ELECTRICAL MACHINES

ENEE 254

Lecture : 4 **Year :II**
Tutorial : 1 **Part : II**
Practical : 3/2

Course Objectives:

The objective of this course is to provide students with a comprehensive understanding of various aspects in the field of electrical machine-like constructional details, operating principle, performance characteristics and control of electric machines such as transformers, DC machines and AC machines

1 Magnetism and Magnetic Circuits (4 hours)

1.1 Review of magnetic field and electromagnet
1.2 Magnetic hysteresis: B-H curve and B-H loop with DC excitation
1.3 Magnetic hysteresis with AC excitation
1.4 Magnetic circuit: Series and parallel circuit with air gaps
1.5 Faraday's laws of electromagnetic induction: Statically induced EMF and dynamically induced EMF
1.6 Force on current carrying conductor

2 Transformer (10 hours)

2.1 Transformer, its different parts and their functions
2.2 Transformer types: Core and shell types
2.3 Working principle and EMF equation
2.4 Ideal and practical transformer
2.5 No load and load operation, equivalent circuits and phasor diagrams
2.6 Transformation of impedances, voltage regulation
2.7 Losses and efficiency of single-phase transformer, all day efficiency
2.8 Tests: Polarity test, open circuit test, short circuit test
2.9 Instrument transformers: Potential transformer (PT) and current transformer (CT) and their applications
2.10 Auto transformer: Construction, working principle and Copper saving
2.11 Three phase transformers: Introduction, types of connections
2.12 Introduction of three winding transformer

3 DC Generator (5 hours)

3.1 Introduction of DC machine and its construction
3.2 Armature windings (Lap and wave winding)

3.3 Working principle, commutator action, EMF equation
3.4 Method of excitation: Separately and self-excited, types of DC generator
3.5 Characteristics of series, shunt and compound generator, and applications
3.6 Losses and efficiency

4 DC Motors (5 hours)

4.1 Working principle, back EMF and torque equation
4.2 Types of DC motor, characteristics of DC motors and their applications
4.3 Losses and efficiency
4.4 Starting of DC motors: 4-point starters for shunt motor
4.5 Speed control of DC motor: Series, shunt, and reversing the direction of rotation

5 Three-Phase Induction Machines (12 hours)

5.1 Three phase induction motor
- 5.1.1 Introduction, constructional details, rotor types- squirrel cage and phase wound
- 5.1.2 Operating principle: Rotating magnetic field, synchronous speed, slip
- 5.1.3 Analysis of standstill condition: Equivalent circuit, starting torque equation
- 5.1.4 Analysis of running condition: Equivalent circuit, running torque equation
- 5.1.5 Torque-slip (T-S) characteristics and effect of rotor resistance
- 5.1.6 Power stages in three phase induction motor, losses and efficiency
- 5.1.7 Methods of starting: Direct on-line method, auto-transformer starter, star-delta starter, rotor rheostat starter
- 5.1.8 Speed control methods for three phase induction motor: Primary voltage control method, frequency control method, and rotor rheostat method

5.2 Three phase induction generator
- 5.2.1 Operating principle, T-S characteristic for generating mode, requirements of excitation capacitor

6 Three Phase Synchronous Machine (12 hours)

6.1 Three phase synchronous generator
- 6.1.1 Working principle, necessity of constant speed operation, speed governor
- 6.1.2 EMF equation, distribution factor, pitch factor
- 6.1.3 Operation at no-load and Load conditions
- 6.1.4 Armature reaction and its affects with resistive load, inductive load and capacitive load, phasor diagrams

6.1.5 Concept of synchronous reactance and impedance.
6.1.6 Parallel operation of two synchronous generators
6.1.7 Losses and efficiency

6.2 Three phase synchronous motor
6.2.1 Operating principle, synchronous speed operation and torque production
6.2.2 Starting methods
6.2.3 No-load and load operation: Power angle (δ), phasor diagram
6.2.4 Effect of excitation on power factor of motor, V and inverted V curves
6.2.5 Hunting in synchronous motor
6.2.6 Losses and efficiency

7 Single Phase AC Motor and Special Purpose Motors (12 hours)

7.1 Single phase induction motor, construction, operating principle, double revolving field theory,
7.2 Self-starting split phase induction motors
7.2.1 Capacitor start motor, its operating principle and characteristic curve
7.2.2 Capacitor start and run motor, its operating principle and characteristic curve
7.3 Permanent magnet synchronous motor
7.3.1 Construction and principle of operation
7.3.2 EMF equation of Brushless BLPM sine wave motor
7.3.3 Torque equation of BLPM sine wave motor
7.4 Permanent magnet brushless dc motor
7.4.1 Constructional feature of PMBLDC motors
7.4.2 Comparison of brushless dc motor relative to induction motor drives
7.4.3 Principle of operation of brushless pm dc motor
7.4.4 Classification of BLPM dc motor
7.4.5 EMF and Torque equation of BLPM
7.5 Special purpose motor: Universal, stepper, servo, switch reluctance motors

Tutorial (15 hours)

1. Problems on series and parallel magnetic circuit
2. Problems on no load, load operation, open circuit test, short circuit test, evaluation of equivalent circuit parameter, voltage regulation, efficiency of a single-phase transformer
3. Problems on EMF and efficiency calculation for different types generator
4. Problems on back EMF, speed control and efficiency for shunt and series motors
5. Problems on slip, starting current, load current, starting torque, maximum torque, external resistance, mechanical power developed. rotor efficiency and overall efficiency of three phase induction motor
6. Problems on synchronous generator and synchronous motor
7. Problems on single-phase induction motors, self-starting methods

Practical **(22.5 hours)**

1. Magnetic circuits: Draw B-H curve for two different samples of iron core and compare their relative permeabilities
2. Two winding transformers: Perform turn ratio test, open circuit (OC) and short circuit (SC) test
3. DC generator: Draw open circuit characteristic (OCC) of a DC shunt generator and calculate maximum voltage built up, critical resistance, critical speed of the machine and load characteristic of shunt generator
4. DC motor: Perform speed control of DC Shunt motor by armature control method and field control method and draw Torque-Speed characteristic curve of DC shunt motor
5. Three phase Induction motor: Draw torque-slip characteristics of three phase induction motor and observe the effect of rotor resistance on torque-speed characteristics
6. To study no-load characteristic and load characteristic of 3-phase synchronous generator with resistive load, inductive load and capacitive load.

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	4	4
2	10	10
3	5	5
4	5	5
5	12	12
6	12	12
7	12	12
Total	**60**	**60**

* There may be minor deviation in marks distribution.

Reference

1. Nagrath, I. J., Kothari, D.P. (2017). Electric Machines (5th Edition). McGraw-Hill.
2. Chapman J., S. (2004). Electric machinery fundamentals. McGraw-Hill.
3. Guru, B. S., Hiziroglu, H. R. (2001). Electric machinery and transformers (Vol. 726). Oxford University Press.
4. Bimbhra, P. S. (2010). Electrical machinery. Khanna Publishers.
5. Ghosh, S. (2012). Electrical machines. Pearson Education India.
6. Bakshi, U. A., and Bakshi, M. V. (2020). Electrical Machines-I. Technical Publications