GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering

Level: Diploma

Branch: Electrical Engineering / Renewable Energy

Subject Code: DI04000321

Subject Name: Electrical Machines – II

w. e. f. Academic Year:	2025-26
Semester:	4th
Category of the Course:	PCC

Prerequisite:	Electrical Engineering Fundamentals, Electric & Magnetic Circuits and Electromagnetism
Rationale:	This syllabus is designed to provide diploma students with a comprehensive understanding of core electrical machines widely used in industry, power systems and commercial applications. It builds foundational knowledge in the construction, working principles, performance characteristics and control methods of single-phase and three-phase induction motors and synchronous machines. Emphasis on energy-efficient designs and modern control techniques prepares students to meet current industrial standards and sustainability goals. Practical exposure through tests, maintenance, and troubleshooting equips them with skills to ensure reliable operation and enhance machine performance. This prepares students for technical roles requiring maintenance, repair, and optimization of electrical machines within evolving energy and industrial landscapes.

Course Outcome:

After Completion of the Course, Student will able to:

CO No	Course Outcomes	RBT Level
01	Understand the construction, working and starting methods of single-phase induction motors and select appropriate motors for various applications.	A
02	Analyze the construction, working, performance and control of three-phase induction motors.	A
03	Analyze, evaluate, and apply the principles, characteristics, control methods and modern advancements of three-phase synchronous machines for efficient power generation and utilization.	A

**Revised Bloom's Taxonomy (RBT)*

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA(M)	PA(I)	ESE(V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Single Phase Induction Motors** Contents: • Necessity of Single-Phase Induction Motor • Double Field Revolving Theory • Self-Starting Techniques (Phase Splitting, Shaded Pole, Reluctance) • Construction and Working Principle, Torque-Speed Characteristics • Types of Single-Phase Induction Motors: Capacitor Start-Induction Run, Capacitor Start-Capacitor Run, Shaded Pole Motor, Repulsion Type Motor, Universal Motor • Motor Selection for Different Applications • Maintenance of Single-Phase Induction Motors	07	16 %
2.	**Three Phase Induction Motors** Contents: • Classification of Three Phase AC Machines • Construction of Squirrel Cage and Slip Ring Induction Motors • Rotating Magnetic Field and Synchronous Speed • Working Principle and Comparison (Squirrel Cage vs. Slip Ring) • Rotor Behaviour: Speed, Slip, Frequency, Power Factor (Standstill & Running) • Slip Measurement Techniques	20	44 %

	• Torque Analysis: Starting, Full Load, Maximum Torque & Ratios • Torque-Slip Characteristics • Losses and Power Stages in Induction Motor • Necessity and Types of Starters (Stator Resistance, DOL, Autotransformer, Star-Delta, Rotor Resistance, Soft Starters) • Speed Control Methods: Stator Voltage, Pole Changing, Rotor Resistance, VVVF • Induction Motor as Transformer (Phasor Diagram) • Four Quadrant Operation & Power Flow • Motor Selection based on Load Requirements • Different Standards and Specifications of Three-Phase Induction Motors (IS, IEC, NEMA, Efficiency Classes, Frame and Mounting Standards) • Maintenance of Three Phase Induction Motors		
3.	**Three Phase Synchronous Machines** Contents: • Constructional Details of Three Phase Synchronous Machines • Principle of Operation of Three Phase Synchronous Motors • Load Angle Significance • Torque Characteristics (Starting, Running, Pull-in, Pull-out) • V-Curves and Inverted V-Curves • Methods of Starting Synchronous Motors • Hunting and Phase Swinging • Applications and Power Factor Improvement • Working Principle of Alternators • Types of Alternators and Brief Comparison (Turbo, Hydro) • Speed and Frequency Relation • Armature Windings: Short Pitch & Distribution Factor • Brushless Excitation System • E.M.F. Equation of Alternator • Synchronous Reactance and Armature Reaction • Voltage Regulation Methods (Direct Loading, Synchronous Impedance)	18	40 %

	• Synchronisation of Alternators: Definition, Necessity, and Conditions • Introduction of various Standards and Specifications of Three-Phase Synchronous Machines (IS, IEC, NEMA, Efficiency Classes, Frame, and Mounting Standards)		
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks(in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
25 %	**35 %**	**40 %**	**-**	**-**	**-**

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1.	Theraja B. L., "Electrical Technology Vol-II (AC and DC machines)", S. Chand and Co. Ltd., New Delhi, ISBN: 9788121924375.
2.	Gupta J. B., "Theory & Performance of Electrical Machine", S-K-Kataria, ISBN-13: 978-9350142776
3.	Dr. P. S. Bimbhra, Electrical Machinery, Khanna Publications, ISBN: 978-9389139105.
4.	Kothari D. P. and Nagrath, I. J., "Electrical Machines", McGraw Hill Education. New Delhi, ISBN: 9780070699670
5.	Ashfaq Husain, Electric Machines, Dhanpat Rai & Co. (P) Ltd., ISBN: 978-8177001662.
6.	Mehta V. K. and Mehta, Rohit, "Principles of Electrical Machines", S. Chand and Co. Ltd., New Delhi, ISBN: 9788121930888.
7.	Mittle V. N. and Mittle, Arvind., "Basic Electrical Engineering", McGraw Hill Education, New Delhi, ISBN: 9780070593572.
8.	Bhattacharya S. K., "Electrical Machines", McGraw Hill Education, New Delhi, ISBN: 9789332902855.

(b) Learning Websites & Web-Portals:

Sr. No.	Web-Link of Websites / Web-Portal	Description
1.	https://www.youtube.com/watch?v=exfUnnxnGEw&list=PLbRMhDVUMngcDrGXlt-hX-ekpldUlC2b6	NPTEL Course on Electrical Machines - II NOC Jan 2019: Electrical Machines - II NPTEL IIT Kharagpur
2.	https://www.electrical4u.com/electrical-engineering-articles/electric-motor/	Electric Motor - A free site with clear articles on induction motors, synchronous machines
3.	https://www.youtube.com/playlist?list=PLqQE5uI_2_7k0601t2dt_3lHKqTjZpd4p	Single Phase Induction Motors
4.	https://www.youtube.com/playlist?list=PLqQE5uI_2_7nMuEfkgX358-sJlI3jpJG2	Three Phase Induction Motors
5.	https://www.youtube.com/playlist?list=PLqQE5uI_2_7k2QDlpPuxKQb5CxJLtNdGT	Three Phase Synchronous Motors
6.	https://www.youtube.com/playlist?list=PLqQE5uI_2_7mzaJgqV25wNghzlbAljAct	Alternators
7.	https://electrical-engineering-portal.com/category/electrical-machines	Electrical-Engineering Portal (EEP) - Technical articles on electrical machines - Good for deeper articles, case studies, maintenance practices
8.	https://www.iec.ch/government-regulators/electric-motors?utm	IEC / NEMA comparisons, nameplate standards - Helps understanding of how standards differ and how nameplate data is formatted
9.	https://www.sogaenergyteam.com/iec-asynchronous-motors-technical-specifications/?utm	Induction motor standards and specifications-SOGA (IEC induction motor specs - Shows IEC standards, frame sizes, duty, mounting, etc.
10.	https://innovationspace.ansys.com/product/electrical-machines-and-magnetic-fields/	To enhance understanding of electrical machines with various tutorials

Suggested Course Practical List:

The following Practical Outcomes (PrOs) are the sub-components of the Course Outcomes (COs). Some of the PrOsmarked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.

Sr. No.	Practical Outcomes /Title of experiment	CO1	CO2	CO3
1.	Identification of parts and demonstration of direction reversal in single-phase induction and universal motors (ceiling fans/ mixer motor).	√		
2.	Test the ceiling fan to identify starting and running winding with capacitor connection.	√		
3.	Direct load test on single-phase induction motor to determine efficiency and speed regulation; plot curves with respect to output power.	√		
4.	Identification of parts, interpretation of nameplate and function/materials for three-phase squirrel cage and slip ring induction motors.		√	
5.	Demonstrate reversal of direction of rotation for three-phase induction motors.		√	
6.	Connect and run three-phase squirrel cage induction motors using DOL, star-delta, and autotransformer starters.		√	
7.	Measure slip of a three-phase induction motor using tachometer, and stroboscope.		√	
8.	Perform direct load (brake) test on three-phase induction motor and plot (i) efficiency vs output, (ii) power factor vs output/motor current, and (iii) torque-slip/speed characteristics.*		√	
9.	Conduct no-load and blocked-rotor tests on three-phase squirrel cage induction motor to determine equivalent circuit parameters and calculate iron and copper losses. Plot circle diagram using data from no-load and blocked-rotor test. *		√	
10.	Control speed of three-phase squirrel cage or slip ring induction motors by (i) auto-transformer, (ii) rotor resistance (iii) VVVF drive (VFD).		√	
11.	Direct loading test on a three-phase alternator to determine voltage regulation and efficiency with various types of loads. *			√
12.	Perform open circuit and short circuit tests on three-phase alternator to determine synchronous impedance, efficiency, and			√

	voltage regulation. *			
13.	Perform parallel operation and synchronization of two alternators (synchronize with infinite bus bar).			√
14.	Construct 'V' curves of synchronous motor at different load conditions to analyze effect of excitation. *			√
15.	Demonstrate use of synchronous motor to improve power factor.			√

* Compulsory Performance

Subject In-charge can add Performance Experiments only.

Suggested List of Laboratory/Learning Resources Required:

Sr. No.	Suggested Equipment Name with Specifications
1.	Three Phase Induction Motor 3 hp / 5 hp, 415 V, 50 Hz, 1440 RPM Squirrel Cagetype coupled with suitable DC Shunt Machine.
2.	Three Phase Induction Motor 3 hp / 5 hp, 415 V, 50 Hz, 1440 RPM Squirrel Cagetype with Brake and Pulley arrangement.
3.	Three Phase Induction Motor 3 hp / 5 hp, 415 V, 50 Hz, 1440 RPM Slip Ring type.
4.	Stroboscope or relative Mobile app (e.g. Strobolight/RPM meter).
5.	Auto Transformer: 3-Phase, 5kVA, 0 to 470V.
6.	Ammeters MI Type: AC/DC 0-5-10A, 0-10-20A.
7.	Voltmeters MI Type: AC/DC, 0-150/300V, 0-250/500V.
8.	Clip on Meter Digital/Analog.
9.	Digital Multimeter with standard makes for measurements.
10.	Tachometers: Contact and non-contact types: 100 to 10000 RPM.
11.	Wattmeters: Single Phase, Single Element, 2.5/5A, 200/400V.
12.	Wattmeters: Three Phase Double Element, 5/10A, 250/500V.
13.	Low Power Factor Wattmeter: Single Phase, 2.5/5A, 250/500V.
14.	Single Phase Induction Motor, Permanent Capacitor (single value), 1 hp, 230 V, 50Hz, 1440 RPM.

15.	Star- Delta Starter (Auto/Manual), DOL Starter, VFD for 3 to 5 hp Motors.
16.	Ceiling Fan 230V preferably dismantled.
17.	Mixer Grinder (as a Universal Motor) 230V, 500W, 2800RPM.
18.	Frequency Meter.
19.	Load Bank: Resistive, 3-Phase, 5kW, 415V.
20.	Load Bank: Inductive, 3-Phase, 20A, 415V.
21.	Load Bank: Capacitive, 3-Phase, 20A, 415V.
22.	Three Phase Alternator: 5kVA, 415V, 50 Hz, 4 Pole, 1500 RPM coupled withappropriate DC Shunt Motor/Induction Motor.
23.	Synchronizing panel - With lamps and synchroscope
24.	Three Phase Synchronous Motor: 3HP, 415 V, 1500 RPM, 4-pole, 50 Hz

SuggestedActivities / Project List:

1. Single Phase Induction Motors

Reports / Seminars / Presentations:

- Necessity and applications
- Double field revolving theory
- Self-starting techniques overview
- Torque-speed characteristics of types
- Motor selection criteria
- Maintenance practices

Projects / Activities / Demonstrations:

- Demonstrate self-starting methods (phase splitting, shaded pole)
- Construct capacitor start/run motor model
- Torque-speed curve plotting for various types
- Direction reversal and speed control demonstration
- Maintenance and dismantling of single-phase motors

2. Three Phase Induction Motors

Reports / Seminars / Presentations:

- Classification of three phase AC machines
- Rotating magnetic field and synchronous speed
- Torque-slip characteristics and losses
- Different types of starters and speed control methods
- Standards and specifications (IS, IEC, NEMA, efficiency classes)
- Motor selection and maintenance

Projects / Activities / Demonstrations:

- Starting methods: DOL, star-delta, auto-transformer
- Slip measurement (tachometer, galvanometer, stroboscope)
- Direct load and no-load test; torque-speed and torque-slip plots
- Speed control using VVVF and rotor resistance
- Circle diagram plotting
- Direction reversal and motor mounting
- Motor maintenance tasks

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3. Three Phase Synchronous Machines

Reports / Seminars / Presentations:

- Construction and operation principles of synchronous motors and alternators
- Load angle and torque characteristics
- V-curves and excitation effects
- Synchronisation and parallel operation of alternators
- Standards and specifications (IS, IEC, NEMA)
- Power factor improvement and maintenance

Projects / Activities / Demonstrations:

- Alternator open circuit and short circuit tests
- Direct loading test and regulation calculation
- Synchronization with infinite bus bar and parallel operation
- Plotting V-curve and inverted V-curve
- Synchronous motor starting and hunting phenomenon
- Power factor improvement demonstration
- Maintenance and inspection of alternator and synchronous motors

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