INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad -500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	SOLID STATE ELECTRIC MOTOR DRIVES				
Course Code	AEE013				
Programme	B.Tech				
Semester	VI	EEE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	3	2
Chief Coordinator	Mr. S. Srikanth, Assistant Professor				
Course Faculty	Dr. B. Muralidhar nayak, Professor Mr. S. Srikanth, Assistant Professor				

I. COURSE OVERVIEW:

This course is an extension of power electronics applications to AC and DC drives. Control of DC Motor drives with single phase and three phase converters and choppers are given in detail. The control of AC motor drives with variable frequency converters and variable voltage are presented.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AEE010	V	Power Electronics	4
	AEE007	IV	AC Machines	4
	AEE004	III	DC Machines	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total marks
Solid State Electric Motor Drives	70 Marks	30 Marks	100

IV.   DELIVERY / INSTRUCTIONAL METHODOLOGIES:

X	Chalk & talk	√	Quiz	√	Assignments	X	Moocs
√	LCD/ PPT	√	Seminars	X	Mini project	X	Videos
X	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 units and each unit carries equal weightage 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 skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):
CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz/ Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	Theory		Total marks
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	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 25 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		Level	Proficiency assessed by
PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	2	Discussions

	Program Outcomes	Level	Proficiency assessed by
PO2	**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.	3	Seminar
PO3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Discussions
PO4	**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	Seminar

3= High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

	Program Specific Outcomes	Level	Proficiency assessed by
PSO1	**Professional Skills:** 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.	-	--------
PSO2	**Problem-Solving Skills:** To 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	Discussions
PSO3	**Successful Career and Entrepreneurship:** To be able to utilize of technologies like PLC, PMC, process controllers, transducers and HMI and design, install, test, maintain power systems and industrial applications.	-	--------

3= High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES:

	The course should enable the students to:
I	Demonstrate DC drives through phase controlled rectifiers and choppers.
II	Analyze operating principle of four quadrant DC drives.
III	Illustrate the speed control of induction motors through various parameters.
IV	Outline the separate and self control of synchronous motors.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Analyze the speed control of DC motors with phase controlled rectifiers	CLO 1	Understand the speed control of DC motors with single phase controlled rectifiers
		CLO 2	Analyze the speed control of DC motors with three phase controlled rectifiers
		CLO 3	Describe the speed torque characteristics of DC motors with variation in firing angle of the controlled rectifiers
CO 2	Describe the four	CLO 4	Demonstrate the motoring and braking operations of DC motor drives

COs	Course Outcome	CLOs	Course Learning Outcome
	quadrant operation of DC Drive with dual converter and operation of DC drives with choppers	CLO 5	Analyze the four quadrant operation of DC Drive with dual converter and closed loop operation
		CLO 6	Describe the operation of chopper fed DC motors
CO 3	Apply the variable voltage and variable frequency operation of induction motors with suitable converters	CLO 7	Apply the variable voltage operation of induction motors with AC voltage controllers
		CLO 8	Analyze the variable frequency operation of induction motors with voltage source inverters and current source inverters
		CLO 9	Describe the variable frequency operation of induction motors with cycloconverters and closed loop operations
CO 4	Understand the speed control of induction motor through static rotor resistance control and vector control	CLO 10	Understand the speed control of induction motor through static rotor resistance control
		CLO 11	Demonstrate the vector control operation of induction motor with direct methods
		CLO 12	Describe the vector control operation of induction motor with indirect methods
CO 5	Demonstrate the speed control of synchronous motor with suitable converters	CLO 13	Analyze the speed control of synchronous motor with voltage source inverters and current source inverters
		CLO 14	Understand the speed control of synchronous motor with variable frequency control using cycloconverters
		CLO 15	Demonstrate the closed loop control of synchronous motors with block diagram

X. COURSE LEARNING OUTCOMES:

Students, who complete the course, will have demonstrated the ability to do the following:

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's mapped	Strength of mapping
AEE013.01	CLO 1	Understand the speed control of DC motors with single phase controlled rectifiers	PO1, PO3	3
AEE013.02	CLO 2	Analyze the speed control of DC motors with three phase controlled rectifiers	PO1, PO2	3
AEE013.03	CLO 3	Describe the speed torque characteristics of DC motors with variation in firing angle of the controlled rectifiers	PO1, PO4	2
AEE013.04	CLO 4	Demonstrate the motoring and braking operations of DC motor drives	PO2, PO4	2
AEE013.05	CLO 5	Analyze the four quadrant operation of DC Drive with dual converter and closed loop operation	PO1, PO4	2
AEE013.06	CLO 6	Describe the operation of chopper fed DC motors	PO2, PO3	3
AEE013.07	CLO 7	Apply the variable voltage operation of induction motors with AC voltage controllers	PO2, PO4	2
AEE013.08	CLO 8	Analyze the variable frequency operation of induction motors with voltage source inverters and current source inverters	PO4	2
AEE013.09	CLO 9	Describe the variable frequency operation of induction motors with cycloconverters and closed loop operations	PO3	3
AEE013.10	CLO 10	Understand the speed control of induction motor through static rotor resistance control	PO2, PO4	2
AEE013.11	CLO 11	Demonstrate the vector control operation of induction motor with direct methods	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
AEE013.12	CLO 12	Describe the vector control operation of induction motor with indirect methods	PO1, PO4	2
AEE013.13	CLO 13	Analyze the speed control of synchronous motor with voltage source inverters and current source inverters	PO2, PO4	2
AEE013.14	CLO 14	Understand the speed control of synchronous motor with variable frequency control using cycloconverters	PO1, PO3	3
AEE013.15	CLO 15	Demonstrate the closed loop control of synchronous motors with block diagram	PO2, PO4	2
AEE013.16	CLO 16	Apply the concept of solid state electric drives to solve real time world applications	PO1	3
AEE013.17	CLO 17	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations	PO2	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 3	PO 4	PSO2
CO 1	3	2	2	1	2
CO 2	2	2		2	2
CO 3		2	3	2	1
CO 4	1	2		2	2
CO 5	2	2	1	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	3		2												
CLO 2	3	2												2	
CLO 3	3			2											
CLO 4		2		3											
CLO 5	2			2										3	
CLO 6		2	3												
CLO 7		2		2											
CLO 8				2										2	
CLO 9			3												
CLO 10		2		3											
CLO 11		2												2	

CLOs	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 12	2			2										3	
CLO 13		2		2											
CLO 14	3		2											3	
CLO 15		2		2											
CLO 16	3														
CLO 17		3												3	

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XIII. ASSESSMENT METHODOLOGIES – DIRECT:

CIE Exams	PO1 PO2 PO3 PO4 PSO2	SEE Exams	PO1 PO2 PO3 PO4 PSO2	Assignments	PO1 PO2 PO3 PO4 PSO2	Seminars	PO1 PO2 PO3 PO4 PSO2
Laboratory practices	PO3 PO4	Student viva	PO1 PO2 PO3 PO4 PSO2	Mini project	-	Certification	-
Term paper	-						

XIV. ASSESSMENT METHODOLOGIES – INDIRECT:

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

XV. SYLLABUS:

UNIT - I	CONTROL OF DC MOTORS THROUGH PHASE CONTROLLED RECTIFIERS

Introduction to thyristor controlled drives: Single phase semi and fully controlled converters connected to DC separately excited and dc series motors, continuous current operation, output voltage and current waveforms, speed and torque expressions, speed torque characteristics, problems on converter fed DC motors; Three phase semi and fully controlled converters connected to DC separately excited and DC series motors, output voltage and current waveforms, speed and torque expressions, speed torque characteristics and problems.

UNIT - II	SPEED CONTROL OF DC MOTORS

Introduction to four quadrant operation: Motoring operations, electric braking, plugging, dynamic and regenerative braking operations; Four quadrant operation of DC motors by dual converters, closed loop operation of DC motor; Chopper fed DC drives: Single quadrant, two quadrant and four quadrant chopper fed DC separately excited and series excited motors, continuous current operation output voltage and current wave forms, speed torque expressions, speed torque characteristics, problems on chopper fed DC motors and closed loop operation.

UNIT - III	SPEED CONTROL OF INDUCTION MOTORS THROUGH VARIABLE VOLTAGE AND FREQUENCY

Variable voltage characteristics: Control of induction motor by AC voltage controllers, waveforms, speed torque characteristics.
Variable frequency characteristics: Variable frequency characteristics, variable frequency control of induction motor by voltage source and current source inverter and cycloconverters, pulse with modulation control, comparison of voltage source inverter and current source inverter operations, speed torque characteristics, numerical problems on induction motor drives, closed loop operation of induction motor drives.

UNIT - IV	SPEED CONTROL OF INDUCTION MOTORS THROUGH ROTOR RESISTANCE AND VECTOR CONTROL

Static rotor Resistance control: Slip power recovery schemes, static Scherbius drive, static Kramer drive, their performance and speed torque characteristics, advantages and applications, vector control of induction motor drives: Principles of vector control, vector control methods, direct methods of vector control, indirect methods of vector control and problems.

UNIT - V	SPEED CONTROL OF SYNCHRONOUS MOTORS

Separate control and self control of synchronous motors, operation of self controlled synchronous motors by voltage source inverter and current source inverter cyclo converters. Load commutated CSI fed synchronous motor, operation, waveforms, speed torque characteristics, applications, advantages and numerical problems, closed loop control operation of synchronous motor drives (block diagram only), variable frequency control, cycloconverter, PWM, variable frequency inverter and current source inverter.

Text Books:

1. PV Rao, "Power Semiconductor Drives", BS Publications, 1st Edition, 2014.
2. G K Dubey, "Fundamentals of Electric Drives", Narosa Publications, 2nd Edition, 2001.
3. SB Devan, GR Slemon, A Straughen, "Power semiconductor drives", Wiley Pvt. Ltd,. 4th Edition, 2001.
4. B K Bose, "Modern Power Electronics and AC Drives", Prentice Hall India Learning Private Limited, 2005

Reference Books:

1. Vedam Subramanyam, "Thyristor Control of Electric Drives", Tata McGraw Hill Publication, 5th Edition, 2008.
2. John Hindmarsh, Alasdair Renfew", Electrical machines and drive systems", Oxford Butterworth Heinemann, 3rd Edition.
3. Austin Hughes, "Electrical motors and drives Fundamentals Types and Applications", Elsevier, 3rd Edition, 2006.
4. M D Singh, K B Kanchandhani, "Power Electronics", Tata Mc Graw Hill Publishing Company, 2nd Edition, 1998.
5. M H Rashid, "Power Electronics, Circuits, Devices and Applications", Pearson, 3rd Edition, 2001

XVI. COURSE PLAN:

The course plan is meant as a guideline. There may probably be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1.	Understand the principle of thyristor controlled drives	CLO1	T2: 1.1
2.	Describe the operation of Single phase semi controlled converters connected to DC separately excited motors	CLO1	T2: 5.11
3.	Understand the operation Single phase semi controlled converters connected to DC series motors	CLO1	T2: 5.1.2
4.	Analyze the problems on Single phase semi controlled converters fed DC motors	CLO3	T2: 5.11 & 5.1.2
5.	Discuss the operation of Single phase fully controlled converters connected to DC separately excited motors	CLO1	T2: 5.10
6.	Describe the operation of Single phase fully controlled converters connected to DC series motors	CLO1	T2: 5.1.2
7.	Analyze the problems on Single phase fully controlled converters fed DC motors	CLO3	T2: 5.10 & 5.1.2
8.	Demonstrate the operation of Three phase semi controlled converters connected to DC separately excited motors	CLO2	T2: 5.13
9.	Understand the operation of Three phase semi controlled converters connected to DC series motors	CLO2	T2: 5.13
10.	Analyze the problems on three phase semi controlled converters fed DC motors	CLO3	T2: 5.13
11.	Describe the operation of Three phase fully controlled converters connected to DC separately excited motors	CLO2	T2: 5.12

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
12.	Discuss the operation of Three phase fully controlled converters connected to DC series motors	CLO2	T2: 5.12
13.	Analyze the problems on three phase fully controlled converters fed DC motors	CLO3	T2: 5.12
14.	Understand the four quadrant operation of DC motors	CLO5	T2: 5.3
15.	Describe the electric braking operations	CLO4	T2: 5.3.1
16.	Demonstrate the Regenerative braking operations of DC motors	CLO4	T2: 5.3.2
17.	Discuss the Four quadrant operation of DC motors by dual converters	CLO5	T2: 5.14.2
18.	Describe the closed loop operation of DC motor with four quadrant operations	CLO5	T2: 5.14.3
19.	Understand the operation of Single quadrant chopper fed DC separately excited and series motors	CLO6	T2: 5.18
20.	Describe the operation of Two quadrant chopper fed DC separately excited and series motors	CLO6	T2: 5.19
21.	Analyze the problems on Chopper fed DC motors	CLO6	T2: 5.19
22.	Discuss the operation of Four quadrant chopper fed DC separately excited and series motors	CLO6	T2: 5.20
23.	Analyze the problems on Chopper fed DC motors	CLO6	T2: 5.20
24.	Demonstrate the Closed loop operation of chopper fed DC motors	CLO6	T2: 5.21
25.	Understand the variable voltage characteristics of induction motor	CLO7	T2: 6.1.1
26.	Discuss the speed control of induction motor by AC voltage controllers	CLO7	T2: 6.11
27.	Describe the Speed torque characteristics of induction motor with variable voltage	CLO7	T2: 6.11.1
28.	Demonstrate the variable frequency characteristics of induction motor	CLO7	T2: 6.12.1
29.	Understand the operation of voltage source inverter fed induction motor	CLO8	T2: 6.13.1
30.	Discuss the operation of current source inverter fed induction motor	CLO8	T2: 6.17
31.	Describe the operation of cycloconverter fed induction motor	CLO9	T2: 6.14
32.	Apply the pulse width modulation control for variable frequency control of induction motor	CLO9	T2: 6.9
33.	Distinguish voltage source inverter and current source inverter	CLO8	T2: 6.17.3
34.	Analyze the numerical problems on induction motor drives	CLO9	T2: 6.12 & 6.13
35.	Demonstrate the Closed loop operation of induction motor drives	CLO8	T2: 6.15
36.	Analyze the numerical problems on induction motor drives	CLO9	T2: 6.12 & 6.13
37.	Understand the operation of rotor resistance control of induction motors	CLO10	T2: 6.20
38.	Discuss the Static rotor Resistance control of induction motors	CLO10	T2: 6.20.2
39.	Demonstrate the Slip power recovery schemes of induction motor	CLO10	T2: 6.21
40.	Describe the operation of static Scherbius drive	CLO10	T2: 6.21.1
41.	Understand the operation of static Kramer drive	CLO10	T2: 6.21.2
42.	List the advantages and applications of slip power recovery schemes	CLO10	T2: 6.21

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
43.	Analyze the problems on rotor resistance control	CLO10	T2: 6.21
44.	Discuss the vector control of induction motor drives	CLO11	T2: 6.24
45.	Understand the principles of vector control of induction motor	CLO11	T2: 6.25
46.	Describe the vector control methods of induction motor	CLO11	T2: 6.26
47.	Demonstrate the direct methods of vector control	CLO11	T2: 6.26.1
48.	Discuss Indirect methods of vector control and problems.	CLO12	T2: 6.26.2
49.	Analyze the problems on vector control of induction motor	CLO11	T2: 6.26.1
50.	Understand the Separate control of synchronous motors	CLO13	T2: 7.5.1
51.	Describe the Self control of synchronous motors	CLO13	T2: 7.5.2
52.	Demonstrate the operation of self controlled synchronous motors by voltage source inverter	CLO13	T2: 7.3
53.	Discuss the operation of self controlled synchronous motors by current source inverter	CLO13	T2: 7.3.1
54.	Understand the operation of self controlled synchronous motors by cycloconverter	CLO14	T2: 7.3.2
55.	Describe the operation of Load commutated CSI fed synchronous motor	CLO13	T2: 7.5
56.	List the Applications and advantages of synchronous motor drives	CLO13	T2: 7.7
57.	Analyze the Numerical problems on synchronous motor drives	CLO13	T2: 7.5
58.	Demonstrate the closed loop control operation of synchronous motor drives with block diagram	CLO15	T2: 7.6
59.	Discuss the operation of variable frequency control of synchronous motor with cycloconverter	CLO14	T2: 7.6.1
60.	Describe the Variable frequency inverter and current source inverter fed synchronous motor	CLO13	T2: 7.6.2

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

S. No	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Inverters fed AC motor drives and its control methods	Discussions	PO2	PSO2
2	Speed control of special motors using converters	Discussions	PO2	PSO2

Prepared by:
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