

# **ELECTRICAL MACHINE I**

## **ENEE 202**

**Lecture** : 3  
**Tutorial** : 1  
**Practical** : 3/2

**Year : II**  
**Part : I**

### **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 generators, DC motors and three phase induction 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 (14 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 Mutual inductance and coupled circuit model
- 2.6 No load and load operation, equivalent circuits and phasor diagrams
- 2.7 Transformation of impedances, voltage regulation
- 2.8 Capacity of transformers
- 2.9 Exciting current harmonics
- 2.10 Transformer inrush current
- 2.11 Losses and efficiency of 1-phase transformer, all day efficiency
- 2.12 Tests: Polarity test, open circuit test, short circuit test, Sumpner's test
- 2.13 Instrument transformers: Potential transformer (PT) and current transformer (CT) and their applications
- 2.14 Auto transformer: Construction, working principle and Cu saving
- 2.15 Three phase transformers: Introduction, types of connections, Scott-T connection

- 2.16 Introduction of three winding transformer
- 2.17 Parallel operation of transformer: 1-phase and 3-phase
- 2.18 Introduction of three winding transformer
- 2.19 Parallel operation of transformer: 1-phase and 3-phase

**3 DC Generator (8 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 Voltage build up process
- 3.7 Armature reaction
- 3.8 Commutation: Interpoles and compensating windings
- 3.9 Losses, efficiency and voltage regulation

**4 DC Motors (7 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: 3 point and 4 point starters for shunt motor
- 4.5 Speed control of DC motor: Series, shunt, and reversing the direction of rotation
- 4.6 Testing of DC machine: Retardation test and Swinburne's test for shunt motor

**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 characteristics and effect of rotor resistance
  - 5.1.6 Power stages in three phase induction motor, losses and efficiency
  - 5.1.7 Testing of three phase induction motor: No-load test and Block rotor test

- 5.1.8 Methods of starting: Direct on-line method, primary resistor method, auto-transformer starter, star-delta starter, rotor rheostat starter
- 5.1.9 Speed control methods for three phase induction motor: Primary voltage control method, frequency control method, Cascade connection method and rotor rheostat method
- 5.2 Three phase induction generator
  - 5.2.1 Induction generator: Operating principle, T-S characteristic for generating mode, requirements of excitation capacitor, voltage build-up process
  - 5.2.2 Operation: Isolated and grid connected

**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

**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, determine regulation and efficiency at full load and examine exciting current waveform and harmonics
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 generator
5. Three phase Induction motor: Perform the no-load test and blocked rotor test of three phase induction motor, draw torque-slip characteristics of three phase induction motor and observe the effect of rotor resistance on torque-speed characteristics

## 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	6
2	14	18
3	8	12
4	7	9
5	12	15
<b>Total</b>	<b>45</b>	<b>60</b>

\* There may be minor deviation in marks distribution.

## References

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., Bakshi, M. V. (2020). Electrical Machines-I. Technical Publications.