INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	**ELECTRICAL MACHINES-II**				
Course Code	**AEEB15**				
Programme	**B.Tech**				
Semester	**IV**	**EEE**			
Course Type	**Core**				
Regulation	**IARE - R18**				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	3	1.5
Chief Coordinator	Mr. K Devender Reddy, Assistant Professor				
Course Faculty	Mr. K Devender Reddy, Assistant Professor Mr. A Satish Kumar, Assistant Professor				

I. COURSE OVERVIEW:

This course deals with the pulsating, revolving magnetic fields and construction, principle, classification, starting methods and different types of testing methods on AC machines including single phase, three phase induction motors and synchronous motors, this course also enlightens the students with the construction, principle, classification and different testing methods of synchronous generator

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AEEB11	III	Electrical Machines - I	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Electrical Machines - II	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✘	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✔	Videos
✔	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five modules and each module carries equal weight age in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each unit. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical and application skills of the concept.

Continuous Internal Assessment (CIA):
CIA is conducted for a total of 30 marks (Table 1), with 20 marks for Continuous Internal Examination (CIE), 05 marks for Quiz and 05 marks for Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	**Theory**			**Total marks**
Type of Assessment	CIE Exam	Quiz	AAT	
CIA marks	20	05	05	30

Continuous Internal Examination (CIE):
Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 20 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz / Alternative Assessment Tool (AAT):
Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Marks shall be awarded considering the average of two quizzes for every course. The AAT may include seminars, assignments, term paper, open ended experiments, five minutes video and MOOCs.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		**Strength**	**Proficiency assessed by**
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Seminars
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	2	Assignments
PO 4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	2	Laboratory Practice

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Problem Solving:** Able to utilize the knowledge of high voltage engineering in collaboration with power systems in innovative, dynamic and challenging environment, for the research based team work.	-	-
PSO 2	**Professional Skills:** Can explore the scientific theories, ideas, methodologies and the new cutting edge technologies in renewable energy engineering, and use this erudition in their professional development and gain sufficient competence to solve the current and future energy problems universally.	2	Seminars
PSO 3	**Modern Tools in Electrical Engineering:** The understanding of technologies like PLC, PMC, process controllers, transducers and HMI one can analyze, design electrical and electronics principles to install, test , maintain power system and applications.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Explain the concepts of rotating magnetic fields
II	Understand the operation of AC machines
III	Analyse performance characteristics of AC machines

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Analyze constant, pulsating and revolving magnetic fields	CLO 1	Understand the concept of constant magnetic fields
		CLO 2	Analyze pulsating fields produced by spatially displaced windings
		CLO 3	Describe revolving magnetic fields
CO 2	Describe the operation and performance of three phase induction motors	CLO 4	Understand the principle of operation, constructional features different types of torques, various losses, efficiency and torque- slip characteristics of three phase induction motor
		CLO 5	Describe no -load and blocked rotor test of three phase induction motor for calculating the equivalent circuit parameters and circle diagram
		CLO 6	Understand the starting and speed control methods of three phase induction motor, induction generator and doubly-fed Induction machines
CO 3	Understand the operation and performance characteristics of synchronous generator	CLO 7	Understand the principle of operation and constructional features and different types of armature windings of synchronous alternator
		CLO 8	Understand the phasor diagrams of alternator on no-load, load and analyze the harmonics and its suppression methods.
		CLO 9	Describe the different methods for calculating the voltage regulation, parallel operation and slip test

COs	Course Outcome	CLOs	Course Learning Outcome
CO 4	Demonstrate the construction and operation of synchronous motor	CLO 10	Understand the principle of operation, constructional features and starting methods of synchronous motor
		CLO 11	Describe the importance of power, excitation circles and effect of varying different parameters on synchronous motor performance
		CLO 12	Understand the concept of constructing V, inverted V curves and synchronous condenser
CO 5	Understand the construction, starting methods and torque speed characteristics of various single phase induction motors	CLO 13	Understand double revolving, cross field theory and the principle of operation and constructional features of single phase induction motor
		CLO 14	Describe the starting methods of single phase induction motor
		CLO 15	Describe the torque-speed characteristics of single phase induction motor and equivalent circuit.

X. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's mapped	Strength of mapping
AEEB15.01	CLO 1	Understand the concept of constant magnetic fields	PO1, PO2	2
AEEB15.02	CLO 2	Analyze pulsating fields produced by spatially displaced windings	PO1, PO2	3
AEEB15.03	CLO 3	Describe revolving magnetic fields	PO2	3
AEEB15.04	CLO 4	Understand the principle of operation, constructional features different types of torques, various losses, efficiency and torque- slip characteristics of three phase induction motor	PO1, PO2	3
AEEB15.05	CLO 5	Describe no -load and blocked rotor test of three phase induction motor for calculating the equivalent circuit parameters and circle diagram	PO1, PO2, PO4	3
AEEB15.06	CLO 6	Understand the starting and speed control methods of three phase induction motor, induction generator and doubly-fed Induction machines	PO2, PO4	2
AEEB15.07	CLO 7	Understand the principle of operation and constructional features and different types of armature windings of synchronous alternator	PO1	3
AEEB15.08	CLO 8	Understand the phasor diagrams of alternator on no-load, load and analyze the harmonics and its suppression methods.	PO2	2
AEEB15.09	CLO 9	Describe the different methods for calculating the voltage regulation, parallel operation and slip test	PO2, PO4	2
AEEB15.10	CLO 10	Understand the principle of operation, constructional features and starting methods of synchronous motor	PO1, PO2	2
AEEB15.11	CLO 11	Describe the importance of power, excitation circles and effect of varying different parameters on synchronous motor performance	PO1	3
AEEB15.12	CLO 12	Understand the concept of constructing V, inverted V curves and synchronous condenser	PO2, PO4	3
AEEB15.13	CLO 13	Understand double revolving, cross field theory and the principle of operation and constructional features of single phase induction motor	PO2, PO4	2
AEEB15.14	CLO 14	Describe the starting methods of single phase induction motor	PO1, PO2	2

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's mapped	Strength of mapping
AEEB15.15	CLO 15	Describe the torque-speed characteristics of single phase induction motor and equivalent circuit.	PO2	2
AEEB15.16	CLO 16	Apply the concept of electromagnetic and electrostatic fields to solve real time world applications.	PO1, PO2	3
AEEB15.17	CLO 17	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations.	PO1	3

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XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES

Course Outcomes (COs)	Program Outcomes (POs)			
	PO 1	PO 2	PO 4	PSO2
CO 1	2	2		
CO 2	3	3	3	2
CO 3	2	2	3	2
CO 4	3	3	3	2
CO 5	2	2	2	2

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XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

CLOs	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 1	2	2													
CLO 2	2	2													
CLO 3		3													
CLO 4	3	3													
CLO 5	3	3		3											
CLO 6		2		2										2	
CLO 7	3														
CLO 8		2													
CLO 9		2		2											
CLO 10	2	2												2	
CLO 11	3														
CLO 12		3		3										2	
CLO 13		2		2										2	
CLO 14	2	2													
CLO 15		2													
CLO 16	3	3													
CLO 17	3														

3 = High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1, PO2, PO4, PSO2	SEE Exams	PO1, PO2, PO4, PSO2	Assignments	PO1, PO2, PO4, PSO2	Seminars	PO1, PO2, PO4, PSO2
Laboratory Practices	PO1, PO2, PO4, PSO2	Student Viva	PO1, PO2, PO4, PSO2	Mini Project	-	Certification	-
Term Paper	PO1, PO2, PO4, PSO2						

XIV. ASSESSMENT METHODOLOGIES - INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XV. SYLLABUS

MODULE-I	**PULSATING AND REVOLVING MAGNETIC FIELDS**
Constant magnetic field, pulsating magnetic field, alternating current in windings with spatial displacement, Magnetic field produced by a single winding, fixed current and alternating current. Pulsating fields produced by spatially displaced windings, windings spatially shifted by 90 degrees. Addition of pulsating magnetic fields. Three windings spatially shifted by 120 degrees (carrying three-phase balanced currents), revolving magnetic field	
MODULE -II	**INDUCTION MACHINES**
Three phase induction motors: Introduction, construction, types of induction motors, slip and frequency of rotor currents, rotor MMF and production of torque, equivalent circuit, power across air gap, torque and power output, torque slip characteristics, generating and braking modes, maximum (breakdown) torque, starting torque, maximum power output, problems. Equivalent circuit model: No load test and blocked rotor test, circuit model, starting methods, speed control of induction motors, induction generator, principle of operation, isolated induction generator, Doubly-Fed Induction Machines, circle diagram, determination of induction motor parameters from circle diagram, problem	
MODULE -III	**ALTERNATORS**
Synchronous generators: Introduction, principle of operation, constructional features, armature windings, integral slot and fractional slot windings, distributed and concentrated windings, winding factors, basic synchronous machine model, circuit model of a synchronous machine, phasor diagrams, determination of synchronous impedance, short circuit ratio, armature reaction, ampere turns and leakage reactance. Voltage regulation: Calculation of regulation by synchronous impedance method, MMF, ZPF and ASA methods, slip test, parallel operation of alternators, synchronization of alternators, problems.	
MODULE -IV	**SYNCHRONOUS MOTORS**
Synchronous motors: Principle of operation, power developed, synchronous motor with different excitations, effect of increased load with constant excitation, effect of change in excitation with constant load, effect of excitation on armature current and power factor, construction of "V" and inverted "V" curves, power and excitation circles, starting methods, salient pole synchronous motor, phasor diagrams and analysis, synchronous condenser.	
MODULE -V	**SINGLE-PHASE INDUCTION MOTORS**
Single phase induction motor: Principle of operation, two reaction theory, equivalent circuit analysis, split phase motor, construction, principle of operation, capacitor start, capacitor run, capacitor start - capacitor run motor, shaded pole motor, torque speed characteristics.	

Text Books:
1. 1. P S Bimbhra, “Electrical Machinery”, Khanna Publishers, 1st Edition, 2011. 2. A E Fitzgerald and C Kingsley, "Electric Machinery”, New York, McGraw Hill Education, 1st Edition, 2013. 3. A E Clayton and N N Hancock, “Performance and design of DC machines”, CBS Publishers, 1st Edition, 2004. 4. I J Nagrath and D P Kothari, “Electric Machines”, McGraw Hill Education, 1st Edition, 2010.
Reference Books:
1. M G Say, E O Taylor, “Direct Current Machines”, Longman Higher Education, 1st Edition, 1985. 2. M V Deshpande, “Electrical Machines”, PHI Learning Private Limited, 3rd Edition, 2011. 3. Ian McKenzie Smith, Edward Hughes, “Electrical Technology”, Prentice Hall, 10th Edition, 2015.

XVI. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	CLOs	Reference
1	Understand constant and pulsating magnetic fields	CLO 1	T1: 6.1 R1:6.1-6.2
2	Describe the alternating current in windings with spatial displacement and magnetic field produced by a single winding	CLO 2	T1: 6.2 R1:6.2-6.3
3	Demonstrate magnetic field produced by a fixed current and alternating current	CLO 2	T1: 6.3 R1:6.3-6.4
4	Understand pulsating fields produced by spatially displaced windings	CLO 2	T1: 6.2 R1:6.3-7.4
5	Discuss pulsating fields produced by spatially displaced windings spatially shifted by 90 degrees	CLO 2	T1: 6.6 R1:6.5-6.6
6	Discuss pulsating fields produced by three windings spatially displaced by 120 degrees	CLO 2	T1: 6.7 R16.7-6.8
7	Discuss the rotating magnetic field and derive the mathematical proof	CLO 3	T1: 6.8 R1:6.9
8	Understand the principle of operation and constructional features of three phase induction motor	CLO 4	T1: 6.9 R1:7.1-7.2
9	Discuss the types of induction motor based on rotor structure like caged and wound rotor type and concept of slip	CLO 4	T1: 6.3 R1:7.35
10	Describe the frequency of rotor currents, rotor MMF, power	CLO4	T1: 6.4-6.5 R1:7.4-7.9
11	Numerical problems on rotor EMF, current and power	CLO 4	T1: 6.4-6.5 R1:7.4-7.9
12	Discuss the types of torques under different slip conditions and derive torque derivation, starting torque and condition for maximum torque	CLO 4	T1: 6.6 R1:7.1- 7.9
13	Understand the relation between rotor input, losses and power developed and numerical problems on rotor losses and power developed	CLO 4	T1: 6.9 R1:7.22
14	Describe equivalent circuit of three phase induction motor	CLO 4	T1: 6.8 R1:7.28
15	Understand the torque slip characteristics and numerical problems on equivalent circuit and torque – slip	CLO 5	T1: 6.9.1 R1:7.11
16	Understand no load and blocked rotor test of three phase induction motor	CLO 5	T1:6.11 R1:7.31
17	Numerical problems on no load and blocked rotor test	CLO 5	T1:6.11 R1:7.31
18	Explain the procedure for drawing circle diagram	CLO 5	T1:6.12 R1:8.1-8.3
19	Numerical problems on circle diagram	CLO 5	T1:6.12 R1:8.1-8.3

Lecture No	Topics to be covered	CLOs	Reference
20	Understand starting methods of three phase induction motor	CLO 6	T1:6.14 R19.1
21	Numerical problems on starting methods of three phase induction motor	CLO 6	T1:6.14 R19.1
22	Explain speed control methods of three phase induction motor	CLO 6	T1:6.15 R1:3.1-3.2
23	Numerical problems on speed control methods of three phase induction motor	CLO 6	T1:6.15 R1:3.1-3.2
24	Discuss the induction generator principle of operation, isolated induction generator	CLO 6	T1:6.16.1 R1:6.16
25	Explain the working principle of synchronous generators	CLO 7	T1: 5.2 R1:3.5
26	Understand constructional details like stator, rotor and types of synchronous generators	CLO 7	T1: 5.1 R1:3.5
27	Discuss the types of armature windings like single layer, double layer, short pitch, full pitch windings	CLO 7	T1: 5.1 R13.6-3.7
28	Derive the equation for distribution, pitch , winding factors and EMF equation	CLO 7	T1: 7.7 R1:3.12
29	Describe armature reaction, leakage reactance, synchronous impedance and numerical problems on windings and EMF equation	CLO 7	T1: 5.2 R1:3.13-3.15
30	Discuss the experimental determination of synchronous reactance and impedance	CLO 7	T1: 5.2.1 R1:3.14
31	Explain load characteristics of synchronous generator	CLO 7	T1: 5.7 R1:3.17
32	Numerical problems on efficiency	CLO 7	T1: 5.7 R1:3.17
33	Describe harmonics in generated EMF and suppression methods	CLO 8	T1: 5.3.1 R1:3.17
34	Explain the procedure of calculating the voltage regulation by synchronous impedance method	CLO 9	T1: 5.4.1 R1:3.17
35	Use EMF method for solving numerical problems on voltage regulation	CLO 9	T1: 5.4.1 R1:3.18
36	Explain the procedure for calculating the regulation by MMF method	CLO 9	T1: 5.4.2 R1:3.18
37	Use MMF method for solving numerical problems on voltage regulation	CLO 9	T1: 5.4.2 R1:3.19-3.20
38	Use MMF method for solving numerical problems on voltage regulation	CLO 9	T1: 5.4.2 R1:3.19-3.20
39	Explain the procedure for calculating the regulation by Zero power factor method	CLO 9	T1: 5.4.3 R1:3.21
40	Use Zero power factor method for solving numerical problems on voltage regulation	CLO 9	T1: 5.4.3 R1:6.1-6.2
41	Use Zero power factor method for solving numerical problems on voltage regulation	CLO 9	T1: 5.4.3 R1:6.1-6.2
42	Explain the procedure for calculating the regulation by American standard association method	CLO 9	T1: 5.4.4 R1:6.4-6.6
43	Use American standard association method for solving numerical problems on voltage regulation	CLO 9	T1: 5.4.4 R1:6.13
44	Discuss two reaction analysis and experimental determination of X_d and X_q(slip test), phasor diagram	CLO 9	T1: 5.16 R1:6.7
45	Explain the regulation of salient pole alternators	CLO 9	T1: 5.12 R1:6.13
46	Discuss the parallel operation and necessary conditions for parallel operation	CLO 9	R1:3.22
47	Explain different types of parallel operation methods like dark lamp and bright lamp methods and numerical problems on	CLO 9	R1:6.13
48	Understand load shearing of alternators	CLO 9	R1:5.3 R1:5.8

Lecture No	Topics to be covered	CLOs	Reference
49	Numerical problems on load shearing	CLO 9	R1:5.3 R1:5.8
50	Explain synchronous motor principle of opertion and constructional features	CLO 10	T1: 5.12 R1:5.5
51	Discuss the starting methods of synchronous motor and hunting effect	CLO 10	T1: 5.20 R1:5.5
52	Describe the effect of increased load with constant excitation on armature current, power factor and voltage	CLO 11	T1: 5.14 R1:5.8-5.9
53	Understand excitation and power circles	CLO 11	T1: 5.14.1 R1:5.14-5.15
54	Derive formula for power developed by synchronous motor and numerical problems on power developed	CLO 11	T1: 5.116 R1:5.10
55	Numerical problems on power developed	CLO 11	T1: 5.116 R1:5.10
56	Discuss the operation of synchronous condenser and numerical problems	CLO 12	T1: 5.419 R1:5.10
57	Discuss double revolving and cross field theory	CLO 13	T3:36.3 R1:10.2
58	Explain constructional features and principle of operation of single phase induction motor	CLO 13	T3:36.2 R1:5.11
59	Explain single phase induction motor starting methods like split phase, capacitor start, capacitor run, shaded pole induction motor and numerical problems on starting methods of single phase induction motor	CLO 14	T3:36.8 R1:10.3- 10.5
60	Understand the equivalent circuit and its parameters and numerical problems on equivalent circuit of single phase induction motor.	CLO 15	T3:36.2 R1:10.6-10.10

XVII. GAPS IN THE SYLLABUS - TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S. No	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Cascaded connection of induction motor	Guest lecture	PO1, PO2	-
2	Stepper motor	Seminars	PO1, PO2	-
3	Encourage students to solve real time applications and prepare towards competitive examinations.	NPTEL	PO 1	-

Prepared by:

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