ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2023
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR ELECTRICAL ENGINEERING

Date : October 7, 2023
Total Marks : 100
Writing Time : 150 minutes (2.5 hours)
Reading Time : 15 minutes (prior to writing time)

GENERAL INSTRUCTIONS:

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is provided to check the number of pages of the Question Paper, printing errors, clarify doubts and to read the instructions. You are NOT permitted to write during this time.
3. This paper consists of **TWO SECTIONS**, namely SECTION A & SECTION B:
   - **SECTION A** has two parts: Part I - 30 Multiple Choice Questions
     Part II - 4 Short Answer Questions
     All questions under SECTION A are **COMPULSORY**.
   - **SECTION B** consists of two Case Studies. Choose only **ONE** case study and answer the questions of your choice.
4. All answers should be written on the Answer Booklet provided to you. Candidates are not allowed to write anything on the question paper. If required, ask for additional Answer Booklet.
5. All answers should be written with correct numbering of Section, Part and Question Number in the Answer Booklet provided to you. Note that any answer written without indicating the Section, Part and Question Number will NOT be evaluated and no marks will be awarded.
6. Begin each Section and Part on a fresh page of the Answer Booklet.
7. You are not permitted to tear off any sheet(s) of the Answer Booklet as well as the Question Paper.
8. Use of any other paper including paper for rough work is not permitted.
9. **You must hand over the Answer Booklet to the Invigilator before leaving the examination hall.**
10. This paper has **10 printed pages**, including this instruction page.

GOOD LUCK

SECTION A

PART I: Multiple Choice Questions [30 marks]

Choose the correct answer and write down the letter of your chosen answer in the Answer Booklet against the question number e. g. 31 (d). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.

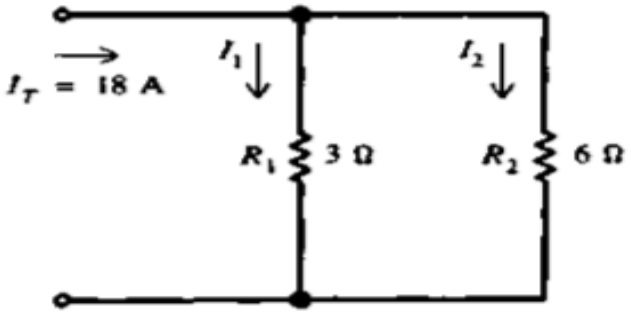
1. In an electronic circuit, three capacitors of 4 μF, 6 μF, 8 μF are connected in parallel. What is the total capacitance of the given circuits?
   a) 1.8 μF
   b) 18 μF
   c) 10.7 μF
   d) 4 μF

2. A thyristor is triggered by
   a) a negative pulse applied to the gate.
   b) a negative pulse applied to the anode.
   c) a positive pulse applied to the cathode.
   d) a positive pulse applied to the gate.

3. If a capacitor is placed in the feedback path of an op-amp circuit, then the circuit act as:
   a) Integrator
   b) Multiplier
   c) Divider
   d) Subtractor

4. If the voltage across a 25000 Ω resistor is 500 V, what is the power dissipated in the resistor?
   a) 10 W
   b) 0.02 W
   c) 50 W
   d) 45 W

5. The branch current I_1 and I_2 for the circuit shown below is:



   a) I_1=12, I_2=6
   b) I_1=6, I_2= 12
   c) I_1=12, I_2= 18
   d) I_1=6, I_2= 18

6. When the primary winding of an iron-core transformer is operated at 120V, the current in the winding is 2 A. Find the current in the secondary winding load if the voltage is stepped up to 600V.
   a) I_S =2 A
   b) I_S =10 A
   c) I_S =4 A
   d) I_S =0.4 A

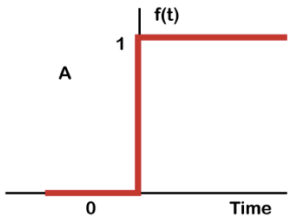
7. A Chopper converts:
   a) AC to DC
   b) DC to DC
   c) DC to AC
   d) AC to AC

8. A full wave rectifier with resistive load produces
   a) Second harmonic
   b) Third harmonic
   c) Fifth harmonic
   d) Do not produce harmonics

9. The main components used in a ripple filter circuit is the:
   a) Capacitor
   b) Resistor
   c) Diode
   d) Transformer

10. What is the binary equivalent of the decimal number 25?
   a) 1010
   b) 1100
   c) 11001
   d) 10011

11. Laplace transform of a step function shown below is:



   a) 1
   b) $\frac{1}{s^2}$
   c) $\frac{1}{s}$
   d) 0

12. The negative feedback closed-loop system was subjected to 15V. The system has a forward gain of 2 and a feedback gain of 0.5. Determine the output voltage:
    a) 1
    b) 15
    c) 0.25
    d) 3.7

13. A synchronous motor operates at synchronous speed with no load. What is the power factor of the motor under this condition?
    a) Lagging
    b) Leading
    c) Unity
    d) Zero

14. When a number of alternators are operating in parallel, the power factor at which each operates is determined by:
    a) Power factor of the load
    b) Driving torque of the prime mover
    c) Its field excitation
    d) None of the above.

15. The field winding of an alternator is excited by?
    a) d.c.
    b) a.c.
    c) both d.c. and a.c.
    d) None of the above.

16. Which of the following equipment will draw the reactive power?
    a) Electrical iron
    b) Tubelight
    c) Three phase motor
    d) rectifier

17. In star-star connection of three phase transformer, if V_L is the line voltage and I_L is the line current then phase voltage and phase current is given by:
    a) $V_L/\sqrt{3}, I_L$
    b) V_L , I_L
    c) $\sqrt{3}V_L , I_L / \sqrt{3}$
    d) $V_L, I_L / \sqrt{3}$

18. What is the frequency of a typical DC power supply used in electronic devices?
    a) 60 Hz
    b) 50 Hz
    c) 120 Hz
    d) 0 Hz

19. The three-phase motor has a power factor of 0.9 lagging and an apparent power of 200 kVA. What is the real power consumed by the motor?
    a) 180 kW
    b) 222.2 kW
    c) 160 kW
    d) 240 kW

20. In the case of the HVDC systems, there is:
    a) Charging current but no skin effect
    b) No charging current but skin effect
    c) Neither charging current nor skin effect
    d) Both charging current and skin effect

21. The "voltage flicker" phenomenon in a power system is primarily caused by:
    a) Voltage sags and interruptions
    b) Harmonic distortion in the voltage waveform
    c) Transient over-voltages during switching events
    d) Unbalanced voltage conditions

22. The transfer of power between two stations is maximum when the phase displacement between the voltages of two stations is:
    a) Zero
    b) 90^{o}
    c) 120^{o}
    d) 180^{o}

23. Shunt reactors are connected with transmission lines for
    a) Producing reactive power
    b) Absorbing reactive power
    c) Absorbing high voltage surges
    d) Limiting fault current

24. Two lamps 100 W and 40 W are connected in series across 230 V. Which of the following statement is correct?
    a) 100 W lamp will glow brighter
    b) 40 W lamp will glow brighter
    c) Both lamp will glow equally bright
    d) 40 W lamp will fuse.

25. If the height of transmission towers is increased, which of the following parameters is likely to change?
    a) Resistance
    b) Capacitance
    c) Inductance
    d) Impedance

26. If the loading of the line corresponds to the surge impedance, the voltage at the receiving end is:
    a) Greater than sending end
    b) Less than sending end
    c) Equal to the sending end
    d) None of the above is necessary.

27. A line trap in a long transmission line is used to:
    a) Improve the power factor
    b) Dampen the over voltage oscillations
    c) Confine the carrier signals in the line
    d) Protect the line against direct lightning stroke

28. If the positive, negative, and zero sequence reactance of an element in power system are 0.3, 0.3 and 0.8 pu respectively, then the element would be a:
    a) Synchronous generator
    b) Synchronous motor
    c) Static load
    d) Transmission line.

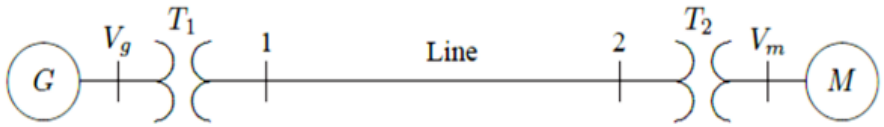
29. The impedance relaying scheme is used for protection of:
    a) Transformer
    b) Synchronous generator
    c) Bus-bar
    d) Transmission line

30. Buchholz relay is used for the protection of
    a) Alternators
    b) Transformers
    c) Switch yard
    d) Transmission lines

PART II – Short Answer Questions [20 marks]

This part has 4 Short Answer Questions. Answer ALL the questions. Each question carries 5 marks. Mark for each sub-question is indicated in the brackets.

1. The three phase power and line-line ratings of the electrical power systems is shown in figure given below:



$G1$: 60 MVA 20 kV $X = 9\%$
$T1$: 50 MVA 20/200 kV $X = 10\%$
$T2$: 50 MVA 200/20 kV $X = 10\%$
M : 43.2 MVA 18 kV $X = 8\%$
Line: 200 kV $Z = 120 + j200$ -

a) Draw an impedance diagram showing all impedances in per unit on a 100- MVA base. Choose 20 kV as the voltage base for generator (3 marks)

b) The motor is drawing 45 MVA, 0.80 power factor lagging at a line-to-line terminal voltage of 18 kV. Determine the terminal voltage and the internal emf of the generator in per unit and in kV (2 marks)

2. Answer the following questions :

a) Why is the stator core of alternator laminated? (1 mark)

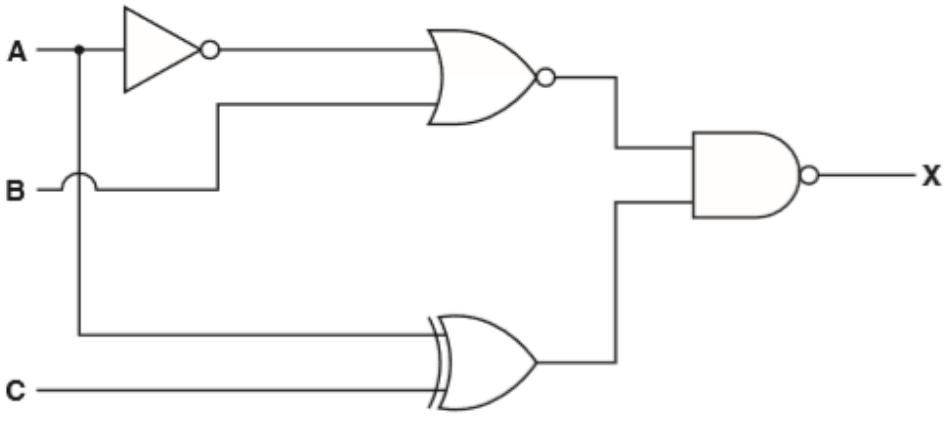
b) What are the conditions for parallel operation of alternator with infinite busbars? (2 marks)

c) A 6-pole, 3-phase induction motor is connected to 50Hz supply. If it is running at 970 r.p.m., find the slip. (2 marks)

3. Answer the following questions:

a) Which gates are called universal gates? (1 mark)

b) Write the truth table for the logic circuit shown below (4 Marks)



4. Answer the following questions:

a) What is Ferranti effect? (1 mark)

b) What are the methods to reduce the corona effect? (2 marks)

c) What are the methods to improve the string efficiency of the suspension insulators? (2 marks)

SECTION B: CASE STUDY [50 marks]

Choose either CASE I OR CASE II from this section. Each case study carries 50 marks. Mark for each sub-question is indicated in the brackets.

CASE I

The Kingdom of Bhutan is blessed with abundant hydropower reserves with overall hydropower potential estimated at 37GW from 155 sites identified in the updated Power System Master Plan 2040. The 90 sites having installed capacity of about 33GW have been identified as techno-economically viable for implementation. Sustainable hydropower development is critical for Bhutan to reap the benefits of this huge hydropower reserves. The Department of Energy under the Ministry of Energy and Natural Resources is responsible to formulate national energy policies, plans, procedures, and guidelines for sustainable development, planning, construction, promotion, efficient utilization and management of energy resources and power systems, and cross border trade of electricity. The Department serves as the central coordinating agency and the focal point on all matters related to energy, power systems and energy markets including cross-border trade of electricity. Assuming that you are working in this Department, please answer the following questions:

1. What is the total installed capacity of hydropower plant in the country? List down all the existing and under-construction hydroelectric projects with their generating capacity. (4 marks)

2. Discuss the merits and demerits of hydro-power plants. (4 marks)

3. The electricity generation from hydropower in Bhutan is seasonal with maximum in summer and minimum in winter. We face power shortage during the lean generation period posing a major energy security concern. Propose some comprehensive energy security strategies to safeguard the nation from potential power supply disruptions? (8 marks)

4. A hydro-power plant is to be designed to operate at a mean head of 205m and supplied from a reservoir having a catchment area of 1,000 km^2 with average annual rainfall of 125cm of which 80% is available for power generation. The expected load factor at the plant is 75%. Allowing a head loss of 5 m and assuming efficiency of turbine and generator to be respectively 90% and 95%, calculate the MW rating of the station (5 marks)

5. What type of turbine are available in existing hydropower plant in Bhutan and which one would you recommend for high head and medium head power plant? (3 marks)

6. What is the difference between reaction and impulse turbine? (4 marks)

7. What is the Generator Capability Curve? Explain with the help of diagram (5 marks)

8. What is the effect of change of field excitation to the synchronous generator (4 marks)

9. A power is exported to India from one of the hydropower plant through a three-phase, 50-Hz, completely transposed 400 kV, 150 km transmmission line. The line has the following positive sequence constants:

   $z = 0.032 + j0.35\ \Omega/km$

   $y = j4.2 \times 10^{-6}$ S/km

   Full load at the receiving end of the line is 700 MW at 0.99 p.f. leading and at 95% of rated voltage. Assuming a medium length line, determine the following:

   a) A, B, C, and D parameters of the nominal π circuit (4 marks)

   b) Sending-end voltage V_S, current I_S. (4 marks)

   c) Percent voltage regulation (2 marks)

10. What is the surge impedance loading? How is it different from thermal loadings in power transmission lines? (3 marks)

CASE II

The electrification rate in Bhutan is 99.99%. While the country has been able to supply electricity to the remotest human settlement, the challenge of providing secure, reliable and quality power supply has been challenging for the utility company. Undesirable power interruptions due to various types of faults have affected all categories of customers. With the growing economy and the living standards, power interruptions are increasingly associated with disruptions in the economic activities and comforts of people. A low reliability of electricity supply affects the development and economic condition, thus impacting the GDP of the country. The Bhutan Power Corporation Limited (BPC) that looks after electricity transmission and distribution functions in the country is responsible for supply of reliable and quality power to the domestic consumers. Assuming that you are working in BPC, please answer the following questions:

1. Define the term reliability and explain some common reliability indices used in the electricity industry. (4 marks)

2. What are the reasons for the poor reliability in the remote areas of Bhutan? Propose some innovative measures to improve the reliability. (4 marks)

3. What is 'Power quality', and why is it essentials for electrical systems? What are the main parameters used to assess the power quality in electrical networks. (5 marks)

4. What is power system fault? Arrange different types of fault occurring in transmission lines in the increasing order of severity. Which type fault is the most common? (4 marks)

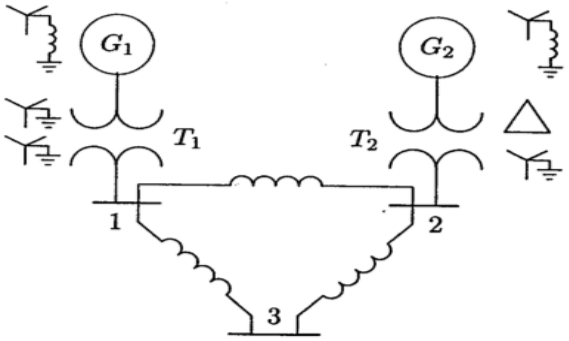
5. Explain the protection scheme used in the parallel transmission lines. (4 marks)

6. What is the Power Flow Analysis. Explain its significance in power system planning? (5 marks)

7. Explain the transient, steady- state, and dynamic stability in power systems. (5 marks)

8. What is the relation between reactive power and voltage profiles? What are the various methods to control voltage profiles in the power systems? (5 marks)

9. The one-line diagram of a simple power system is shown in figure below. The neutral of each generator is grounded through a current-limiting reactor of 0.25/3 per unit on a 100 MVA base. The system data expressed in per unit on a common 100-MVA base is tabulated below. The generators is running on no-load at their rated frequency with their emfs in phase.

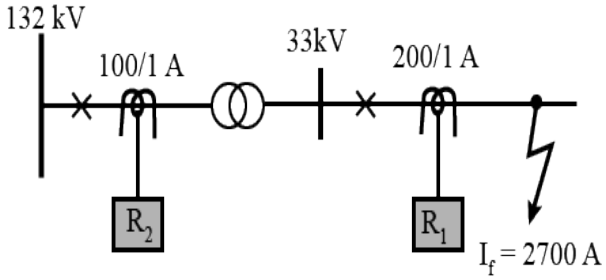


Item	Base MVA	Voltage Rating	X^1	X^2	X^0
G_1	100	20 kV	0.15	0.15	0.05
G_2	100	20 kV	0.15	0.15	0.05
T_1	100	20/220 kV	0.10	0.10	0.10
T_2	100	20/220 kV	0.10	0.10	0.10
L_{12}	100	220 kV	0.125	0.125	0.30
L_{13}	100	220 kV	0.15	0.15	0.35
L_{23}	100	220 kV	0.25	0.25	0.7125

Draw the positive sequence impedance, negative sequence impedance, and zero sequence impedance diagram of the given power system network. (6 marks)

Determine the fault current for a balanced three-phase fault at bus 3 through a fault impedance $Z_f = j0.1$ per unit. (2mark)

10. It is given that fault current level at 33 kV side is 2700 A; CT ratio at 33kV side is 200:1 and 132 kV side is 100:1 as shown in figure below. If both relays R_1 and R_2 are set for 100% plug setting, determine the operating time for both the relays when time grading margin of 0.6 second is given and TMS for relay R_1 is 0.15. Calculate the TMS for relay 2 as well. (6 marks)



PSM	3.6	6.75	13.5
Time in sec for Time Multiplier	6	3.6	2.6

TASHI DELEK