

NAME OF THE EXAMINATION: B.E. POWER ENGINEERING THIRD YEAR FIRST SEMESTER - 2025

SUBJECT: ADVANCED TOPICS IN ELECTRICAL MACHINES (HONS.)

TIME: 3 HOURS

FULL MARKS: 100

Answer **ALL QUESTIONS**

- CO1:** Describe generalized theory of electrical machines and apply mathematical transformations on different rotating machines
- CO2:** Apply the concepts of heat transfer mechanisms for heating/cooling of electrical machines and hence evaluate heating/cooling efficiency of electrical machines
- CO3:** Explain surge phenomena in power system and examine the effects of surge voltage on electrical machines
- CO4:** Investigate different type tests, routine tests and special tests on electrical machines

Q1. Choose the correct option for any TWENTY (20) questions:

(20@1 = 20)

- (i) The main diagonal elements in the impedance matrix of a Kron's primitive machine contain [CO1]
 a) only self-inductance and resistance
 b) self-inductance and mutual inductance
 c) resistance and mutual inductance
 d) only mutual inductance
- (ii) In 3-phase to 2-phase transformation (a, b, c, to α, β), the impedance per phase of the equivalent 2-phase system as compared to the 3-phase system are different when [CO1]
 a) both number of turns and current are transformed identically
 b) only current is transformed
 c) only number of turns is transformed
 d) both (b) and (c)
- (iii) The 2-axis generalized equivalent model of a 3-phase squirrel cage type induction machine consists of: [CO1]
 a) three coils, one in stator and two in rotor
 b) four coils, two in stator and two in rotor
 c) five coils, two in stator and three in rotor
 d) six coils, three in stator and three in rotor
- (iv) The 2-phase generalized model of a separately excited DC Shunt generator without interpoles consists of: [CO1]
 a) Three coils, one in stator and two in rotor
 b) Three coils, two in stator and two in rotor
 c) Two coils, one in stator and one in rotor
 d) Four coils, two in stator and two in rotor
- (v) Speed voltage of a moving coil is maximum when its magnetic axis is [CO1]
 a) 180° away from the other coil
 b) 120° away from the other coil
 c) 90° away from the other coil
 d) 0° away from the other coil
- (vi) While studying transient short circuit condition of an initially unloaded alternator using 2-axis theory, which of the following statement(s) is (are) true? (Select all that are applicable) [CO1]
 a) The short circuit has no effect on field voltage
 b) The short circuit has no effect on field current
 c) The short circuit has no effect on q-axis armature voltage
 d) The effect of short circuit is to reduce the d-axis armature voltage suddenly to zero
- (vii) Air pockets present inside solid insulation is damaging because: [CO2]
 (i) It causes localized heating
 (ii) It causes trapping of moisture
 (iii) It may cause localized corona discharge
 (iv) It reduces insulation strength of the solid insulation
 (v) It degrades the heat conduction capability

[Turn over

Out of the above, the correct options are:

- a) (i), (ii), (iv), (v)
 - b) (i), (iii), (iv), (v)
 - c) (ii), (iii), (iv), (v)
 - d) (i), (ii), (iii), (v)
- (viii) The cooling time constant is usually _____ when a machine cools down owing to _____ ventilating conditions as compared to during heating. (Fill in the blanks) [CO2]
- a) smaller ; better
 - b) larger ; poorer
 - c) smaller ; poorer
 - d) larger ; better
- (ix) Electric machine frame surfaces are painted with dull metallic paints: [CO2]
- a) to enhance heat radiation
 - b) to reduce heat generation
 - c) to enhance heat convection
 - d) to enhance heat conduction
- (x) Chose the correct sequence of heat transfer during transformer cooling: [CO2]
1. oil carries heat by conduction and convection
 2. heat generated in the core and winding is conducted to oil
 3. heat is dissipated to the atmosphere by radiation
 4. heat is generated inside the transformer due to various losses
 5. heat dissipates out of the tank surface by convection due to air flow
- a) 4-1-2-5-3
 - b) 4-1-2-3-5
 - c) 4-2-3-1-5
 - d) 4-2-1-3-5
- (xi) Which of the following coolant may be used to cool rotating machines: [CO2]
- a) Carbon monoxide
 - b) Water
 - c) Helium
 - d) Oxygen
- (xxii) When a machine is switched off and allowed to cool down, its final steady state temperature reaches ambient temperature NOT because: [CO2]
- a) there are no further losses taking place in the machine
 - b) the cooling time constant is large enough to bring down the temperature rise to zero
 - c) only when the machine temperature reaches ambient value, there is no further heat dissipation
 - d) at ambient temperature, heat generated becomes equal to heat dissipated during cooling
- (xiii) Temporary over-voltages in power system can be caused by any one or combination of: (choose one or more) [CO3]
- a) Ground fault
 - b) Sudden change of load
 - c) Resonance
 - d) Ferro-resonance
 - e) Lightning
- (xiv) BIL of an electrical equipment is defined as: [CO3]
- a) The minimum withstand voltage level of the equipment before the lightning impulse over-voltage gets discharged through surge protecting devices
 - b) The minimum withstand voltage level of the equipment after the lightning impulse over-voltage gets discharged through surge protecting devices
 - c) The maximum withstand voltage level of the equipment after the lightning impulse over-voltage gets discharged through surge protecting devices
 - d) The maximum withstand voltage level of the equipment before the lightning impulse over-voltage gets discharged through surge protecting devices
- (xv) Voltage surges or transients in power system can be caused by: [CO3]
- a) Resonance
 - b) Circuit breaker contact bouncing
 - c) Sudden change of load

- d) Ground fault
- (xvi) Parameters used to define an impulse generated in the laboratory are: [CO3]
 a) energy content
 b) front time
 c) number of repetitions per second
 d) frequency
- (xvii) A switching surge takes _____ time to die down as compared to lightning surge of same amplitude [CO3]
 a) more
 b) less
 c) equal
 d) either more or less (depending on the cause)
- (xviii) The most common equipment used for protection of power transformers from lightning surge is: [CO3]
 a) MCB
 b) Circuit breaker
 c) Isolator
 d) Lightning arrester
- (xix) While performing insulation resistance measurement on transformers, it is generally measured 1 min after application of the voltage so that the reading does not include effects of: [CO4]
 a) Polarization current & absorption current
 b) Conduction current & polarization current
 c) Conduction current & absorption current
 d) Leakage current & polarization current
- (xx) Short circuit test on a transformer is generally performed with its LV winding shorted because that will enable: [CO4]
 a) Low range ammeter to be used for performing the measurements on HV side
 b) Low range voltmeter to be used for performing the measurements on HV side
 c) Reduced power losses during the test thereby restricting temperature rise
 d) More than one of the above reasons
- (xxi) Winding resistance of a high current rating induction motor can be measured using [CO4]
 a) Voltmeter-ammeter method
 b) Ohm-meter
 c) Kelvin's double bridge
 d) Multimeter
- (xxii) Insulation resistance of an induction motor is independent of: [CO4]
 a) Magnitude of test voltage
 b) Thickness of the insulation
 c) Measurement temperature
 d) Motor current rating
- (xxiii) A common feeder line supplies an induction motor and synchronous motors at the same time. In order to keep the feeder line at unity power factor, the synchronous motors is: [CO4]
 a) Under excited
 b) Over excited
 c) Normally excited
 d) Not excited
- (xxiv) The current consumed by a synchronous motor at a given load is minimum when its power factor is [CO4]
 a) Unity
 b) Leading
 c) Lagging
 d) Zero

Q2 Answer any TWO (2) questions (2@10 = 20) [CO1]

- (a) Voltage equations in Kron's primitive machine in matrix form is given below. Write the names of all symbols used. How this matrix gets modified for a separately excited DC machine generalized model?

$$\begin{array}{c}
 \begin{array}{c} v_{ds} \\ v_{qs} \\ v_{dr} \\ v_{qr} \end{array} = \begin{array}{c} ds \\ qs \\ dr \\ qr \end{array} \begin{array}{cc|cc}
 ds & qs & dr & qr \\
 \hline
 r_{ds} + L_{ds}p & & M_d p & \\
 & r_{qs} + L_{qs}p & & M_q p \\
 M_d p & -M_q \omega_r & r_{dr} + L_{dr}p & -\omega_r L_{qr} \\
 M_d \omega_r & M_q p & \omega_r L_{dr} & r_{qr} + L_{qr}p
 \end{array} \begin{array}{c} i_{ds} \\ i_{qs} \\ i_{dr} \\ i_{qr} \end{array}
 \end{array}$$

- (b) For 2-phase rotating to 2-phase stationary axis transformation matrix given by:

$$\begin{array}{c}
 \begin{array}{c} i_d \\ i_q \end{array} = \begin{array}{c} d \\ q \end{array} \begin{array}{cc} \alpha & \beta \\ \hline \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{array} \begin{array}{c} i_\alpha \\ i_\beta \end{array}$$

Derive the inverse transformation matrix. Show that for time-varying quadrature currents in stationary axis $i_d = I_m \sin(\omega t + \phi)$ and $i_q = I_m \cos(\omega t + \phi)$, the two rotating axis currents are time-invariant.

- (c) Starting from the expression for one of the 3-phase armature currents of a synchronous machine under sudden short circuit fault condition as given below, show that the transient current consist of a fundamental frequency component, a DC component, and a 2nd harmonic component.

$$i_a = \sqrt{\frac{2}{3}} \left[\frac{v_{q0}}{X_d'} \cos(\omega t + \theta_0) - \frac{v_{q0}}{X_d'} \cos \omega t \cos(\omega t + \theta_0) - \frac{v_{q0}}{X_q} \sin \omega t \sin(\omega t + \theta_0) \right]$$

Q3

Answer any TWO (2) questions (2@10 = 20)

[CO2]

Show that the temperature rise of a homogeneous machine during heating after time 't' is given by:

$$\theta = \theta_m \left(1 - e^{-\frac{t}{\tau_h}} \right) + \theta_i e^{-\frac{t}{\tau_h}}$$

Where the symbols have their usual meaning.

Describe how this expression gets modified when the machine starts heating from initial cold condition.

- (b) What steps can be taken further if the final temperature rise of transformer as calculated is more than the specified temperature rise value?

What are the advantages if hydrogen is use as cooling medium as compared to air?

- (c) The initial temperature rise of a transformer is 25° C after one hour and 37.5° C after two hours of starting from cold condition. Calculate its final steady state temperature rise and the heating time constant. If its temperature falls from the final steady state value to 40° C in 2.5 hours when disconnected, calculate its cooling time constant. The ambient temperature is 30° C.

Q4

Answer any TWO (2) questions (2@10 = 20)

[CO3]

- (a) Differentiate between lightning and switching surge. Draw and label different parts of a standard lightning impulse wave. What are the uses of lightning impulse generators in High Voltage laboratories?
- (b) Describe with relevant sketches, how atmospheric lightning can cause surges on power transmission lines.
- (c) Discuss in brief the different lightning surge protecting devices used in motors.

Q5

Answer any TWO (2) questions (2@10 = 20)

[CO4]

- (a) Describe the steps to be followed for performing lightning impulse test on a transformer.
- (b) List the different routine tests and type tests performed on an induction motor. Describe the methods for determination of temperature rise of an induction motor.
- (c) List the different recommended tests and miscellaneous tests to be performed on a DC machine