City & Guilds

9210-114
Level 6 Graduate Diploma in Engineering
Electrical Energy Systems

Sample Paper

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

No additional data is attached

General instructions
- This examination paper is of **three hours** duration.
- This examination paper contains **nine** questions.
- Answer **any five** questions.
- 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 the candidate **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.

1 a) A 66 kV overhead distribution line, having a length of 60 km delivers power to a load centre. During peak hours, the load centre serves a load of 15 + j8 MVA. Per unit length, resistance and reactance of the line are 0.249 Ωkm^{-1} and 0.414 Ωkm^{-1} respectively. The effect of shunt capacitance of the line is neglected. Voltage at the sending end is maintained at its rated value.

i) Calculate the approximate value of voltage at the load centre during the peak hours. (10 marks)

ii) Express the voltage drop of the line as a percentage. (2 marks)

b) It is proposed to install series capacitors to each phase of the line to reduce the line drop to 5%. The rated voltage and power of the available capacitors are 0.66 kV and 40 kvar respectively.

i) Calculate the number of capacitors that are to be connected in series in each phase of the line to achieve above requirement. (8 marks)

2 A 750 kV, 50 Hz, 315 km overhead transmission line delivers power to a grid substation. Series impedance and shunt susceptance of the line are 0.025 + j0.3 Ωkm^{-1} and j6 x 10^{-6} Skm^{-1}. During peak hours, the grid substation receives 800 MW at 0.8 power factor lagging. Voltage at the receiving end is to be maintained at the rated value.

a) Calculate surge impedance, wavelength and propagation constant. (5 marks)

b) Determine A, B, C, D parameters of the line. (6 marks)

c) Calculate sending end voltage, current and power factor of the line during peak hours. (6 marks)

d) Now the line is opened at the far end. Without any calculation, state giving reasons whether the voltage at the far end is increased or decreased. (3 marks)

3 Consider the power system shown in Figure Q3. Branch data and bus data of the system are given in Table 3.1 and Table 3.2 respectively. Initial estimates of respective buses are given in the voltage column of the Table 3.2. Line reactance is given on 100 MVA base.

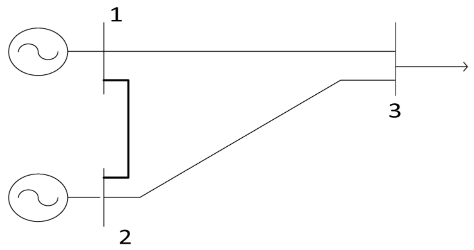

Figure Q3

Bus number	Bus number	Series impedance p.u.
1	2	j0.025
1	3	j0.04
2	3	j0.06

Table 3.1

Bus number	P MW	Q MVar	V p.u.	Voltage angle
1	–	–	1.05	0°
2	400	–	1.02	0°
3	500	200	1.0	0°

Table 3.2

a) Construct bus admittance matrix. (4 marks)
b) Use Gauss-Seidel method to calculate voltages at nodes after one iteration. (10 marks)
c) Determine swing bus power and power factor. (6 marks)

See next page

4 a) i) A power system consists of *n1* number of PV buses and *n2* number of load buses. Determine the order of the following blocks of Jakobian matrix. (4 marks)

$$\frac{\partial P}{\partial \delta}, \frac{\partial P}{\partial V}, \frac{\partial Q}{\partial \delta}, \frac{\partial Q}{\partial V}$$

ii) Describe the advantage of the fast-decoupled load flow calculation method over the Newton-Raphson method. (3 marks)

b) Consider the power system shown in Figure Q4. Voltage at load bus to be calculated using the Newton-Raphson method.

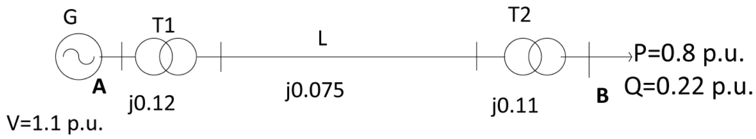

Figure Q4

i) Calculate active and reactive power mismatch at load bus B. (6 marks)

ii) Determine the voltage at bus using the Newton-Raphson method after first round of iteration. (7 marks)

5 a) A 200 MVA, 50 Hz synchronous generator has inertia constant of 8 MJ/MVA.

i) Calculate the kinetic energy stored when the generator is running at synchronous speed. (2 marks)

ii) At the steady state condition, the generator delivers 150 MW. If the electrical load is suddenly dropped to100 MW determine the initial acceleration of the rotor. (2 marks)

b) A three-phase, 50 Hz synchronous generator delivers power of 0.65 p.u. to a system via a transmission line. Sub-transient reactance of the generator and per- phase inductive reactance of the line are 1.25 p.u. and 0.38 p.u. respectively. Voltage magnitudes at the starting and ending points are equal to1.0 p.u.

i) Determine the excitation voltage of the generator. (4 marks)

ii) A three-phase short circuit occurred in the line and after a while, the fault was self-cleared. How long can the fault be continued without losing the synchronism (H = 4 MJ/MW)? (12 marks)

6 a) Describe briefly the importance of short circuit calculations. (5 marks)

b) A synchronous generator G is connected via step-up transformer T1, transmission line L and step-down transformer T2 to a bus that supplies three identical induction motors (shown in Figure Q6). The ratings of all the equipment are given in the Table 4.

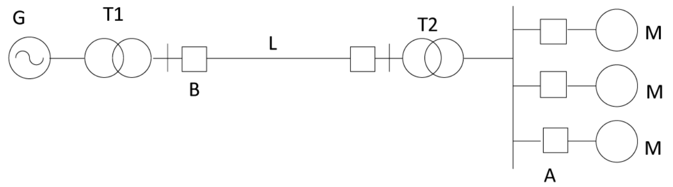

Figure Q6

Equipment	Rating
G	50 MVA, 12.5 kV, 25%
T1	75 MVA, 12.5 kV/132 kV, 11%
T2	75 MVA,132 kV/6.6 kV
M	12 MVA, 6.6 kV, 25%
L	Line reactance of 22% on the base of 50 MVA

Table 4

A three-phase short circuit occurs at the motor terminal.
Determine the current to be interrupted by the circuit breakers A and B. (15 marks)

7 A 100 MVA, 22 kV, 50 Hz synchronous generator is connected to a 100 MVA, 22 kV/132 kV step-up transformer. Both generator winding and transformer windings are Y-connected and their neutral points are solidly earthed. Reactance of generator and transformer in p.u. (On equipment base) are given in Table 7. A line-to-line fault occurs at the high voltage side of the transformer.

G	Xs = 1.50; x' = 0.24, x" = 0.10; X2 = 0.10; X0 = 0.05
T	X1 = X2 = X0 = 0.11

Table 7

a) Calculate the current that flows to the point of fault during sub transient period and transient period separately. (12 marks)

b) Determine voltage at generator terminals during each of the periods given above. (8 marks)

8 a) With suitable sketches, briefly explain the use of differential relays for the protection of the following equipment.

i) Generator. (2 marks)

ii) Bus Bar. (2 marks)

iii) Transformer. (4 marks)

b) Explain why distance protection is preferred compared to over current protection in transmission line protection. (2 marks)

c) A 132 kV overhead transmission line having series impedance of 25 + j110 Ω is protected with the help of Mho relay. The Mho relay has a maximum reach of 5 Ω with an angle of 75°. Voltage and current transformer ratio at the circuit breakers location are 132 kV: 120 V and 400 A: 5 A respectively.

i) Sketch the operating diagram of the relay and clearly identify the operating and non-operating region of the relay. (3 marks)

ii) Calculate the impedance of the line as seen by the relay. (3 marks)

iii) Determine the fraction of the line that is protected by the relay. (4 marks)

9 a) i) With the help of a labelled diagram, explain what is meant by governor droop. (3 marks)

ii) Explain why the power system is not allowed to operate beyond the permissible range of frequency. (3 marks)

iii) Two 50 Hz synchronous generators A and B are feeding power to an isolated system. Generator ratings and their droop characteristics are given in Table 9. Both generators are operating at 50 Hz when generators A and B deliver 50% and 60 % (respectively) of their rated power. The synchronous speed of the both generators is 1500 rpm.
Determine the synchronous speed of generators when they are disconnected from the system. (8 marks)

Generator	Rating (MW)	Droop characteristic (%)
A	200	4
B	350	8

Table 9

b) List three methods of voltage control and describe one of them briefly. (6 marks)