7. SUBJECTWISE DETAILS

7.5 ELECTRICAL MACHINES - II

OBJECTIVE AND RELEVANCE

A high voltage is desirable for transmitting large powers in order to decrease the I^2 R losses and reduce the amount of conductor material. A very much lower voltage, on the other hand, is required for distribution, for various reasons connected with safety and convenience .The transformer makes this easily and economically possible. Although the static transformer is not an energy conversion device, it is an indispensable component in many energy conversion systems. As one of the principle reasons for the widespread use of A.C. power systems, it makes possible electric generation at the most economical generator voltage, power transfer at the most economical transmission voltage, and power utilization at the most suitable voltage for the particular utilization device.

This subject provides a comprehensive understandingg of the transformers, induction motors - construction, principle of operation and other performance characteristics.

PREREQUISITES

This course assumes basic knowledge of mathematics, physics, electricity and magnetism.
Introductory circuit theory, basic mechanics and elementary differential equations are mandatory requisites.

SYLLABUS

UNIT - I

Objective **:**
The objectives of this unit are To explain the function of various parts of a 1-phase transformer, principle of operation and draw the equivalent circuit, phasor diagram of a 1-phase transformer and also to calculate losses & efficiency.

Syllabus **:**
Single phase transformers - types - construction al details - minimization of hysteresis and eddy current losses - emf equation - operation on no load and on load - phasor diagrams and equivalent circuit - losses and efficiency - regulation. All day efficiency - effect of variations of frequency & supply voltage on iron losses.

UNIT - II

Objective **:**
The objectives of this unit is to pre-determine the efficiency, regulation of a 1-phase transformer by performing certain basic tests on it and select proper transformers for parallel operation.

Syllabus
:
OC and SC test - Sumpner's test - predetermination of efficiency and regulation separation of losses test parallel operation with equal and unequal voltage ratios

UNIT -III

Objective:

The objective of this unit is to draw equivalent circuit for an auto transformer.
To explain different types of connections of a 3-phase transformer and explain the principle of operation, constructional features of a 3-phase induction motor.

Syllabus:
Auto and poly phase transformers - auto transformers - equivalent circuit - comparison with two winding transformers.

Polyphase transformers - Polyphase connection - Y/Y, Y/D, D/Y, D/D and open D, Third harmonics in phase voltage - three winding transformers - tertiary windings - determination of Zp, Zs and Zt transients in switching off load and on load tap changing; Scott connection.

UNIT - IV

Objective:
The objective of this unit is to develop an expression for torque of a 3-phase induction motor and draw torque-speed, torque-slip characteristics of a 3-phase induction motor. To draw the equivalent circuit and phasor diagram for Deep-bar / Double cage induction motor

Syllabus:
Polyphase induction motors - construction details of cage and wound rotor machines - production of a rotating magnetic field- principal of operation - rotor emf and rotor frequency - rotor reactance, rotor current and pf at standstill and during operation. Rotor power input, rotor copper loss and mechan ical power developed and their inter relation - torque equation - deduction from torque equation - expressions for maximum torque and starting torque - torque slip characteristic - double cage and deep bar rotors - equivalent circuit - phasor diagram - crawling and cogging.

UNIT -
V

Objective:
The objectives of this unit are to draw circle diagram for determining the various performance characteristics by performing certain basic tests and describe the various methods of starting and speed control of 3-phase induction motor..

Syllabus:
Circle diagram - No load and Blocked rotor tests - predetermination of performance - methods of starting and starting current and torque calculations - speed control - change of frequency; change of poles and methods of consequent poles; cascade connection. Injection of an emf into rotor circuit (qualitative treatment only) - induction generator - principle of operation.

7.5.3.2 SYLLABUS -

GATE UNIT - I
Single phase transformer equivalent circuit, phasor diagram

UNIT - II
OC & SC Test, regulation and efficiency of a 1-phase transformer, parallel operation, auto transformer

UNIT - III
Three phase transformer's connections, three winding transformer. Three phase induction motors, types of windings

UNIT - IV
Performance characteristics of 3-phase induction motors

UNIT - V
Methods of starting and speed control of 3-phase induction motors.

7.5.3.3 SYLLABUS - IES

UNIT - I
Analysis of Power transformers, Construction and Equivalent circuit. Losses and efficiency.

UNIT - II
Testing, Regulation, Auto transformer, Parallel operation.

UNIT - III
3-phase transformer connections. Basic concepts in rotating machines.
3-phase induction motors - construction and operation, Rotating field, leakage reactance, torque.

UNIT - IV
Characteristics and performance analysis of 3-phase Induction Motors, Equivalent Circuit, losses and efficiency.

UNIT - V
Circle diagram. Methods of starting and speed control of 3-phase induction motors.

7.5.4 SUGGESTED BOOKS

TEXT BOOKS

T1 Electric Machinery, A.E.Fitzgerald, C.Kingsley and S. Umans,5th Ed.,Mc Graw Hill Companies
T2 Electrical Machines, P.S. Bimbra,Khanna publishers
T3. Priniples of Eletrical machines VK Mehatha , Rohith Mehatha S. Chand

REFERENCE BOOKS

R1 The Performance and Design of alternating current machines, MG Say, BPB Publishers

R2 Electric Machines, I.J. Nagrath and DP Kothari ,7th Ed.,TMH, 2005.
R3 Electro Mechanics - II (transformers and induction motors), S.Kamakshaiah, Hitech Publishers.
R4 Theory of alternating current machinery,Langsdorf, 2ndEd.,Tata Mc Graw Hill Companies
R5 Electrical Machines,M.V.Deshpande, Wheeler Publishing
R6 Electrical Machines, J.B. Gupta,14thEd., S.K. Kataria and Sons Publications,2005-2006
R7 Electric Machines, Ashfaq Hussain,2nd Ed., Dhanpat Rai and Co
R8. Fundamentals of Electric Machines B. R. Gupta, Singhal Vandana
R9.Electric Machines Mulukutla S. Sarma, Mukesh K. Pathak

7.5.5 WEB SITES

1. www.mit.edu (massachusetts institute of technology)
2. www.soe.stanford.edu (stanford university)
3. www.grad.gatech.edu (georgia institute of technology)
4. www.gsas.harward.edu (harward university)
5. www.eng.ufl.edu (university of florida)
6. www.iitk.ac.in
7. www.iitd.ernet.in
8. www.iitb.ac.in
9. www.iitm.ac.in
10. www.iitr.ac.in
11. www.iitg.ernet.in
12. www.bits-pilani.ac.in
13. www.bitmesra.ac.in
14. www.psgtech.edu
15. www.iisc.ernet.in
16. www.ieee.org
17. www.school - for - champions.com / science / actransformers.html
18. www.onesmartclick.com / engineering / electrical - machines.html

7.5.6 EXPERT

DETAILS

INTERNATION

AL

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   Hyderabad.
   Cell : 9849052608

2. Prof. A.D. Rajkumar Electrical
   Engineering Deptt. University
   College of Engineering Osmania
   University - 500007
   Ph. No.: 27682382 (O)
   27098628 (O)

JOURNALS

INTERNATIONAL

1. IEEE Transactions on energy conversion
2. IEEE Computer applications in power
3. IEE Proceedings : Part-C [Generation, Transmission & Distribution]
4. IEEE Transactions on Power Systems
5. IEEE Electrical Insulation magazine
6. Power Engineering Journal, IEE

NATIONAL

1. Electrical India
2. Journal of Institution of Engineers (India)
3. Electrical Engineering Update

FINDINGS & DEVELOPMENTS

1. "Transformer equivalent circuit from field Managements" - Internal Journal of Electrical Engineering

Education. C.S. Indulkar & K. Ramalingam (to be published)
2. Chang, CS and JS Huang, “Centralized control of transformer tap changing for voltage stability enhancement”, Electric Machines and Power Systems, 27 (1999) : P1161.
3. T.A.Lipo, “Torque Density Improvement in a Six-phase Induction Motor with third harmonic current injection”, in Conference Rec. IEEE IAS Annual Meeting, Chicago, Oct. 2001, P 1779 - 1786.
4. “Deriving an equivalent circuit of transformers insulation for understanding the dielectric response measurements”, IEEE Transactions on Power Delivery, Jan. 2005.
5. D.A. Koppikar, S.V. Kulkarni, S.A. Khaparde, and S.K. Jha, “Evaluation of Eddy losses due to High Current leads in transformers”, IEE Proceedings - Science, Measurement and Technology, Vol.144, No.1, Jan. 1997, PP 34-38.
6. “Effect of on-load tap changing transformer control on power voltage characteristics of compensated EHV transmission line with voltage sensitive loads”. Journal of Institution of Engineers (India), Vol.84, March, 2004, PP 221-226/

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7. “Implementation of Induction Machine Model in the Arbitrary reference frame using simulink” S. Srinivasa Rao, National Conference on Emerging trends in Electrical Engineering & Power Drives, April 2005, PP 249-258.

8. “Simulation and Implementation of Speed Control of Induction Motors (1 and 3) using PIC micro-controllers”, National Conference on Emerging Trends in Electrical Engineering & Power Drives, April 2005, PP 333-339.

GUEST LECTURE TOPICS

1. Effects of on-load tap changing transformer.
2. Characterization of transients in transformers.
3. Induction motor drive for electric vehicles.
4. High voltage testing of transformers

SESSION PLAN

	Topics in JNTU Syllabus	Modules and Sub Modules	Lecture No	Suggested Books	Remarks
1	Introduction to the subject Review of Basic Circuit Theory and EMF concepts		**L1,L2**	T1-Ch2, R1-Ch1 R2-Ch2, R6-P1-Ch1	
		UNIT-I -			
2	Single phase transformers	Faraday's Law Lenz's Law Principle of transformer action Applications	L3	T1-Ch2, T2-Ch1 R2-Ch3, R3-Ch1 R6-PIII-Ch1 R7-Ch1 T3-Ch20 R9-Ch4	GATE IES
3	Types and constructional details	Core type transformer Shell type transformer	L4	T2-Ch1, R2-Ch3 R6-PIII-Ch1, R7-Ch1 T3-Ch20 R9-Ch4	GATE IES
4	Transformer on No-load, EMF equation	Ideal transformer on No-load Phasor diagram on No-load Problems	L6	T2-Ch1, R2-Ch3 R3-Ch1, R6-PIII-Ch1 T3-Ch20 R7-Ch1 R9-Ch4	GATE IES
		Derivation of EMF equation Voltage and current transformation ratio	L7	T2-Ch1, R2-Ch3 R6-PIII-Ch1,R7-Ch1 T3-Ch20	GATE IES
5	Transformer on load	Resistive drop, leakage flux Leakage reactance drop with Phasor diagrams	L8	T1-Ch2, T2-Ch1 R2-Ch3, R3-Ch1 R6-PIII-Ch1,R7-Ch1 T3-Ch20 R8-CH2 R9-Ch4	GATE IES
		Full load phasor diagram Lagging and leading power factor	L9	T2-Ch1, R2-Ch3 R3-Ch1, R6-PIII-Ch1 Ch20 R8-CH2 R7-Ch1 T3-Ch20	GATE IES
6	Minimization of hysteresis and eddy current losses	Iron losses Copper losses Minimization of hysteresis and eddy current losses	L10	T2-Ch1, R2-Ch2 R6-PI-Ch1, R7-Ch1 T3-Ch20 Ch20 R8-CH2 R9-Ch4	GATE IES

7	Equivalent circuit	Referred values Equivalent circuit referred to Primary and secondary	L9	T1-Ch2, T2-Ch1 R2-Ch3, R3-Ch2 R6-PIII-Ch1,R7- Ch1 T3-Ch20	GATE IES
		Approximate equivalent circuit referred to primary and secondary Problems	L10	T2-Ch1,R2-Ch3 R3-Ch2, R6-PIII- Ch1 T3-Ch20 R7-Ch1 T3-Ch20 Ch20 R8-CH2 R9- Ch4	GATE IES
8	Losses and Efficiency	Effect of variation of frequency and supply voltage on iron losses Determination of efficiency at full load	L11	T2-Ch1, R2-Ch3 R3-Ch2, R6-PIII- Ch1 T3-Ch20 R7-Ch1 T3-Ch20 Ch20 R8-CH2	GATE IES
		Condition for maximum efficiency Current and KVA at maximum efficiency Problems	L12	T2-Ch1, R2-Ch3 R3-Ch2, R6-PIII- Ch1 T3-Ch20 R7-Ch1	GATE IES
9	Regulation	Voltage regulation at lagging and leading power factor	L13	T2-Ch1, R2-Ch3 R6-PIII-Ch1, R7- Ch1	GATE IES
		Approximate regulation at lagging & leading power factor Problems	L14	R2-Ch3,T2-Ch1 R3-Ch2, R7-Ch1 T3-Ch20 R9-Ch4	GATE IES
10	All day efficiency	Concept and problems on determination of All day efficiency	L15	T2-Ch1, R2-Ch3 R6-PIII-Ch1, R7- Ch1 T3-Ch20 R9- Ch4	
		UNIT-II			
11	OC and SC test	OC and SC tests circuit diagram and determination of equivalent circuit parameters	L16	T1-Ch2, T2-Ch1 R2-Ch3, R3-Ch3 R6-PIII-Ch1, R7- Ch1 T3-Ch20 R9- Ch4	GATE IES
		Problems	L17	T2-Ch1, R2-Ch3 R6-PIII-Ch1, R7- Ch1 T3-Ch20 Ch20 R8-CH2	
12	Sumpner’s test	Circuit diagram and operation	L18	T2-Ch1, R2-Ch3 R3-Ch3, R6-PIII- Ch1 T3-Ch20 R7-Ch1 Ch20 R8- CH2 R9-Ch4	GATE IES
13	Predetermination of efficiency and regulation	Calculation of efficiency and regulation using OC and SC test data	L19	T2-Ch1, R2-Ch3 R3-Ch3, R6-PIII- Ch1 T3-Ch20 R7-Ch1 R9-Ch4	GATE IES
14	Separation of losses test	Separation of Hysteresis and Eddy current losses Problems	L20	T2-Ch1, R3-Ch3 R6-PIII-Ch1,R7- Ch1 T3-Ch20 Ch20 R8-CH2 R9- Ch4	GATE IES

15	Parallel operation with equal and unequal voltage ratios	Reasons for parallel operation Load sharing Equal & unequal voltage ratios	L21	T2-Ch1, R2-Ch3 R3-Ch3, R6-PIII-Ch2 Ch20 R8-CH2 R7-Ch2 T3-Ch20 R9-Ch4	GATE IES
		Conditions for parallel operation Circulating current and calculation of load voltages Problems	L22	T2-Ch1, R2-Ch3 R3-Ch3, R6-PIII-Ch2 R7-Ch2 T3-Ch20 R9-Ch4	GATE IES
		Unit-III			
16	Auto Transformers	Construction Transformation ratio Volt-Ampere relation Equivalent circuit & efficiency	L23	T1-Ch2, T2-Ch1 R2-Ch3, R3-Ch3 R6-PIII-Ch2, R7-Ch2 T3-Ch20 R9-Ch4	GATE IES
17	Comparison with two winding transformer	Saving in conductor material Problems Advantages and Disadvantages of auto transformers compared to two winding Transformer Applications and problems	L24	T2-Ch1, R2-Ch3 R3-Ch3, R6-PIII-Ch2 Ch20 R8-CH2 R7-Ch2 T3-Ch20 R9-Ch4	GATE IES
18	Polyphase transformers	Construction of 3-ph transformers	L25	T2-Ch1, R2-Ch3 R6-PIII-Ch2, R7-Ch2 Ch20 R8-CH2	GATE IES
19.	Polyphase connections Y/Y Y/Δ, Δ/Y, Δ/ Δ and open Δ	Factors affecting the choice of connections Y/Y, Δ/ Δ circuit diagram with 00 phase shift &1800phase shift	L26	T1-Ch2, R2-Ch3 R3-Ch4, R6-PIII-Ch2 Ch20 R8-CH2 R7-Ch2	GATE IES
		Δ/Y, Y/ Δ connection and phasor diagrams	L27	T1-Ch2, R2-Ch3 R6-PIII-Ch2, R7-Ch2 Ch20 R8-CH2	GATE IES
		Open Δ connection and phasor diagram Applications and problems	L28	R2-Ch3,R3-Ch4 R6-PIII-Ch2, R7-Ch2 R9-Ch4	GATE IES
20	Harmonics in phase voltages	Wave shape of no-load exciting current and effects of 3rd harmonic Inrush of magnetizing current Star and delta connections	L29	R2-Ch3,R3-Ch4 R6-PIII-Ch2, R7-Ch2 T3-Ch20 Ch20 R8-CH2	GATE IES
21	3-winding transformer Tertiary windings	Schematic diagram Equivalent circuit	L30	R2-Ch3,R3-Ch4 R6-PIII-Ch2, R7-Ch2	GATE
22	Determination of Zp, Zs and Zt, transients in switching	SC test on 3-winding transformer Open circuit test Problems	L31	R3-Ch4, R6-PIII-Ch2 T3-Ch20 R7-Ch2 Ch20 R8-CH2	GATE
23	Off load and on load tap changing	Off load and on load tap changing	L32	T2-Ch1, R2-Ch3 R3-Ch4, R6-PIII-Ch2 T3-Ch20 R9-Ch4	
24	Scott connection	Circuit diagram and load analysis with phasor diagram for balanced load	L33	R2-Ch3,R3-Ch4 R6-PIII-Ch2, R7-Ch2 Ch20 R8-CH2	

				R9-Ch4	
		Unbalanced load and problems	L34	R2-Ch3,R3-Ch4 R6-PIII-Ch2, R7-Ch2 R9-Ch4	
		UNIT-IV			
25	Polyphase induction motors-constructional details of cage and wound rotor machines	Introduction Cage and Wound rotor	L35	T2-Ch3, R2-Ch9 R3-Ch5, R6-PIII-Ch7 T3-Ch21 R7-Ch4 Ch20 R8-CH7 R9-Ch7	GATE IES
		Comparison	L36	T2-Ch3, R2-Ch9 R3-Ch5, R6-PIII-Ch7 T3-Ch21 R9-Ch7 R7-Ch4 R8-CH7	GATE IES
26	Production of a rotating magnetic field-principle of operation	Analytical method	L37	T2-Ch3, R2-Ch9 R3-Ch5, R6-PIII-Ch7 R8-CH7 R7-Ch4	GATE IES
		Graphical method	L38	T2-Ch3, R2-Ch9 R3-Ch5, R6-PIII-Ch7 T3-Ch21 R7-Ch4 R8-CH7	GATE IES
27	Rotor emf, rotor frequency, rotor reactance, rotor current and pf at standstill and during operation	Speed Slip	L39	T2-Ch3, R2-Ch9 R3-Ch5, R6-PIII-Ch7 T3-Ch21 R7-Ch4	GATE IES
		Frequency of rotor voltage and current Rotor parameters during operation	L40	T2-Ch3, R2-Ch9 R3-Ch5, R6-PIII-Ch7 T3-Ch21 R7-Ch4	GATE IES
28	Rotor power input, copper loss and mechanical power developed and their interrelation	Relation between rotor copper loss and rotor input Power flow in Induction motor	L41	T2-Ch6, R2-Ch9 R6-PIII-Ch7, R7-Ch4 R9-Ch7	GATE IES
29	Torque equation-deduction from torque equation-expression for max. torque and starting torque	Torque equation of an induction motor Starting torque Torque at synchronous speed	L42	T1-Ch7, T2-Ch6 R2-Ch9, R3-Ch6 R6-PIII-Ch7, R7-Ch4 R8-CH7 R9-Ch7	GATE IES
		Condition for maximum torque maximum starting torque Problems	L43	T1-Ch7, T2-Ch6 R2-Ch9, R3-Ch6 R6-PIII-Ch7, R7-Ch4 R8-CH7 R9-Ch7	GATE IES
30	Torque-Slip characteristics	Torque-Slip characteristics Torque-speed characteristics	L44	T1-Ch7, T2-Ch6 R2-Ch9, R3-Ch6 R6-PIII-Ch7, R7-Ch4 R9-Ch7	GATE IES
31	Double cage and deep bar rotors	Constructional details and working	L45	R2-Ch9, R3-Ch6 R6-PIII-Ch7, R7-Ch4 T3-Ch21 R8-CH7 R9-Ch7	

32	Equivalent circuit Phasor diagram	Development of stator and rotor circuit model	L46	T2-Ch6, R2-Ch9 R6-PIII-Ch7, R7-Ch4 T3-Ch21 R9-Ch7	GATE IES
		Equivalent ckt. referred to stator approximate equivalent circuit Problems	L47	T1-Ch7, T2-Ch6 R2-Ch9, R3-Ch6 R6-PIII-Ch7, R7-Ch4 T3-Ch21 R9-Ch7	GATE IES
33	Cogging and crawling	Effect of space harmonics Harmonic induction torque	L48	R2-Ch9,R6-PIII-Ch7 T3-Ch21 R8-CH7 R9-Ch7 R7-Ch4 T3-Ch21	
		UNIT-V			
34	No-load test	Determination of no-load losses and equivalent circuit parameters	L49	R2-Ch9,R6-PIII-Ch7 T3-Ch21 T2-Ch6,R7-Ch4 T1-Ch7 R8-CH7 R9-Ch7	IES
35	Blocked rotor test	Determination of equivalent circuit parameters	L50	T1-Ch7, T2-Ch6 R2-Ch9,R6-PIII-Ch7 T3-Ch21 R7-Ch4 R8-CH7 R9-Ch7	IES
36	Circle diagram Predetermination of performance	Construction of the circle diagram Problems	L51	R2-Ch9,R6-PIII-Ch7 T3-Ch21 T2-Ch6,R7-Ch4	IES
		Results obtainable from the circle diagram Significance of some lines in the circle diagram	L52	R2-Ch9,R6-PIII-Ch7 T3-Ch21 R8-CH7 T2-Ch6,R7-Ch4 R3-Ch7 R9-Ch7	IES
37	Methods of starting-starting current and torque calculation	Starting methods for cage motors- DOL starter-Y/Δ starter, Auto transformer starter Starting methods for slip ring induction motors	L53	T2-Ch6, R2-Ch9 R3-Ch8,R6-PIII-Ch8 T3-Ch21 R7-Ch4 R9-Ch7	GATE IES
38	Speed control-change of frequency, change of poles and consequent poles, cascade connection	Voltage control, Rotor Resistance Control	L54	T1-Ch8, R2-Ch9 R3-Ch8, R6-PIII-Ch7 T3-Ch21 R7-Ch4 R9-Ch7	GATE IES
		Consequent poles Connection for high speed and low speed Frequency control	L55	R2-Ch9, R3-Ch8 R6-PIII-Ch7, R7-Ch4 R9-Ch7	
39	Injection of an EMF into rotor circuit (qualitative treatment only)	Injection of an EMF into rotor circuit (qualitative treatment only)	L56	R2-Ch9, R3-Ch8 R6-PIII-Ch7, R7-Ch4 R9-Ch7	
40	Induction generator principle of operation	Comparison of Induction motor and Induction generator	L57	T2-Ch6, R2-Ch9 R3-Ch8, R6-PIII-Ch7 R9-Ch7 R7-Ch4	

Q U E S T I O N

Note : latest questions updated at the end of each unit

QUESTION BANK

UNIT-I

1. i. Explain the constructional details of a single-phase transformer with a neat sketch.
   ii. The e.m.f per turn for a single phase, 2310/220 volts, 50Hz transformer is 13 volts. Calculate.
   a. The number of primary and secondary turns.
   b. The net cross sectional area of the core, for a maximum flux density of 1.4 T.
   c. Why is the transformer core laminated?
   iii. Why is the transformer core laminated? **(May 09)**

2. i. Explain the following with respect to single phase transformer: **(May 09)**
   a) Core b) windings c) Methods of cooling and d) conservator and bushings.
   ii. A single phase transformer is connected to a 230V, 50Hz supply. The net cross sectional area of the core is $50cm^2$. The number of turns of the primary is 460 and the secondary is 80. Determine a) transformation ratio b) peak value of the flux density in the core c) e.m.f in the secondary winding.

3. i. Derive the e.m.f equation of a 1-phase transformer?
   ii. A tansformer has a primary winding of 800 turns and a secondary of 200 turns. When the load current on the secondary is 80A at 0.8pf lagging. Determine the no-load current of the transformer and the phase angle with respect to the voltage. **(May 09)**

4. i. Explain how do you minimize the hysteresis and eddy current losses in a single phase transformer?
   ii. When a single phase transformer is supplied at 400V, 50Hz, the hysteresis loss is found to be 320 watts and eddy current loss is found to be 250 watts. Determine the hysteresis loss and eddy current loss when the transformer is supplied at 800V, 100Hz. **(May 09)**

5. i. In detail give the advantages & disadvantages of core & shell type construction.
   ii. A 25 kVA, 2400 / 240 V, 50 Hz, single phase distribution transformer operates at no-load in step down mode, draws 138 W at a pf of 0.21 lagging. Determine the magnetising current components, magnetizing reactance & core loss resistance. **(May 09)**

6. i. What are the various losses taking place in transformer? How these losses can be minimized?
   ii. A 2.4 kV / 115 V transformer has sinusoidal flux density expressed by 0.113 sin 188.5t. Determine the primary & secondary turns. **(May 09, Sep 08)**

7. i. Explain the various types of material used in construction of core of transformer? Briefly explain all the properties. Explain how quality of core material is related with core losses in transformer.
   ii. A single phase transformer has 400: 1000 turns ratio. The net cross sectional area of the core is 60 cm^2. The primary winding be connected to 50 Hz supply & 500 V. Calculate the peak value of flux density in the core. The voltage induced in the secondary winding. **(May 09)**

8. i. With phaser diagram, explain the operation of transformer at no-load.
   ii. The no-load current of a transformer is 5 A at 0.25 pf when supplied at 235 V, 50 Hz. The number of turns on the primary winding is 200. Calculate
   a. The maximum value of flux in the core
   b. The core loss
   c. the magnetizing component current. **(May 09)**

9. i. With neat phaser diagram explain the operation of transformer with resistive load. **(Sep 08)**

ii. A single phase transformer with a primary (HV) voltage of 1600 V with a ratio of 8:1. The transformer supplies a load of 20 kW at a pf of 0.8 lagging and takes a no-load current of 2 A at pf of 0.2, estimate the current taken by the primary.

10. i. A 6.6 kV/440 V, 50 Hz transformer has primary impedance of 17 + j 42 Ω & secondary impedance of 0.58 + j 1.7 Ω. A short circuit occurs on secondary of transformer with 6.6 kV applied to primary. Calculate the primary current & its power factor, if no load magnetising current is 12.6 A at 0.28 pf lagging (LV side)

ii. Explain the importance of phasor diagram of in operation of transformer. Give step by step procedure while developing the phasor diagram of transformer. **(Sep 08)**

11. i. Derive the EMF equation of transformer? Hence derive the voltage ratio.

ii. A 15kVA 2400-240-V, 60 Hz transformer has a magnetic core of 50-cm^2 cross section and a mean length of 66.7 cm. The application of 2400 V causes magnetic field intensity of 450 AT/m (RMS) and a maximum flux density of 1.5 T . Determine

a. The turn’s ratio

b. The numbers of turns in each winding

c. The magnetizing current **(Sep 08, May 08, 07)**

12. i. With neat phasor diagram explain the operation of transformer with capacitive load. **(May 08)**

ii. The voltage ratio of single phase 50 Hz transformer is 5000/500 V at no-load. Calculate the number of turns in each winding, if the value of the flux in the core is 7.82 mWb.

13. i. With neat phasor diagram explain the operation of transformer with inductive load. **(May 08)**

ii. The exciting current for a 50 kVA, 480/240V 50 Hz transformer is 2.5% of rated current at a phase angle of 79.8^0. Find the components of magenetising current & loss component. Also find the magnetising reactance & core loss resistance.

14. Give the constructional features of "CORE" and "SHELL" types of transformers, state their advantages and disadvantages. **(May 07, Apr 05, 03)**

15. State various losses that takes place in transformer. On what factors do they depend ? Explain the steps taken to minimize these losses ? **(May 07, Jan 03)**

16. i. With neat phasor diagram explain the operation of transformer at No-load

ii. A 2000 kVA 4800/600 V, 50 Hz core type transformer has a no load current equal to 2% of full load current. The core has mean length of 3.15 m & is operated at a flux density of 1.55 Tesla. The magnetic flux intensity is 360 AT/m. Determine the magnetising current,the number of turns in two coils, the core flux & the cross sectional area of core. **(May 07)**

17. A 22 kV/ 2.2 kV, 500 kVA, 60 Hz transformer is charged with rated voltage on 22 kV side. If the resultant core flux is 0.0683 Wb (max), determine the number of turns on primary & secondary. Find the new value of flux if the voltage is increased by 20% and frequency is decreased by 5%. **(May 07)**

18. In detail explain the classification of transformer? **(May 07)**

19. Explain why hysteris and eddy current losses occur in a transformer. **(May 07)**

20. Prove that the EMF induced in the windings of the transformer will lag behind the flux by 90^0.

(May, 07, Apr 06, 05)

21. Draw the phasor diagram of a transformer on no load and explain the function of active and reactive components of no load current of transformer. **(Sep 06, Apr 05)**

22. i. Explain the functions of the following in a transformer **(Sep 06, Apr 04, Nov 04)**
    a. Breather b. Conservator c. Oil
    ii. Draw and explain phasor diagram of transformer on lagging load.

23. i. Explain the working principle of transformer and derive the emf equation.
    ii. A single phase 50 Hz transformer has 100 turns on the primary and 400 turns on the secondary winding. The net cross-sectional area of core is 250cm^2. If the primary winding is connected to a 230V 50 Hz supply, determine
    a. The EMF induced in the secondary winding.
    b. The maximum value of flux density in the core. **(Apr 06, 03, Nov 04)**

24. i. Explain why hysterisis and eddy current losses occur in a transformer. **(Apr 06, 05, 04, 03)**
    ii. A transformer on load takes 1.5 amps at a power factor of 0.2 lagging when connected across 50 Hz 230V supply. The ratio between primary and secondary number of turns is 3. Calculate the value of primary current when secondary is supplying a current of 40 amps at a power factor of 0.8 lagging. Neglect the voltage drop in the windings. Draw the relevant phasor diagram.

25. What are the sources of heat in a transformer. Describe briefly various methods used for cooling of transformers. **(Apr 06, 05, 03)**

26 i. Give the equivalent circuit of a transformer and its various parameters. Clearly, state the assumptions made in the applicability of this equivalent circuit.
    ii. Following are the test figures for the 4kVA, 200/400V, 50Hz, single phase transformer.
    O.C test : 200V: 200V, 0.8A, 70w
    S.C test : 17.5V, 9A, 50W.
    Calculate the parameters of equivalent circuit of a transformer. **(May 09)**

27. i. Draw the approximate equivalent circuit of a transformer referred to the primary side and indicate how it differs from the exact equivalent circuit.
    ii. Obtain the equivalent circuit of 1-phase, 4kVA, 200/400V 50Hz transformer from the following test results:
    o.c test: 200V, 0.7A, 70watts on lv side (primary side)
    s.c test: 15V, 10A 80watts on hv side (Secondary circuit). **(May 09)**

28. i. What are the different losses in a transformer? Derive the condition for maximum efficiency of the transformer?
    ii. The full load copper and iron losses of a 15kVA single phase transformer are 320 W and 200 W respectively. Calculate the efficiency of the transformer at unity power factor at full load and half load. **(May 09)**

29. i. Derive the condition for maximum efficiency of a transformer. **(May 09, 08, Sep 08)**
    ii. A single phase 150 kVA transformer has efficiency of 96 % at full load, 0.8 pf and at half load, 0.8 pf lagging. Find maximum efficiency of transformer and corresponding load.

30. i. What is the efficiency of transformer? How the efficiency of transformer can be calculated?
    ii. The turn's ratio of a single phase transformer is 4. The resistance & leakage reactance of HV windings

are 1.4 Ω & 1.6 Ω respectively and that of LV windings are 0.06 Ω & 0.08 Ω respectively. If 200 V is applied to HV winding & LV winding is short circuited, find the current supplied by the source. (Neglect magnetising current) **(May 09, 08)**

31. Two 100 kVA transformer each has maximum efficiency of 98.2 %, but in one transformer it occurs at 92 % load & for other transformer it occurs at full load. For following load cycle fins all day efficiency for each. Suggest which transformer is more suitable for this load.
Full load at 0.8 pf lagging for 8 hours
65 % load with 0.95 pf lagging for 6 hours
90 % load with 0.88 pf lagging for 4 hours
10 % load with 0.72 pf lagging for 6 hours.
Also find the maximum all day efficiency for both the transformers if both transformers are supplying constant load. **(May 09)**

32. i. What is the importance of equivalent circuit of transformer? **(Sep 08)**
ii. The equivalent circuit parameters of 200 / 2000 V transformer as follows:
$R_{eq} = 0.16\ \Omega$, $X_{eq} = 0.7\ \Omega$, $X_o = 231\ \Omega$, $R_o = 400\ \Omega$ (all referred to LV side) If load impedance is 600 + j 500 Ω; find secondary load voltage & primary current.

33. i. Derive the condition for the maximum efficiency of the transformer. **(Sep 08, Nov 04)**
ii. A 100 kVA single phase transformer has an iron loss of 1 KW and full load copper loss of 1.5 KW. Find the maximum efficiency at a power factor of 0.8 lagging and the corresponding kVA loading.

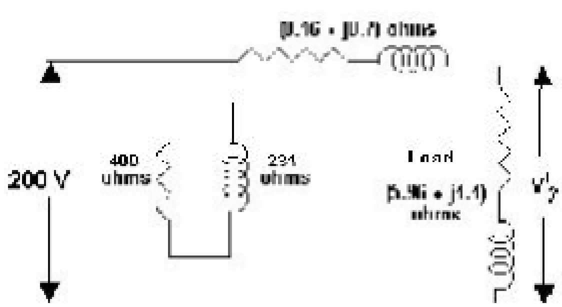
34. Explain how equivalent circuit of transformer can be obtained? **(May 07, Apr 06, 05)**

35. Explain the principle of operation of transformer. Deduce its equivalent circuit. **(May 07, Sep 06)**

36. Explain how equivalent circuit of transformer can be obtained? **(May 07)**

37. A transformer on load takes 1.5 amps at a power factor of 0.2 lagging when connected across 50 Hz 230 V supply. The ratio between primary and sec- ondary number of turns is 3. Calculate the value of primary current when secondary is supplying a current of 40 amps at a power factor of 0.8 lagging. Neglect the voltage drop in the windings. Draw the relevant phasor diagram. **(May 07)**

38. The equivalent circuit of a single phase transformer is shown. Figure relates to primary side. The ratio of secondary to primary turns is 10 and load is inductive. Find
i. Secondary terminal voltage
ii. Primary current
iii. Efficiency



(May 07)

39. Derive the condition for zero voltage regulation. Also show that the magnitude of maximum voltage regulation equals to per unit value of leakage impedance. **(May 07)**

40. A 40 kVA single phase transformer has got maximum efficiency of 97% at 80% of full load at UPF. During the day, the load on the transformer is as follows :

No. of hours	Load	Power factor
9	6 KW	0.6 lag
8	25 KW	0.8 lag
7	30 KW	0.9 lag

Determine the all day efficiency of the transformer. **(Apr 06, 05, 03)**

41. i. Write a short note on All day efficiency of the transformer.
ii. Find the All day effieciency of single phase transformer having maximum efficiency of 98% at 15 kVA at UPF and loaded as follows :
12 hours - 2 KW at 0.5 power factor lagging
6 hours - 12 KW at 0.8 power factor lagging
6 hours - no load **(Apr 06, 03)**

42. i. Explain various losses and derive the condition for minimum efficiency of a transformer.
ii. The efficiency at unity power factor of 6600/384 volts 100 kVA 50 Hz single phase transformer is 98% both at full load and at half full load. The power factor on no load is 0.2 and the full load regulation at a lagging power factor of 0.8 is 4 %. Draw the equivalent circuit referred to L.V. side and insert all the values. **(Sep 06, May 05, Apr 04)**

43. Explain why transformer rating will be given in kVA but not in KW. **(Sep 06, Apr 05)**

44. i. Define efficiency and regulation of a transformer. Show how the power factor affects both of them.
ii. The maximum efficiency of 50 kVA transformer is 97.4% and occurs at 90% of the full load. Calculate the efficiency of transformer at
a. Full load 0.8 power factor lagging. b. Half full load 0.9 power factor. **(Sep 06)**

45. i. Draw the equivalent circuit of a single phase transformer. Show how the equivalent circuit can be simplified without introducing much error.

46. i. Derive the expression for voltage regulation of a transformer from the simplified approximate equivalent circuit and obtain condition for zero regulation. **(Nov 04)**
ii. The primary and secondary windings of 30 kVA 6000/230 V transformer have resistances of 10 and 0.016 respectively. The total reactance of transformer referred to primary is 23. Calculate the percentage regulation of transformer when supplying full load current at a power factor of 0.8 lagging.

47. i. A single phase 120 kVA 2000/200 V 50 Hz transformer has impedance drop of 9% and resistance drop of 4.5 %. Find
a. the regulation at 0.8 power factor lagging on full load.
b. At what power factor is the regulation zero.
ii. The efficiency of 1000 kVA, 110/220 V,50 Hz single phase transformer is 98.5% at half full load at 0.8 power factor leading and 98% at full load, UPF. Determine
a. Iron loss
b. Copper loss
c. Maximum efficiency at UPF **(Nov 04)**

48. i. Discuss the effects of variation of frequency and supply voltage on iron losses of transformer.
ii. The flux in a magnetic core is alternating sinusoidally at a frequency of 600 Hz. The maximum flux density is 2 tesla. The eddy current loss is 15 watts. Find the eddy current loss in the core if the frequency is raised to 800 Hz and the maximum flux density is reduced to 1.5 tesla. **(Apr, 04, 03)**

49. Describe the constructional details of single phase transformers. A 2200/200V transformer draws a no-load

primary current of 0.6 A and absorbs 400W. Find the magnatising and iron loss current and also find no-load power factor?

50. Give the concept of single phase ideal transformer. Describe its performance with the help of neat phasor diagrams. A 25 KVA, single-phase transformer has 250 turns on the primary and 40 turns on the secondary winding. The primary is connected to 1500 volt, 50 Hz mains. Calculate i)Primary and secondary currents ii)Secondary emf iii)Maximum flux in the core.

51. Discuss the construction details of a transformer. Mention how hysteresis and eddy current losses are minimized. A 2200/200 V, transformer takes 1A at the H.T side on no-load at a p.f of 0.385 lagging. Calculate the iron losses. If a load of 50A at a power of 0.8 lagging is taken from the secondary of the transformer, calculate the actual primary current and its power factor.

52. Give the concept of single-phase ideal transformer. Describe its performance with the help of phasor diagrams. The emf per turn of a 1- φ , 2200/220 V, 50 Hz transformer is approximately 12V.Calculate i)The number of primary and secondary turns, and ii)The net cross-sectional area of core for a maximum flux density of 1.5 T.

53.Define ‘efficiency’ and ‘all-day efficiency’ of a transformer. Mention how these are effected by the power factor. A 300 KVA, single - phase transformer is designed to have a resistance of 1.5% and maximum efficiency occurs at a load of 173.2 KVA. Find its efficiency when supplying full-load at 0.8 p.f lagging at normal voltage and frequency.

54.Derive an expression for computing the per unit voltage regulation of a transformer. Calculate the regulation of a transformer in which the Ohmic loss is 1% of the output and the reactance drop is 4% of the voltage, when the power factor is i)0.8 lagging ii)Unity iii)0.8 leading.[8+8]

55.Distinguish between efficiency, condition for maximum efficiency and all-day efficiency of a transformer. A 200 KVA transformer has an efficiency of 98% at full load. If the maximum efficiency occurs at three quarters of full-load, calculate the efficiency at half full- load. Assume negligible magnetizing current and 0.8 lagging power factor at all loads.

56.Give the equivalent circuit of a transformer and define its various parameters. A 100 KVA, 50 Hz, 440/11000 V, 1-phase transformer has an efficiency of 98.5% when supplying full-load current at 0.8 p.f and an efficiency of 99% when supplying half full-load current at unity p.f. Find the iron losses and copper losses corresponding to full load current.

UNIT II

1. i. Discuss how will you perform O.C and S.C. tests on a single phase transformer in the laboratory?
   ii. The maximum efficiency of a 500 kVA, 3300/500V, 50Hz, single phase transformer is 97% and occurs at $3/4^{th}$ Full load and unity power factor. If the impedance drop is 10%, calculate the regulation at load and 0.8 p.f lagging. **(May 09)**

2. i. Show that one transformer may have slightly less temperature rise than the other in sumpner’s test.
   ii. A 50kVA, 2200/1100V, single phase, 50Hz transformer has a full load efficiency of 95% and iron loss of 500w. The transformer is connected as an auto transformer to a 3300V supply. When it delivers a load of 50kW at unity power factor at 1100V, calculate the currents in the windings. Find also, the increase is output as auto-transformer. Also, calculate the copper loss as two winding transformer. **(May 09)**

3. i. In sumpner's test, the reading of the wattmeter recording the core losses, remains unaffected when low voltage is injected in the secondary series circuit. Explain.

   ii. Discuss the relative merits and demerits of an auto transformer.

   iii. A 11000/2200V, 100kVA, single phase two winding transformer is to be used as an auto-transformer by connecting the two windings in series. Give the possible values of voltage ratios and kVA outputs. **(May 09)**

4. i. State the essential and desirable conditions which should be satisfied before two single phase transformers may be operated in parallel.

   ii. Two single phase 500kVA and 400kVA transformers are connected in parallel to supply a load of 800kVA at 0.8 p.f lagging. The resistance and leakage reactance of the first transformer are 2.5 percent and 6 percent respectively and of the second transformer 1.6 percent and 7 percent respectively. Calculate the kVA loading and power factor at which each transformer operates. **(May 09)**

5. A 500 kVA , 500 V single phase transformer with a reactance drop of 4 % and resistance drop of 1 % is conncted in parallel with a 250 kVA, 500 V transformer with a reactance drop of 6 % and resistance drop of 1.5 % . The total load is 800 kW at unity power factor. Calculate secondary current in each transformer, the circulating current and secondary terminal voltage when

   i. OC secondary voltage of both transformers is 505 V

   ii. OC secondary voltage of 500 kVA transformer is 505 V and that of other is 509 V. **(May 09)**

6. With neat diagram, explain the various tests conducted on transformer to obtain its equivalent circuit. Derive all related equations. **(May 09, 08)**

7. i. Draw the vector diagrams of transformer with resistive, inductive & capacitive load.

   ii. A single phase transformer is working at 0.8 pf lagging has efficiency of 94 % at full load and $3/4^{th}$ load. Calculate the efficiency at half full load with unity pf.

8. i. Explain the procedure for OC test of transformer. **(Sep 08)**

   ii. A single phase transformer has the following data: Turns ratio 10:1, Z1= 1.6 +j 4.3 Ω, Z2 = 0.019 + j0.048 Ω. The input voltage of the transformer is 5000 V and the load current at the secondary is 250 A at 0.8 pf lagging. Neglecting no load current, calculate secondary terminal voltage and output power.

9. i. With all necessary instruments draw a neat experimental set up to conduct OC & SC tests on a single phase transformer.

   ii. A single phase 250/500 V transformer gave the following results:
   OC test: 250 V, 1 A, 80 W on LV side
   SC test: 20 V, 12 A, 100 W on HV side.
   Find the maximum efficiency of the transformer. **(Sep 08)**

10. i. Compare the results & procedure of OC-SC tests & Back to back tests conducted on tran An auto transformer used two windings with a turn's ratio of $N_1/N_2 = k$. Find the ratio of magnetising current & short circuit current as auto transformer to two winding transformer. **(Sep 08)**

11. i. What are the limitations of Sumpners test? Give the related calculation to find the approximate equivalent circuit of transformer.

    ii. Two similar single phase transformer are put to back to back test. Power input from supply line is 16 kW on no load and power output of auxiliary transformer when the rated current is circulated through the secondaries is 25 kW. Calculate for each transformer the full load efficiency at 0.8 pf lagging, the maximum efficiency and the corresponding load. **(Sep 08)**

12. i. Derive the condition for maximum efficiency of a transformer.

ii. A single phase 150 kVA transformer has efficiency of 96 % at full load, 0.8 pf and at half load, 0.8 pf lagging. Find maximum efficiency of transformer and corresponding load. **(May 08)**

13. i. What are the advantages of Sumpner's test? Give the related calculation to find the efficiency of a transformer.
    ii. In Sumpner's test on two identical transformer rated 500 kVA, 11/0.4 kV, 50 Hz, the wattmeter reading on HV side is 6 kW on rated voltage and on LV side is 15 kW when circulated full load current. Find the efficiency of each transformer on $3/4^{th}$ load & 0.8 pf lagging. What will be the maximum efficiency of each transformer? **(May 08)**

14. Calculate the voltage regulation for a 200/400 V, 4 kVA transformer at full load & pf. 0.8 lagging with following test data: **(May 08)**
    OC test: 200 V, 0.8 A, 70 W (LV side)
    SC test: 20 V, 10 A, 60 W (HV side)

15. i. Explain the various simple tests conducted on a single transformer to find the approximate equivalent circuit of transformer.
    ii. OC test is preferred to conduct on LV side & SC test is preferred to conduct on HV side. Explain the reasons. **(May 08)**

16. i. What are the conditions required for the parallel operation of two transformers.
    ii. Derive the equations for the currents supplied by each transformer when two transformers are operating in parallel with equal voltage ratios. **(Sep 06, Apr 05, 04, 03)**

17. i. Derive the equation for saving in copper in using Auto transformer when compared to two winding transformer.
    ii. Obtain the equivalent circuit of an auto transformer. **(Sep 06, Apr 05, 03, Nov 04)**

18. i. Explain the procedure for conducting OC and SC tests with neat diagrams.
    ii. A 20 kVA, 2500/250V, 50Hz, Single phase transformer gave the following test results:OC test(LV side): 250V, 1.6A, 110W; SC test(HV side): 90V, 7A, 300W. Compute the parameters of the approximate equivalent circuit referred to LV side. **(Sep 06, Nov 03)**

19. i. Explain the following characteristics of an auto transformer with two winding transformer:
    a. Rating b. Losses c. Impedance drop d. Voltage regulation
    ii. The primary and secondary voltages of an auto transformer are 500V and 400V respectively. Show with the aid of a diagram, the current distribution in the winding when the secondary current is 100A and calculate the economy of Cu in this particular case. **(Sep, Apr 06, Nov 03)**

20. A 20kVA, 2300/230V, two winding transformer is to be used as an auto transformer, with constant source voltage of 2300V. At full load of unity power factor, calculate the power output, power transformed and conducted. If the efficiency of the two winding transformer at 0.6 p.f. is 96% find the auto transformer efficiency at the same power factor. **(Apr 06, 05, 04, 03, Nov 04)**

21. A 4 kVA, 200/400V, 50Hz, single phase transformer gave the following test results: No-load : low voltage data, 200V, 0.7A, 60W., Short-circuit : High voltage data, 9V, 9A, 21.6W. Calculate
    i. The magnetizing current and the component corresponding to iron loss at normal voltage and frequency.
    ii. The efficiency on full load at unity power factor,
    iii. The secondary terminal voltage on full-load at power factors of unity, 0.8 lagging and 0.8 leading. **(Apr 06)**

22. i. What precautions should be observed during the operation of on-load tap changer.
    ii. Explain the function of center-tapped reactor in on load tap changer. **(May 09, 05)**

23. i. Describe four possible ways of connections of 3-phase transformers with relevant relations amongst voltages and currents on both h.v and l.v. sides.

ii. A bank of three single phase transformers has its h.v. terminals connected to 3 wire, 3-phase, 11KV system. It's l.v. terminals are connected to a 3 wire, 3-phase load rated at 1500kVA, 2200V. Specify the voltage, current and KVA ratings of each transformer for both h.v. and l.v. windings for the following connections:

a) Y-Δ b) Δ-Y c) Y-Y **(May 09)**

24.Describe the tests to be done on a single phase transformer to determine the equivalent circuit parameters. The following results were obtained from tests on 30 KVA, 3000/110 V, and transformer
O.C. test: 3000 V, 0.5 A, 350 W S.C. test: 150 V, 10 V, 500 W Calculate the efficiency of the transformer at full load with 0.8 lagging power factor.

25.Explain why parallel operation of transformers is necessary. Under what conditions, the no-load circulating current is zero in two single-phase transformers operating in parallel. The iron loss in a transformer core at normal flux density was measured at frequency of 30 Hz and 50 Hz, the results being 30 W and 54 W respectively. Calculate i)The hysteresis loss and ii)The eddy current loss at 50 Hz

26.Explain why transformer rating is expressed in KVA or VA. Describe the significance of all the items mentioned on the name - plate of a single - phase transformer. A 20 KVA, 2500/250 V, 50 Hz, 1-phase transformer has the following test results. O.C. test (l.v. side): 250 V, 1.4 A, 105 W S.C. test(h.v. side): 104 V, 8A, 320 W
Calculate the efficiency at full-load and 0.8 lagging power factor.

27.The instrument obtained from open and short circuit tests on 10 KVA, 450/120 V, 50 Hz transformer are:
O.C. test: V1 = 120 V, I1 = 4.2 A, W1 = 80 W. (H.V. side open)
S.C. test: V1 = 9.65 V, I1 = 22.2 A, W1 = 120 W. (L.V. side Short circuited)
Compute a)The equivalent circuit parameters when refered to primary side. b)Efficiency at full load with 0.8 lagging power factor.

UNIT III

1. i. Explain the advantages of using a tertiary winding in a bank of star-star transformers?

ii. Two T-connected transformers are used to supply a 440V, 33kVA balanced load from a 3-phase supply of 3.3KV. Calculate.

a) voltage and current rating of each coil

b) KVA rating of the main and teaser transformer. **(May 09)**

2. i. Why should the tap-changer be connected near the neutral? What about delta connected transformer.

ii. Describe the no load tap changer with a suitable diagram. **(May 09, Nov 04)**

3. i. With neat phasor diagram, explain the voltage regulation of three-phase transformer.

ii. An ideal 3-□ step down transformer connected in delta/star delivers power to a balanced 3-phase load of 120 kVA at 0.8 pf. The input line voltage is 11 kV and the turn's ratio of transformer (phase to phase) is 10. Determine theline voltage line currents, phase voltages, phase currents on both primary & secondary sides. **(May 09, 07, Sep 08)**

4. i. With neat diagram, explain how a three phase transformer can be used for supply of two single phase furnaces.

ii. A 3- □, 1200 kVA, 6.6/1.1 kV transformer has Delta/Star connection. The per phase resistance is 2 □ & 0.03 □ □on primary & secondary respectively. Calculate the efficiency on full load at 0.9 pf lagging, iron losses are 20 kW. **(May 09, 07)**

5. i. What precautions should be observed during the operation of on-load tap changer.
   ii. Describe one type of on load tap changer, with proper sequence of operation for changing the voltage. **(May 09, Apr 04)**

6. i. Explain how the no-load current of a single phase transformer contains harmonics even when the supply voltage is sine wave.
   ii. Why the wave shape of magnetising current of a transformer is non-sinusoidal? Explain the phenomenon of inrush magnetising current. What factors contribute to the magnitude of inrush current? **(May 09)**

7. i. Explain tests to determine the equivalent circuit parameters of a three-phase transformer.
   ii. A 3-□□ 100 kVA, 5000/400 V Star/Star, 50 Hz transformer has an iron loss of 1400 W. The maximum

   efficiency of transformer occurs at 80% of load. Calculate:
   a. The efficiency of transformer at full load and 0.85 pf lagging
   b. The maximum efficiency at UPF. **(Sep, May 08)**

8. Two single phase furnaces are supplied at 250 V from a 6.6 kV, 3-□ system through a pair of Scott connected transformer, if the load on the main trans- former is 85 kW at 0.9 pf lagging and that on the teaser transformer is 69 kW at o.8 pf lagging. Find the values of line currents on the three phase side. Neglect the losses. **(May 08)**

9. i. What is tap changer? What are the various types of tap changers? Explain the need of tap changers. ii. The primary & secondary windings of two transformers, each rated 250 kVA, 11/22kV and 50 Hz are connected in open delta. Find
   a. The kVA load that can be supplied from this connection
   b. Currents on the HV side if a delta connected 3-□□load of 250 kVA, 0.8 pf lagging, 2 kV is connected on the LV side of connection
   (May 07)

10.Discuss in detail about on-load tap changing of a transformer. A 100 KVA, 3-phase, 50 Hz, 3,300/400V transformer is Δ connected on the h.v side and Y connected on the l.v side. The resistance of the h.v winding in 3.5 Ω per phase
and that of the l.v winding 0.02 Ω per phase. Calculate the iron losses of the transformer at normal voltage and frequency if its full-load efficiency be 95.8% at 0.8p.f (lag).

11.A 500 KVA, 3-phase, 50 Hz transformer has a voltage ratio (line voltage) of 33/11KV and is delta/star connected. The resistance per phase are: high voltage 35 Ω, low voltage 0.876 Ω and the iron loss is 3050 W. Calculate the value of efficiency at full-load and one-half of full-load respectively at 0.8 p.f lagging.

12.A Δ bank consisting of three 20-KVA, 2300/230V transformer supplies a load of 40kW. If one transformer is removed, find for the resulting V-V connection. a)KVA load carried by each transformer. b)Percent of rated load carried by each transformer c)Total KVA rating of the V-V bank. d)Ratio of the V - V-bank to Δ - Δ bank transformer ratings e)Percent increase in load on each transformer when bank is converted into V-V bank.

Discuss in detail about Δ / Δ and V/V connection. Mention the merits and demerits of each connection & Justify.

UNIT-IV

1. i. Describe the constructional features of both squirrel cage induction motor and slip-ring induction motor. Discuss the merits of one over the other.
   ii. A 4-pole, 50Hz induction motor runs with a slip of 0.01 p.u on full load. Calculate the frequency of the rotor current
   a) at stand still and b) on full load.
   iii. Explain why a 3-phase induction motor, at no-load, operators at a very low power factor? **(May 09)**

2. i. Explain the principle of operation of a 3-phase induction motor with a neat sketch.
   ii. A 4-pole, 3-phase induction motor operates from a supply whose frequency is 50Hz. Calculate
   a) the speed at which the magnetic field of the stator is rotating
   b) the speed of the rotor current when the slip is 0.04
   c) the frequency of the rotor current when the ship is 0.03
   d) the frequency of the rotor current at stand still.
   iii. Discuss the points of similarities between a transformer and an induction machine. **(May 09)**

3. i. Explain the principle of operation of a 3-phase induction motor. Explain why the rotor is forced to rotate in the direction of rotating magnetic field?
   ii. A 3-phase, 50Hz induction motor has a full-load speed of 1440rpm. For this motor, calculate the following: a) Number of poles b) Full load slip and rotor frequency c) Speed of stator field with respect to (i) stator structure and (ii) also rotor structure d) Speed of rotor field with respect to (i) rotor structure and (ii) stator field **(May 09)**

4. i. Explain why the rotor of poly phase induction motor can never attain synchronous speed?
   ii. Explain the production of torque in a 3-phase slip ring induction motor when the rotor is running with a slip S. Hence, introduce the concept of load angle.
   iii. A 3-phase induction motor is wound for 4 poles and is supplied from a 50Hz system. Calculate
   a) the synchronous speed.
   b) the rotor speed when slip is 4% and
   c) rotor frequency when rotor runs at 600 rpm.

5. i. Explain the terms Slip, Slip speed, Rotor frequency, Rotor EMF.
   ii. A 3-phase, 50 Hz slip ring IM gives a standstill open circuit voltage of 500 V between slip rings. Calculate the current and power factor at standstill when the per phase rotor winding resistance and inductance are 0.2 ohms & 0.04 H and slip rings are short circuited. Repeat the calculation when slip is 4 %.

6. i. Deduce the expression for (rotor side) starting current, starting power factor, standstill frequency and standstill EMF of squirrel cage IM.
   ii. A 4-pole IM is fed from 50 Hz supply and has rotor speed of 1425 RPM find slip speed & slip.
   iii. A 12 pole, 3-phase alternator driven at a speed of 500 rpm supplies power to an 8-pole, 3-phase, IM. If the slip of the motor at full load is 3 %, calculate the full load speed of the motor.

7. i. Explain the construction of induction motor.
   ii. An 8 pole, 3-phase alternator is coupled to a prime mover running at 750 rpm. It supplies an induction motor which has a full load speed of 960 rpm. Find the number of poles of IM and slip. **(May 09, 08)**

8. i. With neat diagram explain the construction of Sq. cage IM. **(Sep 08)**
   ii. Calculate the speed in RPM & RPS for a 6 pole IM which has a slip of 6 % at full load with a supply frequency of 50 Hz. What will be the speed of a 4 pole alternator supplying power to this motor?

9. i. Deduce the expression for (rotor side) starting current, starting power factor, standstill frequency and standstill EMF of slip ring IM.
ii. A 4-pole, 3-phase, IM operates from a supply whose frequency is 50 Hz. Calculate:
a. the speed at which the magnetic field of stator is rotating
b. the speed of the rotor when the slip is 4 %.
c. the frequency of the rotor current when the slip is 3 %
d. the frequency of rotor current at stand still. **(Sep 08)**

10. i. A 3-phase, 50 Hz, 4 pole, 400 V, wound rotor IM has a △connected stator winding and star connected rotor winding. Rotor conductors are 80 % of stator conductors. For speed of 1425 RPM calculate slip, the rotor induced emf/ph between the two slip rings and frequency of rotor current.
ii. Explain the differences between slip ring & Squirrel cage IM. **(Sep 08)**

11. i. A 3-phase, 400 V IM has transformation ratio of 6 (stator to rotor). The rotor has per phase resistance & reactance of 0.5 □ & 1.5 □ respectively. Calculate rotor current and power factor: when slip rings are short circuited and slip is 5 % and when external resistance of 1 “/ph is connected in rotor circuit and motor is rotating with 8 % slip.
ii. Explain the differences between sq. cage IM & Slip ring IM. **(Sep 08)**

12. i. Explain clearly the principle of operation of Induction motor. **(May 08)**
ii. The frequency of stator EMF is 50 Hz for an 8-pole induction motor. If the rotor frequency is 2.5 Hz, calculate the slip and the actual speed of rotor.

13. i. Discuss the points of similarities between a transformer and an induction machine. Hence explain why an induction machine is called a generalized transformer. **(May 07, Sep, Apr 06, Nov 03)**
ii. Explain why an induction motor at no load operates at a very low power factor.

14. Explain the principle of 3-phase induction motor with the help of rotating magnetic field. **(May 07, Apr 06, 04)**

15. Explain why the rotor of polyphase induction motor can never attain synchronous speed **(May 07, Apr 06, 05)**

16. i. Does the induction motor have any similarities with the transformer ? Compare the similarities and differences between them.
ii. Show that a rotating magnetic field is produced in the air-gap, when a balanced three-phase ac supply is given to the stator of a 3-phase induction motor. Justify your claim with necessary mathematical equations. **(May 07,Apr 03)**

17. Explain the differences between sq. cage IM & Slip ring IM. **(May 07)**

18. i. A 3-□, IM operates from a supply whose frequency is 50 Hz and rotates at a speed of 1485 RPM at no load & 1350 RPM at full load. Calculate:
a. the speed at which the magnetic field of stator is rotating
b. the slip at no load & at full load.
c. the frequency of the rotor current at no load & at full load.
d. the frequency of rotor current at stand still.
ii. Explain the slip? How the slip affects the rotor frequency, emf, current & pf. **(May 07)**

19. i. A 200 HP, 2300 V, 3-□ 60 Hz, wound rotor IM has a blocked rotor voltage of 104 V. The shaft speed and slip speed when operating at rated load are 1775 RPM and 25 RPM respectively. Determine:
a. Number of poles b. Slip c. Rotor frequency d. rotor voltage at slip speed.
ii. Explain how the rotor rotates in IM? Explain how the RMF and rotor rotates in same direction. **(May 07)**

20. i. Explain the classification of induction motors based on construction of rotor. Explain the advantages

& disadvantages of each.

ii. The frequency of stator EMF is 50 Hz for an 8-pole induction motor. If the rotor frequency is 2.5 Hz, calculate the slip and the actual speed of rotor. **(May 07)**

21. The rotor of a slip ring induction motor is connected to an AC source, where as its stator winding is short circuited. If rotating magnetic field produced by rotor winding' rotates clock wise, Explain the direction in which rotor must revolve. **(May 07)**

22. Explain why an induction motor, at noload, operates at a very low power factor. **(May 07)**

23. i. Explain the terms air-gap power Pg, internal mechanical power developed Pm and shaft power Psh. How are these terms related with each other? Hence, show that
Pg: rotor ohmic loss : Pm =1:S: (1-s).

ii. A 20 Kw, 3-phase, 50Hz, 4 pole induction motor has losses at full-load slip of 0.03. Mechanical and stray load losses at full-load are 3.5% of output power. Calculate
a) Power delivered by stator to rotor
b) Electromagnetic (internal) torque at full load, and
c) Rotor ohmic losses at full load. **(May 09)**

24. i. Draw the torque-slip characteristics of a 3-phase induction motor. Explain them briefly.

ii. A 3-phase squirrel case induction motor has a rotor starting current of 6 times its full load value. The motor has a full load slip of 5%. Determine
a) the starting torque in terms of full load torque
b) the slip at which maximum torque occurs; and
c) max. torque interms of full-load torque. **(May 09)**

25. i. Explain the difference between the characteristics of ship-ring and squirrel-cage poly phase induction motors. Sketch a typical characteristic for each.

ii. A 20 kW, 6 pole, 400V, 50Hz, 3-phase induction motor has a full load ship of 0.02. If the torque, lost in mechanical (friction and windage) losses is 20 N-m, find the rotor ohmic loss, motor input and efficiency. Stator losses total 900 watts. **(May 09)**

26. i. Develop the equivalent circuit of a polyphase induction motor. Explain how this equivalent circuit is similar to the transformer equivalent circuit.

ii. A 3-phase squirrel cage induction motor has a rotor starting current of 6 times its full load value. The motor has a full load ship of 5%. Determine
a) the starting torque interms of full load torque.
b) the slip at which maximum torque occur, and
c) maximum torque interms of full load torque. **(May 09)**

27. i. What are the disadvantages of 3-phase Sq. Cage IM?

ii. A 5 kW, 400 V, 50 Hz, 4 pole IM gave the following test data:
No load test: 400 V, 350 W, 3.1 A
Blocked rotor test: 52 V, 440 W, 7.6 A.
DC resistance test: 24 V, 7.6 A (Between two terminals)
Calculate motor efficiency at rated voltage at a slip of 4 %. **(May 09)**

28. i. With neat diagram the explain Torque-Slip characteristics of IM.

ii. A 3-phase, 50 Hz, 4 pole slip ring IM gives a reading of 120 V across slip rings on open circuit, when at rest and supplied with normal supply voltage. The rotor impedance per phase is 0.3 + j1.5 ohms. Find the rotor current and torque when machine is running at 5 % slip. **(May 09)**

29. i. Explain the construction & operation of deep bar rotor IM. **(May 09)**

ii. Compare the torques developed by each cage of double cage IM. Obtain the expression for same.

30. i. Obtain the ratio of Maximum torque to Full load torque & Maximum torque to staring torque.
ii. A 4-pole, 50 Hz, 3-phase IM has rotor impedance of 0.04 + j 0.16 Ω. Calculate the value of external rotor resistance to be inserted in rotor circuit to obtain 70 % of maximum torque at starting. **(May 09, 07)**

31. Derive the torque equation of IM. From this; derive the condition for Maximum torque. Find the ratio of Maximum torque to Full load torque & Maximum torque to staring torque. **(Sep 08)**

32. i. Explain various losses taking place in IM. **(Sep 08)**
ii. A 4-pole, 3-phase, 50 Hz, IM supplies a useful torque of 160 Nm at 5 % slip. Calculate: rotor input, motor input, efficiency if friction & windage losses are 500 W and stator losses are 1000 W

33. i. A 12 pole, 3-phase, 50 HZ, IM draws 280 Amp and 110 kW under the blocked rotor test. Find the starting torque when switched on direct rated voltage & frequency supply. Assume the stator & rotor copper losses to be equal under the blocked rotor test.
ii. Why the starting current of IM is very high? Justify statement ‘Though the staring current of IM is very high, the starting torque is poor’. **(Sep 08)**

34. i. Explain term Maximum torque, Full load torque, Starting torque & No-load torque.
ii. An 8-pole, 50 Hz, 3-phase slip ring IM has effective resistance of 0.08 Ω/phase. The speed correspond to maximum torque is 650 rpm. What is the value of resistance to be inserted in rotor circuit to obtain maximum torque at starting? **(May 08, 07)**

35. A 400 V, 4 pole, 7.5 kW, 50 Hz, 3-phase, IM develops its full load torque at a slip of 4 %. The per phase circuit parameters of the machine are: r1 = 1.08 Ω, x1 = 1.41 Ω, r'_2 =? x'_2 = 1.41 Ω. Mechanical, core & stray losses may be neglected. Find: rotor resistance/ph referred to secondary, maximum torque and corresponding rotor speed. **(May 08)**

36. i. In approximate equivalent circuit of 3-phase IM, explain step by step the development of equivalent load resistance.
ii. A 440 V, 19 kW, 50 Hz, 8 pole, IM has its stator & rotor connected in star. The effective stator to rotor turn is 2.5:1. The parameters of its circuit model are: r_1 =0.4 Ω, x_1 =1.03 Ω, r_2 =0.07 Ω, x_2 =0.18 Ω, r_m =25.9 Ω, r_i = 127.4 Ω (including rotational losses) Neglect any change in mechanical losses due to change in speed, calculate the maximum added rotor resistance required for the motor to run up to the speed for a constant load torque of 300 Nm. **(May 08)**

37. i. A 4 pole, 400 V, 3-phase IM has a standstill rotor EMF of 100 V per phase. The rotor has resistance of 50 mΩ/ph and standstill reactance of 0.5 Ω/ph. Calculate the maximum torque & slip at which it occurs. Neglect stator impedance.
ii. Explain the various losses taking place in IM. Explain the effect of slip on the performance of IM. **(May 08)**

38. i. In an induction motor deduce the condition $P_2 : P_c : P_m :: 1 : 1\text{-}s : s$
ii. A 4-pole wound rotor induction motor is used as a frequency changer. The starter is connected to a 50 Hz 3-phase supply. The load is connected to the rotor slip rings. What are the possible speeds at which the rotor can supply power to this load at 25Hz? What would be the ratio of voltages at load terminals at these speeds? Assume the rotor impedance to be negligible. **(May 07, Sep, Apr 06, 05)**

39. i. A 3-phase, 400 V IM has transformation ratio of 6 (stator to rotor). The rotor has per phase resistance & reactance of 0.5 Ω & 1.5 Ω respectively. Calculate rotor current and power factor: when slip rings are short circuited and slip is 5 % and when external resistance of 1 Ω/ph is connected in rotor circuit and motor is rotating with 8 % slip. **(May 07)**

40. i. Draw and explain the phasor diagram of 3-phase induction motor.
ii. Discuss the phenomenon of crawling and cogging in an induction motor. **(May 07)**

41. A 7.5 kW, 440 V, 3-phase, star connected, 50 Hz, 4 pole Sq. cage IM$_1$ develops full$_1$ load$_2$ torque at the slip of 5 % when fed from a feeder having impedance of 1.8 +j 1.2 □/ph. Rotational, core & windage losses are to be neglected. Motor impedance data is as follows: R = 1.32 □, X = X = 1.46□, Xm = 22.7□. Determine the Maximum torque and the slip at which it will occur. Also calculate the corresponding current. **(May 07)**

42. A 6-pole, 50Hz, 3-phase induction motor running on full load develops a useful torque of 160 N-m and the rotor emf is absorbed to make 120 cycles/min. Calculate the net mechanical power developed. If the torque loss in windage and friction is l2N- m, find the copper loss in the rotor windings, the input to the motor and efficiency.

43.Explain the working of a 3 phase induction motor. Why does an induction motor never runs at synchronous speed?
A 3 phase, 50 Hz induction motor has a full load current speed of 960 rpm. Calculate the speed of rotor field with respect to the rotor structure, with respect to stator structure and with respect to stator field.

44.Describe the constructional features of both slip ring and squirrel cage induction motor. Discuss the merits of one over the other. The emf in the stator of an 8 pole induction motor has a frequency of 50 Hz and that in the rotor is 1.5Hz. At what speed the motor is running and what is the slip?

45.A 3 phase induction motor runs at almost 1000 rpm at no load and 950 rpm at full load when supplied with power from a 50Hz phase line.
a)How many poles have the motor?
b)What is the percentage slip at full load?
c)What is the corresponding speed of the rotor filed with respect to the rotor?
d)What is the corresponding frequency of the corresponding voltage?
e)What is the rotor frequency at the slip of 10%?

46.Develop the phasor diagram for a poly phase induction motor. How does it differ from phasor diagram of transformer? Find the running speed of a 6 pole induction motor working on a 50 Hz supply having 3% slip.

47.A 15kW 400V 950 rpm 3 phase 50 Hz, 6 pole cage motor with 400V applied takes full load current at standstill and develops 1.8 times the full load running torque. The full load current is 32A.
a)What voltage must be applied to produce full load torque at starting?
b)What current will this voltage produces?
c)If the voltage is applied by an auto transformer what will be the line current.
D) If the starting torque is limited to full load current by an auto transformer, what will be the starting torque at 5% of full load torque? The magnetizing current and stator impedance drops are neglected.

48.The power input to the rotor of a 3 phase 6 pole, 440V, 50 Hz induction motor is 60kW. It is observed that the rotor emf makes 90 complete cycles per minute. Calculate
a)Slip
b)Rotor speed
c)Rotor copper loss per phase
d)Mechanical power developed and
e)The rotor resistance/phase if the rotor current is 60A.[16]

49.Develop an expression for torque of an induction motor and obtain the condition for maximum torque.
A 3-phase 50Hz, 500V, 6-pole IM gives an output of 37.3kW at 955 r.p.m. the p.f is 0.86 frictional and windage losses total 1492kW; stator losses amount to 1.5kW. Determine line current, efficiency and rotor copper losses for this load.

50.Explain the following:
a)Why an induction motor cannot develop torque when running at synchronous speed?
b)Why the power factor of a lightly loaded induction motor is quite low?
c)Why in some induction motors double cages are provided?

UNIT V

Given stator losses=200W (inclusive of core loss)

1. A 4 kw, 400V, 50Hz, 3-phase, 4 pole delta connected slip ring induction motor has stator resistance of 0.36ohms per phase, rotor resistance of 0.06 ohms per phase and per phase stator to rotor turns ratio of 2. The following data pertains to the line values during light load tests:
No Load : 400V, 3.3A, $\cos\theta_0$ =0.174
Locked rotor : 210V, 16A, $\cos\theta_0$ =0.45
Draw the circle diagram and compute i) line current, powerfactor, slip, torque and efficiency at full load. **(May 09)**

2. i. What is represented by the circle diagram of an induction motor? What information can be obtained from it?

ii. Show that the diameter of current-locus circle of a polyphase induction motor is $\frac{V_1}{x_1+x_2}$, where x_1 is the per phase stator leakage reactance, x_2 is the standstill per phase rotor leakage reactance referred to stator and V_1

is A 3-phase squirrel cage induction motor has a short circuit current of 5 times the full load current. It's full load ship is 5%. Calculate the starting torque as percentage of full load torque if the motor is started by

i. direct-on-line starter
ii. star-delta starter.
iii. auto-transform starter, limiting the motor starting current to twice the full load current. Also, find the starting current to twice the full load current. Also, find the starting current drawn from the supply, in terms of motor full load current. What is the percentage auto-transformer tapping in this case.
iv. auto transformer starter limiting the supply line starting current to twice the full-load current. Find the auto-transformer tapping in this case also. **(May 09)**

4. i. Explain the procedure of no-load and blocked rotor tests on a 3-phase induction motor?
ii. Explain the procedure of drawing the circle diagram on an induction motor. What information can be drawn from the circle diagram. **(May 09)**

5. With neat diagram explain the various tests to be conducted on 3-phase IM to plot the circle diagram. **(May 09, Sep 08)**

6. i. The short circuit line current of a 6 HP IM is 3.5 times its full load current, the stator of which is arranged for star- Δ starting. The supply voltage is 400 V, full load efficiency is 82 % and full load power factor is 0.85. Calculate the line current at the instant of starting. Neglect magnetising current.
ii. Why are the adverse effects of high starting current? What are the methods by which we can reduce the starting current of IM? **(May 09)**

7. A 300 HP (223.8 kW), 3 kV, 3-phase IM has a magnetising current of 20 A at 0.1 pf and Short circuit (blocked rotor) current of 240 A at 0.25 pf. Draw the circle diagram; determine the pf at full load and maximum horse power. **(Sep 08)**

8. It is desired to install a 3-phase cage IM is restricting the maximum line current drawn from 400 V, 3-phase supply to 120 A. If the starting current is 6 times the full load current, what is the maximum

permissible full load kVA of motor when: **(Sep 08)**

i. It is directly connected to mains
ii. it is connected through an auto transformer with 65 % tapping
iii. it is designed for use with star-△ starter.

9. A 3-phase, △ connected, 32 HP, 480 V, 6-pole, 50 Hz IM gave the following test results: **(Sep 08)**
No load Test: 480 V, 10 A, +1.89 kW & -0.59 kW
Blocked rotor test: 96 V, 36 A, + 1.67 kW & -0.07 kW
All above are the line values. Input power is measured by two wattmeter method.
Plot the circle diagram and for full load find:
i. The line current
ii. The power factor
iii. Slip
iv. Torque
v. Efficiency
vi. Torque
Given that rotor copper losses are equal to stator copper losses at stand still.

10. i. Compare the speed control of 3-phase IM by rotor resistance control & variable frequency control.
ii. Two slip ring IMs having 10 & 6 poles respectively are mechanically coupled.
a. Calculate the possible speed when first motor is supplied from a 50 Hz supply line.
b. Calculate the ratio of power shared by the two motors.
c. If the smallest possible speed is to be attained independently by each machine, calculate the frequency of the voltage to be injected in the rotor circuit. **(May 08)**

11. i. A cage IM when started by means of a star-△ starter takes 180 % of full load current & develops 35 % of full load torque at starting. Calculate the starting current & torque in terms of full load torque when started by means of an auto transformer with 75 % tapping.
ii. Compare DOL starter, Star △ starter, Auto transformer starter & Rotor resistance starter with relate to the following:
a. Starting current
b. Starting torque
c. Flexibility
d. Cost & efficiency **(May 08)**

12. A 3-phase, star connected, 440 V, 4-pole, 50 Hz slip ring IM gave the following test results:
No load Test: 440 V, 9 A, PF = 0.2
Blocked rotor test: 100 V, 22 A, PF = 0.3
All above are the line values. The ratio of primary to secondary turns = 3.5, stator & rotor copper losses are equally divided in blocked rotor test. The full load current is 20 A. Plot the circle diagram and for full load find:
i. The line current, The power factor, Slip
ii. Starting torque
iii. Resistance to be inserted in series with rotor circuit for giving starting torque 200 % of full load torque. Also find current & power factor under this condition. **(May 08)**

13. A 12 pole, 3-phase, 50Hz induction motor draws 2.80A and 110Kw under the block rotor test. Find the starting torque when switched on direct to rated voltage and frequency supply. Assume the stator and rotor copper losses to be equal under the blocked rotor test. **(May 07, Apr 05)**

14. A 3-phase, star connected, 5.6 kW, 400 V, 4-pole, 50 Hz slip ring IM gave the following test results:
No load Test: 400 V, 6 A, 0.187 PF
Blocked rotor test: 100 V, 12a, 720□

All above are the line values. The ratio of primary to secondary turns = 2.62, stator resistance/ph is 0.67 and that of the rotor is 0.185 /ph. Plot the circle diagram and for full load find:

a. The line current b.The power factor c. Slip

d. Maximum Torque / Full load torque. e. Maximum Power **(May 07)**

15. A 12 pole, 3-phase, 50Hz induction motor draws 2.80A and 110kW under the block rotor test. Find the starting torque when switched on direct to rated voltage and frequency supply. Assume the stator and rotor copper losses to be equal under the blocked rotor test. **(May 07)**

16. With neat diagram explain the various tests to be conducted on 3-phase IM to plot the circle diagram. **(May08, 07)**

17. A 400V, 3-phase, 50 Hz star connected squirrel cage induction motor has a total impedance of 11.5 ohm/phase at stand still if the starting current is to be limited to 10A what should be voltage applied and corresponding starting torque in terms of full load torque if the full load current is 4A and full load slip is 0.05. **(May 07)**

18. With the help of rotor equivalent circuit of an induction motor, show that the power transferred magnetically from stator to rotor is given by $\frac{I_2^2 r_2}{s}$ per phase. **(May 07)**

19. i. Explain the no load and blocked rotor tests on 3-phase induction motor. **(Sep 06, Nov 04)**
 ii. Explain how the equivalent circuit parameters 3-phase induction motors are obtained from the tests.

20. Discuss briefly the various methods of speed control of 3-phase induction motors. **(May 09)**

21. i. Explain the pole-changing methods of speed control of 3-phase induction motor?
 ii. Discuss the working of induction generator. Mention its advantages and disadvantages. **(May 09)**

22. i. Explain any two methods of speed control of 3-phase induction motor.
 ii. Explain the principle of operation of induction generator. **(May 09)**

23. i. Explain the principle of speed control of a 3-phase induction motor by
 a) adding resistance b) injecting voltage.
 Draw the corresponding torque-speed characteristics and discuss the applications and limitations of these methods.
 ii. State the applications of induction generator. **(May 09)**

24. i. Explain the rotor emf injection method of speed control of IM.
 ii. A 10 pole, 50 Hz, wound rotor IM has a rotor resistance of 1.03 ohms/ph and runs at 560 rpm at full load. Calculate the additional resistance per phase to be inserted in the rotor circuit to lower the speed to 450 rpm, if the torque remains constant. **(May 09)**

25. i. A 4-pole, 3-phase, 50 Hz, slip ring IM has its rotor resistance of 0.3 ohms/ph and full load speed of 1425 rpm. Calculate the external resistance per phase required to be added in rotor circuit to decrease the speed to 1230 rpm. The torque remains the same as before.
 ii. What is the need of speed control of motors? How speed of 3-phase IMs can be varied. List out all the methods of speed control. **(May 09)**

26. Explain all the modes of operation of induction machine. Plot the neat characteristics. **(May 09, 08, Sep 08)**

27. i. Compare the speed control of 3-phase IM by rotor resistance control & variable frequency control. ii. Two slip ring IMs having 10 & 6 poles respectively are mechanically coupled.
 a. Calculate the possible speed when first motor is supplied from a 50 Hz supply line.

b. Calculate the ratio of power shared by the two motors.

c. If the smallest possible speed is to be attained independently by each machine, calculate the frequency of the voltage to be injected in the rotor circuit. **(May 09, 07)**

28. i. With neat diagram explain the operation of 3-phase IM as induction generator. **(May 08)**

ii. Two motors A & B with 10 poles & 12 poles respectively are cascaded. The motor A is connected to a 50 Hz supply. Find

a. Speed of the set

b. The electrical power transferred to the motor B when the input to the motor A is 60 kW. Neglect losses.

29. i. Explain the speed control of IM by rotor resistance control method. How this method of speed control is different from stator side speed control methods.

ii. A 4 pole, 50 Hz, wound rotor IM has a rotor resistance of 0.56 /ph and runs at 1430 rpm at full load. Calculate the additional resistance per phase to be inserted in the rotor circuit to lower the speed to 1200 rpm, if the torque remains constant. **(May 08)**

30.A four pole 50 Hz 3-phase induction motor develops a maximum torque of 110 Nm at 1360 rpm. The resistance of star connected rotor is 0.25 ohm/phase. Calculate the value of resistance that must be inserted in series with each rotor phase that produces a starting torque equal to half maximum torque.

31. A 400V 3-phase, 8pole, 50Hz star connected induction motor gave following results:
No load test (line values): 400V, 10A, p.f = 0.2
Blocked rotor test (lines values): 160v, 30A, p.f = 0.35
If, at full load and rated voltage, the power factor is at its maximum, then calculate full load current, power factor, torque N-m speed power output, stator and rotor ohmic losses are equal.

32.Draw the circle diagram for a 200V, 3.667KW 3 phase star connected induction motor from the following data No load: 200V, 5.0 A, 350W Locked rotor: 100V, 26A, 1700W From the circle diagram determine a)No load current, full load power factor b)Speed and torque.

33.Calculate the relative values of starting currents and starting torques of a 3-phase squirrel-cage induction motor, when it is started by a)direct-on-line starter, b)star-delta starter and c)auto-transformer starter with 70% tapping.

34.What happens if the emf is injected to the rotor circuit of induction motor. Two 50Hz 3 phase induction motors having 4 poles and 6 poles respectively are cumulatively cascaded. The 6 pole motor being connected to the main supply. Determine the frequency of the rotor currents and slips referred to each stator field if the set has slip of 2%.

35.Explain the principle of operation of induction generator. A 3 phase, 6 pole 50Hz induction motor when fully loaded, runs with a slip of 3%. Find the value of resistance necessary in series per phase of the rotor to reduce the speed by 10%. Assume that the resistance of the rotor per phase is 0.2 ohm.

36.Explain the effect of number of poles on speed control of induction motor. Two 50Hz, 3 phase induction motors having six and four poles respectively are cumulatively cascaded, the 6 pole motor being connected to the main supply. Determine the frequencies of the rotor currents and the slips refereed to each stator field if the set has a slip of 2%.

37.Explain the effect of number of poles and applied voltage on speed control of induction motor. A 6 pole, 50 Hz, 3 phase induction motor is running at 3 percent slip when delivering full load torque. It has standstill rotor resistance of 0.2 ohm and reactance of 0.4 ohm per phase. Calculate the speed of the motor if an additional resistance of 0.6 ohm per phase is inserted in the rotor circuit. The full load torque remains constant.

Assignment Questions

Unit – I

1. Describe the operation of a single-phase transformer, explaining clearly the functions of the different parts. Why are the cores laminated?

2. Explain briefly the action of a transformer and show that the voltage ratio of the primary and secondary windings is the same as their turns ratio.

3. Derive an expression for the induced e.m.f of a transformer. A 3000 / 200 V, 50 Hz, single-phase transformer is built on a core having an effective cross-sectional area of 150 cm^2 and has 80 turns in the low-voltage winding. Calculate (a) the value of the maximum flux density in the core and (b) the number of turns in the high-voltage winding.

4. A 3300/230 V, 50 Hz, single-phase transformer is to be worked at a maximum flux density of 12 T in the core. The effective cross-sectional area of the core is 150 cm^2. Calculate the suitable values of primary and secondary turns.

5. A 100 kVA, 6600/440 V, 50 Hz single-phase transformer has 80 turns on the low-voltage winding. Calculate (a) maximum flux in the core, (b) the number of turns on the high-voltge winding, (c) the current in each winding.

Unit II

1. With the help of Phasor diagram explain the phenomenon of negative voltage regulation of a transformer.

2. State the various losses which take place in a transformer. On what factors do they depend? Explain the steps taken to minimize these losses.

3. What is all-day efficiency of a transformer? How does it differ from ordinary efficiency ?

4. State and prove the condition for maximum efficiency of a transformer?

5. A 150 kVA transformer has a total loss of 4.5 kW on short circuit and a total loss 1800 W. Calculate the efficiency at full load, 0.8 power factor lagging.

Unit – III

1. A 500 kVA transformer has a total loss of 4.5 kW on short circuit and a total loss of 2.5 kW on open circuit. Determine the efficiency at 0.7 power factor.

2. Calculate the voltage regulation of 0.8 lagging power factor for a transformer which has an equivalent resistance of 2 per cent and an equivalent resistance of 2 per cent and an equivalent leakage reactance of 4 per cent.

3. Describe the back-to-back for determining the regulation and efficiency of a pair of similar transformers, giving the circuit diagram.

4. Two similar 200 kVA, 1-phase transformers gave the following results when tested by back-to-back method: W_1 in the supply line, 4 kW ; W_2 in the primary series circuit, when full load current circulated through the secondaries, 6 kW. Calculate the efficiency of each transformer.

Unit – IV

1. Why are tap changing transformers required ? Explain the operation of no load tap changing transformers ?
2 A 3-□ transformer has its primary connected in □ and its secondary connected in Y. It has equivalent Resistance and reactance of 1% and 6% respectively. Primary applied voltage is 6600V. What must be ratio of transformation in order that it will deliver 4800V at full load current and 0.8 p.f. lag ?
3. Draw the diagrams of the following transformer connections.
   a. Scott connection b. Zig-Zag
   c. V-V d. T-connection (3-phase to 3-phase)
4. Describe the principle of regulating the voltage with the help of tap-changers.

5. Two similar 250kVA similar transformers gave the following results when tested by back-to-back method: Mains wattmeter, W_1 = 5.0 KW, Primary series circuit wattmeter, W_2 = 7.5KW (at full load current). Find out the individual transformer efficiencies at 75% full load and 0.8 power factor lead.

Unit – V

1. Explain the differences between sq. cage IM & Slip ring IM.

2. Draw and explain the phasor diagram of a 3 phase induction motor.

3. Explain with the help of suitable diagrams, how rotating magnetic field is produced in a 3-phase induction motor.

4. The frequency of stator EMF is 50 Hz for an 8-pole induction motor. If the rotor frequency is 2.5 Hz, calculate the slip and the actual speed of rotor.

5. A 200 HP, 2300 V, 3-□ 60 Hz, wound rotor IM has a blocked rotor voltage of 104 V. The shaft speed and slip speed when operating at rated load are 1775 RPM and 25 RPM respectively. Determine:
   a. Number of poles b. Slip c. Rotor frequency d. rotor voltage at slip speed.

Unit-VI

1. Describe the methods to reduce the effect of crawling and cogging in an induction motor.

2. an induction motors have a full load slip of 0.05 or less. The measured speed of a 60 Hz motor at rated load is 575 rpm.
(i) How many poles does the motor have and what is its synchronous speed?
(ii) What is the full-load slip?
(iii) if no load slip is 0.01, what is the percentage speed regulation?
(iv) what is the frequency of rotor voltage at no-load, full-load and the instant of starting ?

4. Sketch the torque-slip characteristics of an induction motor working at rated voltage and frequency. Explain and draw these characteristics with respect to the normal one, if the applied voltage and frequency are reduced to half.

5. For a 3-phase induction motor, the rotor ohmic loss at maximum torque is 16 times that at full load torque. The slip at full load torque is 0.03. If stator resistance and rotational losses are neglected, then calculate the starting torque in terms of full load torque.

6.. i. Derive the expression for torque in an induction motor
ii. Derive the condition for maximum torque.

iii. A 3-phase induction motor has a rotor resistance of 0.5 per phase and rotor standstill leakage reactance of 5 per phase. If the ratio of maximum starting torque to full load torque is 2, find the ratio of actual starting torque to full-load torque for direct starting. Neglect stator impedance and rotational losses.

Unit – VII

1. With neat diagram explain the various tests to be conducted on 3-phase IM to plot the circle diagram.
2. A 10kW, 415V, 4-pole, 3-phase star connected induction motor gave the following test results.
No load test: 415V, 8A, 1200 watt
Blocked rotor test : 200V, 45A, 7000 watt
Stator and rotor ohmic losses are equal at stand still. Draw circle diagram and find efficiency and speed at half full load.

3. Explain the starting method of wound rotor induction motor and its advantages.
4. Calculate the value of resistance elements of 5-step starter for 3-phase 400V wound rotor induction motor. The full load slip is 3%, rotor resistance per phase is =0.015. If (i) the starting current is limited to full load current. (ii) the starting current is limited to 1.5 times full load current.

5. Explain the design of n- step wound rotor starter.
Design 4-section 5-stud starter for a 3-phase slip ring induction motor. The full load slip is 2% and rotor resistance per phase 0.03 ohms.
a. If the starting current is limited to full load current.
b. Derive the formulae used.

Unit VIII

1. Explain the speed control of 3-phase IM using 'rotor emf injection method'.
2. A 2-pole, 3-phase, 50 Hz, slip ring IM has its rotor resistance of 0.2□/ph and full load speed of 2900 rpm. Calculate the external resistance per phase required to be added in rotor circuit to decrease the speed to 2500 rpm. The torque remains the same as before.

3. Explain the principle of consequent poles method of speed control of 3-phase IM. Explain the advantages of this method above other methods.
4. A 4-pole, 3-phase, 50 Hz, slip ring IM has its rotor resistance of 0.25 Ω/ph and full load speed of 1425 rpm. Calculate the external resistance per phase required to be added in rotor circuit to decrease the speed to 1275 rpm. The torque remains the same as before.
5. Explain with neat sketch the star-delta starter. Obtain the expression for starting current and torque.

   A 3-phase, 400V, distribution circuit is designed to supply 1200A. Assuming that three phase squirrel cage induction motor has full load efficiency of 0.85 power factor 0.8 starting current is 5 times the rated current what is the maximum possible KW of motor if it is designed to use star-delta starter.