1

a) In a squirrel cage induction motor, explain why no torque is produced if the rotor is rotating at exactly synchronous speed. **(4)**

b) (i) With reference to the full equivalent circuit of an induction motor shown in Figure B1, explain why a very high current is drawn from the supply when the motor is started from rest. **(3)**

(ii) What potential problems can this high starting current cause? **(2)**

c) Sketch the torque-speed curve of a typical induction machine, indicating on it the areas that relate to:

(i) stable motor operation;

(ii) unstable motor operation;

(iii) stable generator operation. **(5)**

d) The speed of an induction motor connected to the 50 Hz mains supply is measured at 970 rpm.

(i) How many pole-pairs is this motor likely to have? **(1)**

(ii) What will be the frequency of the voltages and currents on the rotor? **(1)**

e) If it is necessary to control the speed of an induction motor, discuss how this could be achieved. **(4)**

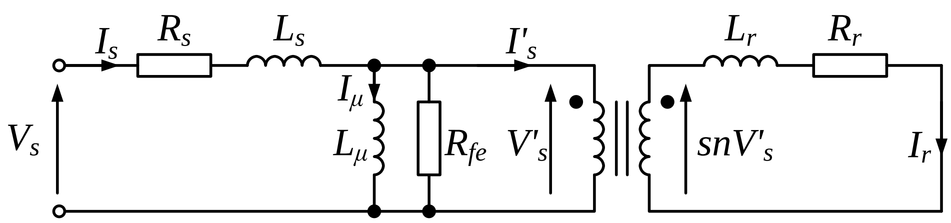

Figure B1

Question B2

A small factory has the following loads supplied from the 230 V, 50 Hz single-phase supply:

- 8 kVA at 0.8 power factor lagging;
- 6 kW at unity power factor;
- 9 kVA at 0.7 power factor lagging.

a) Calculate:

(i) The total active power drawn from the supply; **(4)**

(ii) The overall power factor; **(3)**

(iii) The total current drawn from the supply. **(3)**

b) The power supply company tells the factory management that it will reduce its electricity tariff to the factory if it increases its power factor to at least 0.95 lagging.

(i) Calculate the value of capacitance that the factory would need to install to increase the power factor to 0.95 lagging. **(6)**

(ii) What would be the new total current drawn from the supply? **(2)**

(iii) What are the main benefits to the power supply company if the factory improves its power factor? **(2)**

Question B3

a) Figure B3 shows the equivalent circuit of a separately excited dc motor. Explain why the field current I_f should never be switched off while the motor is running. **(3)**

b) A separately excited dc motor has armature resistance $R_a = 2\ \Omega$ and field resistance $R_f = 1000\ \Omega$. The armature is supplied from a variable voltage source with a maximum output of 110 V, and the field winding is supplied from a separate (variable) 110 V source.
When driving a mechanical load, the armature voltage $V_a = 90$ V, the field voltage $V_f = 100$ V, the motor speed = 1000 rpm and the armature current $I_a = 7.5$ A.

(i) What is the shaft torque (assume zero mechanical losses)? **(6)**

(ii) What are the total electrical losses? **(3)**

(iii) The operator increases the armature voltage to its maximum 110 V, and the speed increases to 1200 rpm (with V_f kept constant). What is the new value of I_a? **(2)**

c) If the operator wishes to increase the speed to 2000 rpm, explain (qualitatively) how this could be achieved? **(3)**

d) Discuss why induction motors are generally preferred to dc motors for large (greater than 1 kW) motor applications. **(3)**

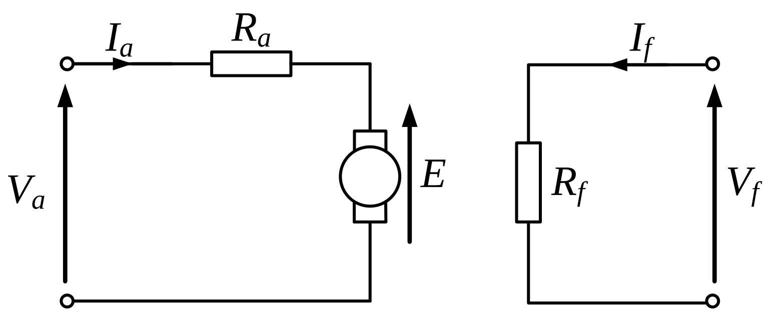

Figure B3

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Power Engineering 2: Formula Sheet

Three-phase systems

	Star	Delta
Voltage	$V_L = \sqrt{3} V_{ph}$	$V_L = V_{ph}$
Current	$I_L = I_{ph}$	$I_L = \sqrt{3} I_{ph}$
Power	$3 V_{ph} I_{ph} \cos\varphi = \sqrt{3} V_L I_L \cos\varphi$	

$$\Delta V \approx \frac{RP + XQ}{V_r} \quad \text{per phase}$$

Transformer

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1} = n$$

$$Z_2 = n^2 Z_1$$

$$V = 4.44 f \Phi_m N$$

Synchronous Motor

$$P = \frac{3.V.E.\sin\delta}{X_s}$$

Induction Motor

$$s = \frac{\omega_o - \omega_r}{\omega_o}$$

DC Motor

$$E = k\, \phi_f\, \omega \approx K I_f \omega$$

$$T \approx K\, I_f\, I_a$$