UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

MAIN EXAMINATION DECEMBER 2015

TITLE OF PAPER:	ELECTRICAL MACHINES
COURSE CODE:	EE451
TIME ALLOWED:	THREE HOURS

INSTRUCTIONS:

1. Answer any five **(5)** questions
2. Each question carries 20 marks
3. Marks for different sections are shown in then right hand margin

This paper has 4 pages including this page

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QUESTION 1 [20]

(a) Which parameters are determined during short circuit test? Sketch its equivalent circuit [3]

(b) Why does the open circuit test essentially show only excitation losses and not i^2R [3]

(c) A 75 –kVA, 24 000/480 V, 3- phase distribution transformer is connected in delta/star. The open circuit test was performed on this transformer , and the following data were recorded:

$$V_{line,\,OC} = 480\text{ V},\ I_{line,\,OC} = 4.10\text{ A},\ P_{3\phi,\,OC} = 945\text{ W}$$

The short circuit test was performed on this transformer bank and the following data were recorded:

$$V_{line,\,SC} = 1400\text{ V},\ I_{line,\,SC} = 1.80\text{ A},\ P_{3\phi,\,SC} = 912\text{ W}$$

(i) Find the equivalent circuit parameters in per unit of this transformer [11]

(ii) Find the voltage regulation of this transformer bank at the rated load and 0.9 PF lagging [3]

QUESTION 2 [20]

(a) Explain why the efficiency of an induction motor is so poor at high slip [3]

(b) Is it possible to run an induction motor at synchronous speed? Explain? [2]

(c) Give three possible reasons which can prevent an induction motor from starting [3]

(d) Evaluate the performance of a 380 V, 18 kW, 50 Hz, 4- pole Y- connected three phase induction motor, when calculating the following: motor speed, stator current, motor power factor, stator copper losses, gap power, rotor copper losses, developed power, output power, developed torque, output torque and the motor efficiency.
Assume that the motor mechanical losses to be 6% of the rated power. Perform the evaluation at rated slip of 38% and the rated voltage. The motor equivalent circuit parameters referred to the stator winding are as follows: [12]

$R_1 = 0.59\ \Omega$ $R_2 = 0.31\ \Omega$ $X_M = 27.1\ \Omega$ $X_1 = 1.21\ \Omega$ $X_2 = 0.42\ \Omega$

QUESTION 3 [20]

(a) Sketch a phasor diagram of a synchronous generator operating at a leading power factor **[2]**

(b) As an engineer, you have been asked by your supervisor to determine the synchronous impedance of a synchronous generator. State the procedure you will follow in determining the synchronous impedance **[3]**

(c) A 100-MVA 11.5-kV 0.8-PF-lagging 50-Hz 2-pole Y-connected synchronous generator has a per-unit synchronous reactance of 0.8 and a per-unit armature resistance of 0.012.

- (i) What are its synchronous reactance and armature resistance in ohms? **[3]**
- (ii) What is the magnitude of the internal generated voltage *EA* at the rated conditions? What is its torque angle δ at these conditions? **[4]**
- (iii) Ignoring losses in this generator, what torque must be applied to its shaft by the prime mover at full load? **[3]**

(d) Define the term infinite bus and describe steps to be followed when synchronizing a generator to the infinite bus **[5]**

QUESTION 4 [20]

(a) What is speed regulation of a dc motor? **[2]**

(b) How can speed of a shunt dc motor be controlled? **[2]**

(c) Provide three risks that may occur during starting of a dc shunt motor if we apply full voltage to a stationary motor as the starting current in the armature will be very high **[3]**

(d) What effect does armature reaction have on the torque-speed characteristic of a shunt dc motor? Can the effects of armature reaction be serious? **[3]**

(e) A 220-V shunt motor runs on no-load at 1500 rpm (157.080 rad/s). The no-load current is 8.5 A. The armature circuit resistance is 0.25 Ω and the shunt field resistance is 220 Ω. Calculate:

- (i) The full-load current. **[2]**
- (ii) The counter electromotive force. **[1]**
- (iii) The motor constant . **[1]**
- (iv) The speed when the load current is 43 A. **[5]**
- (v) The speed regulation **[1]**

QUESTION 5 [20]

(a) Two three phase, transformers **A** and **B** are selected to be connected in parallel to supply a load having an impedance of$(0.25 + j0.1)\Omega$. Transformer A is Yy 0 –connected and Transformer B is Yy 6 –connected. The equivalent impedances of the transformers referred to the secondary windings are $(0.025 + j0.061)$ Ω / phase and $(0.01 + j0.024)$

Ω/phase respectively. The open-circuit e.m.f. of transformer A is 245 V / phase and that of transformer B is 240V / phase.

(i) Comment on the suitability of the two transformers to work in parallel while evaluating their compliance with the essential conditions for parallel operation. Explain what should be done in order the transformers A and B to work properly in parallel. Motivate your answers on appropriate sketches of the phase winding of the transformers. **[4]**

(ii) Construct an equivalent circuit diagram on per-phase basis, showing the transformers and load voltages and currents. **[3]**

(iii) When in parallel and supplying the rated load evaluate the transformers performance by computing:

I. The circulating current due to non-equality of the transformer's voltage ratios **[2]**

II. Derive the equation for the terminal voltage and hence determine the voltage at the load **[7]**

III. The current supplied by each transformer **[4]**

QUESTION 6 [20]

(a) Explain how a squirrel- cage motor can be made to operate at two different speeds when driven at rated supply voltage and frequency **[2]**

(b) It is desired that an air- conditioner driven by three phase induction motor(s) is to be started automatically by direct on line starter that is controlled by the temperature switch in the room. Design a circuit showing the starter and control wires. Use a two – wire control and include a thermal overload relay in the diagram **[8]**

(c) A 20 kW, 400 V, 50 Hz, 3 – phase induction motor is rated at 974 rpm at full load and has 6 poles. The load stator copper loss is 645 W and mechanical rotational loss is 1120 W. Determine the rotor copper loss, the air gap power and efficiency of the motor. Take the magnetic losses as 720 W **[10]**