Title: Electrical Machines

Code Number: EE2203

Credit Hours: 3 (3+1)

Prerequisites: EE1103 Linear Circuit Analysis, NS1106 Applied Physics

Semester: 4th

Course Objectives

The course will enable students to:

1. Develop the concepts of magnetism, magnetic circuits and transformer action
2. Investigate the construction and operation of AC machines for power generation and industrial loads
3. Examine DC machines for DC power generation and DC loads in context of non-conventional power situation
4. Investigate the behavior of electric machines in a hardware-based setup

Contents

Unit 1: Introduction to Electrical Machinery Principles

1. Introduction to magnetic field and circuits
2. Faraday's and Lenz's law
3. Magnetization curves
4. Characteristics of hard and soft magnetic materials
5. Losses.

Unit 2: Transformers Equivalent circuit and phasor diagrams

1. Equivalent circuit of practical transformers
2. Approximate equivalent circuit, and equivalent circuit referred to primary and secondary sides
3. Phasor diagram of ideal and practical transformer without load
4. Phasor diagram of secondary side of practical transformer with unity Lagging and leading power factor
5. Complete phasor diagram of practical transformer.

Unit 3: Transformer Tests

1. Open circuit Test and calculations of magnetizing branch parameters
2. Short circuit test and calculation of impedance
3. Efficiency calculations
4. Calculation of maximum efficiency
5. Output for maximum efficiency

Unit 4: Transformer Taps and Voltage regulation

1. Transformer taps
2. Voltage regulation
3. Reasons of voltage drop
4. Voltage regulation under different load conditions
5. Transformer phasor diagrams.

Unit 5: DC Generator

1. Types of DC generators
2. Equivalent circuit and characteristic equations
3. Separately excited generator
4. Shunt generator
5. Voltage build-up phenomenon
6. Series generator
7. Compounded generator and its type; under compounded
8. Over compounded and flat compounded generator
9. Voltage control in all generators and terminal characteristics of all the generators

Unit 6: DC Motors

1. Working principle, construction, and operation
2. Important parts of DC motor
3. Different types of DC motors
4. Equivalent circuits and terminal equations
5. Magnetic characteristics of DC machines
6. Terminal characteristics of separately excited and shunt type DC motor.
7. Construction and working of stepper motor
8. Brushless DC motor and switched reluctance motor.

Unit 7: DC series motor

1. Expression for torque, applications, terminal characteristics
2. Six methods for speed control

Unit 8: Armature Reaction

1. Concept of magnetic and magnetic neutral axis
2. Placement of carbon brushes
3. Armature reaction and its causes
4. Components of armature reaction
5. Effects of armature reaction
6. Remedies for armature reaction
7. Compensating winding, flux enhancement and brush shifting

Unit 9: Commutation:

1. Commutation process
2. Commutation time
3. Ideal commutation
4. Poor commutation
5. Effects of poor commutation
6. Practical difficulties
7. Ldi/dt effect, interpoles
8. Function of interpoles.

Unit 10: Tests and Losses:

1. Different types of tests
2. Losses and their formulation
3. Power flow diagram of motor and generator
4. Calculation of maximum efficiency
5. Calculation of losses at different loads

Unit 11: Design of Armature Winding:

1. Pole pitch, coil pitch, front pitch, commutator pitch
2. Multiplex winding, slap winding, wave winding, design examples of lap winding
3. Developed diagram, sequence diagram, parallel path diagram, characteristics of lap winding, derivation of induced EMF.

Unit 12: Introduction to AC Machines

1. Introduction to single phase, two phase and three phase systems.
2. Waveforms and equations, phasor and polar representation, balanced and unbalanced poly phase systems.
3. Types of AC motors: Main parts, Stator windings, concentrated winding, distributed winding, full pitched winding, fractional pitched winding, pole formation in AC machines, revolving magnetic field in three phase machines.
4. Nature of magnetic field, properties of DC
5. Single phase, two phase and three phase fields, phase sequence
6. Reversal of magnetic field in three phase machines
7. Speed of revolving magnetic field, conditions to produce RMF
8. Phase splitting in single phase machines.
9. Analytical proof of revolving magnetic field and basic mathematical expression for machines.

Unit 13: Induction motor and Hysteresis motor:

1. Construction, working and principle of Induction motor
2. Development of induced torque in induction motor
3. Types of induction motor, squirrel cage and slip ring induction motor and their merits,
4. Demerits and comparison, concept of rotor slip and its expression
5. Concept of rotor frequency and its relationship with slip
6. Equivalent circuit of induction motor
7. Rotor circuit and slip effects
8. Final equivalent circuit.
9. Working and construction of hysteresis motor

Unit 14: Power and Torque Calculations:

1. Power flow diagram of induction motor
2. Calculation of different losses in an induction motor.
3. Modification of equivalent circuit including Rconv
4. The venin voltage and impedance calculation
5. Calculation of current in rotor circuit
6. Expression of induced torque
7. Torque speed characteristics, variation of torque speed characteristics with rotor resistance and stator frequency.

Unit 15: Speed Control of Induction motor

1. Polle changing method
2. Line frequency method
3. Voltage control method
4. V/f control for controlling the speed
5. Rotor resistance control method and torque speed characteristics for each method
6. Load torque curves.

Unit 16: Tests on Induction motor

1. No load test

2. Blocked rotor test
3. Resistance test and calculation of R1, R2, Xm, X1 and X2 using the data of tests.

Unit 17: Synchronous Generator

1. Basic principle and working
2. Different types of prime movers
3. Salient pole and cylindrical rotors and their comparison
4. Brushless exciters
5. Pilot exciters
6. Application of synchronous generators
7. Synchronous speed expression
8. DC excitation and use of permanent magnets.

Unit 18: Control of a synchronous generator

1. Throttle, control of active power
2. Power frequency characteristics
3. Modes of operation of synchronous generator
4. Working alone, working in parallel with same SG, and connected to infinite bus bar, house diagram and sharing of power
5. Effect of excitation keeping throttle constant
6. Effect of throttle keeping excitation constant
7. Effect of throttle keeping excitation and power factor constant.

Unit 19: Salient pole synchronous generator

1. q and d axis and reactance and their calculations
2. Phasor diagram of salient pole machines
3. Derivation of power and torque expressions
4. Comparison of cylindrical and salient pole synchronous generator
5. Calculation of equivalent circuit parameters and synchronization of alternator with infinite bus bar.

Lab Work Outline:

In this lab, students will explore electrical machinery through hands-on hardware experiments. They will test DC motors and generators, AC motors and generators, transformers, and induction motors, focusing on key performance parameters such as speed, power, torque, and efficiency. Experiments will include open circuit and short circuit tests on transformers, voltage regulation, and load tests on motors and generators. This practical approach provides a thorough understanding of electrical machinery principles and real-world applications, preparing students for engineering challenges in the field.

Teaching-Learning Strategies:

The pedagogical approach to this course relies on face-to-face teaching in a university classroom environment. The lectures are delivered using multimedia support and on white board. Students are engaged and encouraged to solve real world problems using computer-aided tools.

Assignments/Types and Number with calendar:

A minimum of four assignments to be submitted before the written exams for each term.

Assessment and Examinations:

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	It takes place at the mid-point of the semester.
2.	Sessional Assessment	25%	It is continuous assessment. It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Recommended Books:

1. Electric Machinery Fundamental, Latest Edition, Stephen J. Chapman, McGraw-Hill International
2. Fitzgerald, Kingsley and Umans, "Electric Machinery", McGraw-Hill. (Latest Edition)
3. Hindmarsh, "Electrical Machines", McGraw-Hill. (Latest Edition)
4. Theodore Wildi "Electrical Machines, Drives, and Power Systems
5. B.L.Theraja, “Electrical Technology” (Latest Edition)