9210-113
Level 6 Graduate Diploma in Engineering
Electrical machines and electrical energy system fundamentals

Sample Paper

You should have the following for this examination
- one answer booklet
- non-programmable calculator
- pen, pencil, ruler

No additional data is attached

General instructions
- This examination paper is of **three hours** duration.
- This paper contains **ten** questions over Section A and B.
- Answer **five** questions selecting at least **two** questions from each section.
- All questions carry equal marks. The maximum marks for each section within a question are given against that section.
- An electronic, non-programmable calculator may be used but candidates **must** show clearly the steps prior to obtaining final numerical values.
- Drawings should be clear, in good proportion and in pencil. Do **not** use red ink.

Section A

1 a) Describe the differences in application of current transformers and potential transformers. (4 marks)

b) Explain why there is a non-zero primary current when the secondary of a transformer is open? (4 marks)

c) A transformer is required to deliver 1 A current at 12 V from a 240 V supply voltage. The number of turns in the primary winding is 2000.

i) How many turns are required in the secondary winding? (4 marks)

ii) What is the current in the primary winding if the secondary current is 1 A? (4 marks)

d) A single-phase transformer with a ratio of 440/110 V takes a no-load current of 5 A at 0.2 power factor lagging. If the secondary supplies a current of 120 A at a p.f. of 0.8 lagging, estimate the current taken by the primary. (4 marks)

2 a) Write short answers for the following questions.

i) Why do both the voltage and frequency induced in the rotor of an induction motor decrease as the rotor speeds up? (2 marks)

ii) What are the key differences between a squirrel cage motor and a wound-rotor motor, in terms of construction and method of operation? (2 marks)

b) A three-phase, 20 hp, 208 V, 60 Hz, six pole, Y-connected induction motor delivers 15 kW at a slip of 5%. Calculate,

i) synchronous speed (4 marks)

ii) rotor speed (4 marks)

iii) frequency of rotor current. (4 marks)

c) A three-phase, 460 V, 60 Hz, six-pole wound-rotor induction motor drives a constant load of 100 Nm at a speed of 1140 rpm when the rotor terminals are short-circuited. It is required to reduce the speed of the motor to 1000 rpm by inserting resistances in the rotor circuit. Determine the value of the resistance if the rotor winding resistance per phase is 0.2 Ω. Neglect rotational losses. The stator-to-rotor turns ratio is unity. (4 marks)

3 a) Derive the basic power angle characteristic equation for a cylindrical rotor synchronous generator. (4 marks)

b) A 9-kVA, 208 V, 3-phase, Y-connected, synchronous generator has a winding resistance of 0.1 Ω per phase and a synchronous reactance of 5.6 Ω per phase.

i) Determine the voltage generated (exciting emf) by the machine when it is delivering full-load at 0.8 power-factor lagging at rated voltage. (4 marks)

ii) Calculate the voltage regulation for rated load at 0.8 power factor leading. (4 marks)

c) What are the steps that must be adhered to when adding a generator to an existing power grid? (4 marks)

d) Which type of Synchronous generator is used in Hydroelectric plants? Also, explain why such types are better suited. (4 marks)

4 a) What is meant by armature reaction? (4 marks)

b) Derive the expression for torque produced in a d.c. motor. (4 marks)

c) A 230 V d.c. shunt motor with constant field drives a load whose torque is proportional to the speed. When running at 750 rpm it takes 30 A. Find the speed at which it will run if a 10 Ω resistance is connected in series with the armature. The armature resistance may be neglected. (4 marks)

d) Explain the difference between series, shunt and compound DC generators. (4 marks)

e) A 4 pole, long-shunt, compound generator supplies100 A at a terminal voltage of 500 V. If armature resistance is 0.02 Ω, series field resistance is 0.04 Ω and shunt field resistance is 100 Ω, find the generated emf. Take voltage drop per brush as 1 V and neglect armature reaction. (4 marks)

5 a) Discuss the different starting methods of 3 phase Induction motors. (2 marks)

b) After servicing a single-phase fan, it was found to run in reverse direction. What could be the reason? (2 marks)

c) The power input to a 500 V, 50 Hz, 6-pole 3-phase squirrel cage induction motor running at 975 rpm is 40 kW. The stator losses are 1 kW and the friction and wind age losses are 2 kW. Calculate,

i) slip (3 marks)

ii) rotor copper loss (3 marks)

iii) mechanical power developed (3 marks)

iv) the efficiency. (3 marks)

d) Draw the per phase approximate equivalent circuit of a 3-phase induction motor at slip ‘s’ and derive the expression for electromagnetic torque developed by the motor.
Derive also the expression for the maximum torque. (4 marks)

Section B

6 a) Explain the functions of the following elements used in a power system.
   i) DDLO (Drop Down Lift Off).
   ii) Potential Transformer. (4 marks)
 b) List **three** disadvantages of having a single bus bar system. (4 marks)
 c) Give a comparison of outdoor and indoor sub-stations. (4 marks)
 d) What is the difference between
   i) a switch and a circuit breaker (2 marks)
   ii) a fuse and a circuit breaker. (2 marks)
 e) Explain arc interruption methods involved in DC and AC circuits. (2 marks)
 f) Why do we use a C.T. (Current Transformer) in the relay circuits? (2 marks)

7 a) Draw a typical load curve and explain the terms 'Base Load' and the 'Peak Demand'. (4 marks)
 b) i) Explain the terms load factor and diversity factor. (2 marks)
   ii) What are the advantages of an interconnected grid? (2 marks)
 c) A generating station has a maximum demand of 25 MW, a load factor of 60%, a plant capacity factor of 50% and a plant use factor of 72%. Find
   i) the reserve capacity of the plant (2 marks)
   ii) the daily energy produced (2 marks)
   iii) maximum energy that could be produced daily if the plant while running as per schedule, were fully loaded. (2 marks)
 d) A base load station having a capacity of 18 MW and a standby station having a capacity of 20 MW share a common load. Find the annual load factors and plant capacity factors of two power stations from the following data.
   Annual standby station output = $7{\cdot}35 \times 106$ kWh
   Annual base load station output = $101{\cdot}35 \times 106$ kWh
   Peak load on standby station = 12 MW
   Hours of use by standby station/year = 2190 hours (6 marks)

8 a) What is the function of switchgear in a grid substation? (4 marks)
 b) What is the function of a relay? (4 marks)
 c) A single-core cable has a conductor diameter of 1 cm and insulation thickness of 0·4 cm. If the specific resistance of insulation is $5 \times 10^{14}\ \Omega$cm, calculate the insulation resistance for a 2 km length of the cable
   (*Permittivity of free space* = 8.854×10^{-12} *F/m*) (6 marks)
 d) A single core cable has a conductor diameter of 1 cm and internal sheath diameter of 1·8 cm. If impregnated paper of relative permittivity 4 is used as the insulation, calculate the capacitance for 1 km length of the cable. (6 marks)

9 a) Why do you need to improve the power factor in industrial loads? (4 marks)
 b) Discuss **three** types of power factor improvement methods. (4 marks)
 c) A single phase AC generator supplies the following loads
   - Lighting load of 20 kW at unity power factor.
   - Induction motor load of 100 kW at p.f. 0·707 lagging.
   - Synchronous motor load of 50 kW at p.f. 0·9 leading.
   i) Calculate the total kW and kVA delivered by the generator and the power factor at which it works. (2 marks)
   ii) Calculate the capacitance required in parallel with the generator to raise the power factor to 0·95 lagging. (2 marks)
 d) A transmission line has a span of 150 m between level supports. The conductor has a cross-sectional area of 2 cm^2. The tension in the conductor is 2000 kg. If the specific weight of the conductor material is 9·9 g/cm^3 and wind pressure is 1·5 kg/m length, calculate the overall sag and the vertical sag. (8 marks)

10 a) Explain briefly the existence of inductive reactance and capacitive reactance in AC transmission lines. (3 marks)

b) Derive the basic equations for inductive reactance and capacitive reactance in AC transmission lines. (3 marks)

c) A 3-phase, 50 Hz, 150 km line has a resistance, inductive reactance and capacitive shunt admittance of 0·1 Ω, 0·5 Ω and 3×10^{-6} S per km per phase respectively. If the line delivers 50 MW at 110 kV and 0·8 p.f. lagging. Determine

i) the sending end voltage (7 marks)

ii) the sending end current. (7 marks)

Assume a nominal π-equivalent circuit for the line.