



**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. The transfer function of any system is used to calculate the
  - a) Steady state gains
  - b) Time constant
  - c) Output for any given input
  - d) Order of the system
  
2. Ratio of output and input is defined as the transfer function of which system?
  - a) Fourier Transform
  - b) Z- Transformer
  - c) Laplace Transform
  - d) None of above
  
3. Bode plot approach is applied to
  - a) Minimum phase network
  - b) Any network
  - c) Non-minimum phase network
  - d) All of the above
  
4. The inductive interference between power line and communication line can be minimized by
  - a) transposition of the communication line.
  - b) increasing the distance between the conductors.
  - c) transposition of the powerline.
  - d) Both (a) and (c)
  
5. The protection from negative sequence current is provided for
  - a) Transformers
  - b) Generators
  - c) Motors
  - d) Transmission line
  
6. Transmission line is protected by
  - a) Inrush protection
  - b) Distance protection
  - c) Time graded and current graded overcurrent protection
  - d) Both (b) and (c)
  
7. Which relay is preferred for phase fault on short transmission line?
  - a) Induction type
  - b) Reactance type
  - c) Impedance type
  - d) None of the above

8. The weight of copper of both armature and field windings decreases with \_\_\_\_\_ in number of poles.
- increasing
  - decreasing
  - Both (a) and (b)
  - None of the above
9. Material exhibiting zero values of resistivity are known as
- Conductors
  - Superconductors
  - Semiconductors
  - Insulators
10. In Frequency Modulation:
- the amplitude of the carrier remains the same.
  - the frequency of the carrier varies in accordance with the modulating signal.
  - the number of side bands are infinite.
  - All of the above
11. In AC waveform, the relationship between frequency and time period is
- $f = T$
  - $f = T^2$
  - $f = 1/T$
  - $f = 1/T^2$
12. Power transformers are generally designed to have maximum efficiency at
- No-load
  - Closer to full load
  - Half-load
  - 10% overload
13. When the excitation is increased (over-excitation), the synchronous generator operates at
- Leading power factor
  - Unity power factor
  - Lagging power factor
  - Any of the above depending on the grid
14. A good voltage regulation of a transformer means
- output voltage fluctuation from no load to full load is least.
  - output voltage fluctuation with power factor is least.
  - difference between primary and secondary voltage is least.
  - difference between primary and secondary voltage is maximum.

Use the following information to answer **Questions 15, 16 and 17**. A 3-Phase, 300 rpm synchronous motor connected to a 4 kV, 50 Hz line draws a current of 320A and absorbs 2000 kW.

15. What is the apparent power (kVA) supplied to the motor?
  - a) 2017
  - b) 2117
  - c) 2217
  - d) 2317
  
16. What would be the reactive power absorbed (kvar)?
  - a) 946
  - b) 956
  - c) 966
  - d) 976
  
17. The number of poles on the rotor is
  - a) 16
  - b) 18
  - c) 20
  - d) 22
  
18. Which statement best describes reactance in a series circuit?
  - a) Resistance is always dominant.
  - b) The larger of the two reactance is dominant.
  - c) Inductive reactance is always dominant.
  - d) Capacitive reactance is always dominant.
  
19. The most economical area of conductor is that for which the total annual cost of transmission line is minimum. Which law states this?
  - a) Ohm's Law
  - b) Faraday's Law
  - c) Lenz's Law
  - d) Kelvin's Law
  
20. Why are boosters inserted in the circuit?
  - a) To reduce current.
  - b) To increase current.
  - c) To reduce voltage drop.
  - d) To compensate voltage drop.
  
21. What is the reluctance of a material that has a length of 0.045 m, a cross-sectional area of 0.015 m<sup>2</sup> and a permeability of 2500  $\mu$ Wb/AT-m?
  - a) 1200 AT/Wb
  - b) 0.27 AT/Wb
  - c) 833.33  $\mu$ AT/Wb
  - d) More information required to find reluctance

22. If three currents are in the same direction at any instant of time in a given branch of circuit, the net current at that instant
- a) cannot be determined.
  - b) is zero.
  - c) is sum of three currents.
  - d) is the difference of three currents.

23. The output C from logic gates is given as below:

<b>Input A</b>	<b>Input B</b>	<b>Output C</b>
0	0	<b>0</b>
0	1	<b>1</b>
1	0	<b>1</b>
1	1	<b>0</b>

Which gate has been used to determine Output C?

- a) NAND
  - b) NOR
  - c) AND
  - d) XOR
24. For an ideal transformer,  $N_s/N_p = V_s/V_p$ . Which of the statement below is TRUE?
- a) Transformer makes use of Faraday's law.
  - b) Transformer cannot increase Power.
  - c) Both (a) and (b)
  - d) None of the above.
25. A stepper motor converter may be considered as
- a) DC to DC
  - b) AC to AC
  - c) DC to AC
  - d) Digital to analogue
26. A transformer in which both the primary and secondary are in single winding is called
- a) Auto transformer
  - b) Ideal transformer
  - c) Step up by step down transformer
  - d) Step down transformer
27. The force exerted on a charged particle q moving with velocity v through an electric field E and magnetic field B. The entire electromagnetic force F on the charged particle is called
- a) Newton's Force
  - b) Lenz Force
  - c) Lorentz Force
  - d) Miller's Force

28. An ammeter is \_\_\_\_\_ instrument.

- a) absolute
- b) secondary
- c) integrating
- d) recording

29. Corona discharge happens more in

- a) humid weather.
- b) hot weather.
- c) cold weather.
- d) All the above.

30. Relay gets its operating energy from

- a) Transformer
- b) Alternator
- c) Conductor
- d) CT and PT

**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.**

**Question 1**

- a) A 3-phase, 75hp, 440 V induction motor has a full load efficiency of 91% and a power factor of 83 percent. Calculate the nominal current per phase. (2 marks)
- b) If we slightly increase the rotor resistance of an induction motor, what effect does this have (increase or decrease) upon: (3 marks)
  - i. Starting torque
  - ii. Starting current
  - iii. Full load speed
  - iv. Efficiency
  - v. Power factor
  - vi. Temperature rise of the motor at its rated power output

**Question 2**

A 3-phase generator possesses a synchronous reactance of  $6 \Omega$  (line reactance between source and load) and the excitation voltage  $E_0$  is 3 kV (source) per phase. Calculate the line to neutral voltage  $E$  for a resistive load of  $8 \Omega$ . Draw a simple circuit diagram and the phasor diagram. (5 marks)

**Question 3**

- a) Three 5ohm resistors are connected in wye across a 3-phase, 480 V line. Calculate the current flowing in each. If one of the resistors is disconnected, calculate the current that flows in the remaining two. (2 marks)
- b) Three resistors are connected in delta. If the line voltage is 13.2 kV and the line current is 1202 A, calculate the following: (3 marks)
- The current in each resistor
  - The voltage across each resistor
  - The power supplied to each resistor
  - The power supplied to the 3-phase load
  - The ohmic value of each resistor

**Question 4**

In No-Load test of single-phase transformer, the following test data were obtained:

Primary Voltage	:	220 V
Secondary Voltage	:	110 V
Primary Current	:	0.5 A
Power Output	:	30 W

Based on test data, find the following:

- The turn ratio. (1 mark)
- The magnetizing component of no-load current. (2 marks)
- Its working (or loss) component. (1 mark)
- The iron loss with resistance of the primary winding 0.6 ohm. (1 mark)

**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 Royal Government of Bhutan has initiated major activities for economic revival and has been making relentless efforts in industrial development and promotion of industrial activities. Therefore, 10 industries in Jigmeling Industrial Park and another 11 industries are gearing up for construction in Dhamdum Industrial Park. The Industrial park will see industries along with housing colonies and other infrastructure developments. To cater to the industrial load, a proper electrical distribution system is required whereby the right equipment with the right ratings are installed.

- As a newly appointed electrical engineer, you are given the responsibility to oversee the electrical part of the Jigmeling Industrial Park. The 10 industries in Jigmeling Industrial Park have a load of 5 MW each.
  - What are the three schemes of connection for a distribution system and explain each of them with their single line diagrams? (15 marks)

- b) Design the distribution system for the Jigmeling Industrial Park. You are required to provide the list of equipment and their ratings. You may provide single line diagrams along with the connections of the equipment and calculations on how you have chosen the equipment ratings. [Your answer need not have to be accurate; assessment shall be carried out based on your own design and on your understanding of a power distribution system]. (15 marks)
2. As there are housing colonies in the industrial park, you are also responsible to provide solutions to house wiring. Please answer the following questions related to electrical house wiring:
- a) What is MCB? (5x3=15 marks)
  - b) Why earthing is required in electrical wiring?
  - c) What is the difference between neutral and earth wires?
  - d) What is the difference between MCB and Fuse? Which one is preferable?
  - e) Define contactor and state the two main types of electrical contactors.
3. On what principle does electric motor works? What are the two types of electric motors? How is efficiency of motor calculated? (5 marks)

## **CASE II**

One of the main sources of revenue for Bhutan is from the hydro power sector. Department of Hydropower and Power Systems works to ensure that the hydro potential is tapped in a sustainable manner to optimize benefits for the nation. On the other hand, Department of Renewable Energy is focusing on bringing more of solar and wind projects which is trending globally. Druk Green Power Corporation Ltd looks after generation and development of new power plants while Bhutan Power Corporation is the only distribution company in Bhutan which are both under the umbrella of Druk Holdings and Investment. Bhutan Electricity Authority (BEA) acts as a regulatory body for the power sector of Bhutan.

1. As a young electrical engineer, propose your ideas and innovations on how to promote hydropower generation and other renewables in Bhutan with the help of fast advancing technologies that you are acquainted with. Also highlight on the challenges that you foresee for the hydropower and the power sector development. You may use facts and figures along with diagrams wherever necessary, trending technologies and organizational reforms that you feel may foster growth in Bhutan's power sector.
- [Your answer need not have to be accurate; assessment shall be carried out based on your own understanding of the hydropower sector in Bhutan, evolving technologies, growth of renewables and how you have used your analytical skills] (20 Marks)

2. Kurichhu Hydropower Plant is located at Gyelposhing in Eastern Bhutan. It has an installed capacity of 60 MW and has 4 units of each 15 MW. It is a low-head power plant and holds great significance as it supplies power in the eastern Bhutan. The generators are of vertical shaft, salient pole, semi-umbrella with a capacity of 16.667 MVA, 11kV, 50 Hz, 250 rpm and 0.9pf. Each generator is connected to a 20 MVA generator transformer of 11kV/138kV and has a cooling system of OFWF. A shunt reactor of 5 MVAR is connected at the switchyard. Based on the information given, answer the following questions: (5x3=15 marks)
- Why is the power plant rated in MW while the generator is rated in MVA? What do you understand by a salient pole?
  - Explain real, reactive and apparent power. Draw the power triangle.
  - Define *head* in the hydropower context. Why is Kurichhu Hydropower Plant a low head plant? What kind of turbine is used in low head hydro power plants?
  - What is the full form of OFWF in transformer cooling method? Name any three cooling methods for oil immersed transformers?
  - What is a shunt reactor? Why is a shunt reactor connected at Kurichhu Hydropower Plant?
3. How many hydropower plants are under operation and how many are under construction in Bhutan? Name each of them.

Kurichhu Hydropower Plant has an installed capacity of 60MW. How has 60 MW been derived? Suppose you are to calculate the power of a hydropower plant with the following information, how would you calculate it?

- $m$  is the mass flow rate in kg/s (numerically the same as the flow rate in liters/second because 1 liter of water weighs 1 kg). The flow rate given for this case is  $3 \text{ m}^3/\text{s}$ .
- $g$  is the gravitational constant, which is  $9.81 \text{ m/s}^2$ .
- $H_{\text{net}}$  is the net head and  $H_{\text{gross}}$  is the gross head whereby the gross head is physically measured at the site, and net head is less any head losses. Typically,  $H_{\text{net}} = 0.9 * H_{\text{gross}}$ . The gross head given for this case is 35 meters.
- $\eta$  is the overall efficiency, product of all of the component efficiencies like the turbine, drive system and generator. The turbine efficiency is 82%, drive system efficiency is 92% and the generator efficiency is 95%.

With the above information, calculate the Power (P) measured in Watts (W). What is the difference between Power and Energy? What is the unit of Energy? (15 marks)

**TASHI DELEK**