INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	**FLEXIBLE ALTERNATING CURRENT TRANSMISSION SYSTEMS**				
Course Code	AEE524				
Programme	B. Tech				
Semester	VIII	EEE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	--	3	-	-
Chief Coordinator	Ms K.Harshini, Assistant Professor				
Course Faculty	Ms K.Harshini, Assistant Professor				

I. COURSE OVERVIEW:

This course is aimed to introduce the students the principles and applications of FACTS in everyday life. This course gives the importance of FACTS Technology application in Transmission line. The FACTS controllers can also be used to regulate power flow in critical lines and hence, ease congestion in electrical networks. FACTS does not refer to any single device, but a host of controllers such as SVC, Thyristor Controlled Series Capacitor(TCSC), Static Phase Shifting Transformer (SPST), and newer controllers based on Voltage Source Converters (VSC)-Static synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC).

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AEE010	V	Power Electronics	4
UG	AEE012	VI	Power System Analysis	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Flexible Alternating Current Transmission Systems	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL ETHODOLOGIES:

✘	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 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 (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	Assignments and seminar
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 and seminar
PO 3	**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	Assignments and seminar
PO 5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.	3	Assignments and seminar

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**: Exploit 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**: Identify 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	Seminar
PSO 2	**Modern Tools in Electrical Engineering:** Comprehend the 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	Describe the effect of series and shunt compensation using various FACTS controllers.
II	Static VAR compensator for voltage regulation and transient stability enhancement of system.
III	Analyse voltage source converter based FACTs controllers and their coordination.

IX.COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO1	Understand the fundamentals of FACTS controllers and their role in improving power system performance.	CLO 1	Discuss about the introduction of FACTS technology in Power Systems and power flow in transmission lines
		CLO 2	Discuss about the Reactive Power Compensation in Transmission line and also the types of Compensation methods.
		CLO 3	Explain the need of FACTS and types of FACTS Controllers.
CO2	Understand SVC for various functions viz. Transient stability Enhancement, voltage instability prevention and power oscillation damping.	CLO 4	Discuss about the Static VAR Compensator, its configuration and Voltage Regulation
		CLO 5	Study the modeling of SVC for Stability and for Load flow analysis.
		CLO 6	Designing of SVC to regulate transient stability enhancement and power oscillation damping.
CO3	Analyse the use of control schemes of TCSC, TSSC, GSC in improving the power quality.	CLO 7	Understanding the concepts Controlled Series Capacitors.
		CLO8	Explain the operation, analysis and gate turn off characteristics of Thyristor Controlled Series Capacitor.
		CLO9	Modeling of TCSC and GCSC for Stability and for Load flow analysis.
CO4	Analyse the applications of Voltage Source Converter based FACTS Controllers	CLO 10	Operation of Static Synchronous Compensator(STATCOM) and Synchronous Series Compensator(SSSC)
		CLO 11	Modelling of Static Synchronous Compensator (STATCOM) and Synchronous Series Compensator (SSSC) Transient Stability and for Power Flow analysis.
		CLO 12	Modelling of UPFC and IPFC for Transient Stability and for Power Flow analysis.
CO5	Explain the FACTS Controllers and their co-ordination.	CLO 13	Discuss about FACTS controller interactions.
		CLO 14	Explain SVC interaction, co- ordination of multiple controllers using linear control techniques
		CLO 15	Explain the quantitative treatment of control co ordination
		CLO 16	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations.

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
AEE524.01	CLO 1	Discuss about the introduction of FACTS technology in Power Systems and power flow in transmission lines	PO1, PO3	2
AEE524.02	CLO 2	Discuss about the Reactive Power Compensation in Transmission line and also the types of Compensation methods.	PO1, PO2	2
AEE524.03	CLO 3	Explain the need of FACTS and types of FACTS Controllers.	PO1, PO5	2
AEE524.04	CLO 4	Discuss about the Static VAR Compensator, its configuration and Voltage Regulation	PO1, PO5	2
AEE524.05	CLO 5	Study the modeling of SVC for Stability and for Load flow analysis.	PO2, PO3	2
AEE524.06	CLO 6	Designing of SVC to regulate transient stability enhancement and power oscillation damping.	PO2, PO3 PO5	2
AEE524.07	CLO 7	Understanding the concepts Controlled Series Capacitors.	PO1, PO2	2
AEE524.08	CLO 8	Explain the operation, analysis and gate turn off characteristics of Thyristor Controlled Series Capacitor	PO1, PO2	3
AEE524.09	CLO 9	Modeling of TCSC and GCSC for Stability and for Load flow analysis.	PO2, PO3,PO5	2
AEE524.10	CLO 10	Operation of Static Synchronous Compensator(STATCOM) and Synchronous Series Compensator(SSSC)	PO1, PO5	2
AEE524.11	CLO 11	Modelling of Static Synchronous Compensator (STATCOM) and Synchronous Series Compensator (SSSC) Transient Stability and for Power Flow analysis.	PO2, PO3	2
AEE524.12	CLO 12	Modelling of UPFC and IPFC for Transient Stability and for Power Flow analysis	PO2, PO3,PO5	3
AEE524.13	CLO 13	Discuss about FACTS controller interactions	PO1, PO2	2
AEE524.14	CLO 14	Explain SVC interaction, co- ordination of multiple controllers using linear control techniques	PO2, PO3	2
AEE524.15	CLO 15	Explain the quantitative treatment of control co ordination	PO1, PO2	2
AEE524.16	CLO 16	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations.	PO2, PO3	2

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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	PO5	PSO2
CO 1	2	2	1	2	1
CO 2	2	2	2	2	2
CO 3	1	2	2	2	2
CO 4	2	2	1	2	2
CO 5	2	2	2	2	1

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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											1	
CLO 2	1	2													
CLO 3	1				2										
CLO 4	1				2								1		
CLO 5	2	3			3										
CLO 6		1	2		2										
CLO 7	2	3													
CLO 8	1	2													
CLO 9		1	2		1										
CLO 10	1				2										
CLO 11		2	2											1	
CLO 12		1	2		2									2	
CLO 13	1	2													
CLO 14		2	2												
CLO 15	2	2												2	
CLO 16		2	2												

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XIII.ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PPO1, PO2, PO3,PO5, PSO2	SEE Exams	PPO1, PO2, PO3,PO5,	Assignments	PPO1, PO2, PO3	Seminars	PPO1, PO2, PO3
Laboratory Practices	-	Student Viva	-	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	**INTRODUCTION**
FACTS Controllers: Review of basics of power transmission networks, control of power flow in AC transmission line, analysis of uncompensated AC transmission line, passive reactive power compensation, effect of series and shunt compensation at the midpoint of the line on power transfer, need for FACTS controllers, types of FACTS controllers.	
UNIT-II	**STATIC VAR COMPENSATOR (SVC)**
Static VAR compensator: Configuration of static VAR compensator, voltage regulation by static VAR compensator, modeling of static VAR compensator for load flow analysis, modeling of static VAR compensator for stability studies, design of static VAR compensator to regulate the midpoint voltage of SMIB system, applications, transient stability enhancement and power oscillation damping of single machine infinite bus system with static VAR compensator connected at the midpoint of the line	
UNIT-III	**THYRISTOR AND GTO THYRISTOR CONTROLLED SERIES CAPACITORS (TCSC and GCSC)**
Series compensator: Concepts of controlled series compensation, operation of thyristor controlled series capacitor and gate turn off thyristor controlled series capacitor, analysis of TCSC. GCSC modeling of TCSC and GCSC for load flow studies, modeling TCSC and GCSC for stability studies, applications of TCSC and GCSC.	
UNIT-IV	**VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS**
Static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), operation of STATCOM and SSSC power flow control with STATCOM and SSSC, modeling of STATCOM and SSSC for power flow and transient stability studies, operation of unified and interline power flow controllers (UPFC and IPFC) modeling of UPFC and IPFC for load flow and transient stability studies, applications.	
UNIT-V	**CONTROLLERS AND THEIR COORDINATION**
FACTS controller interactions: SVC, SVC interaction, co ordination of multiple controllers using linear control techniques, quantitative treatment of control co ordination	
Text Books:	
1. Mohan Mathur, R Rajiv K Varma, "Thyristor – Based FACTS controllers for Electrical Transmission Systems", IEEE press and John Wiley & Sons, 1st Edition, 2002.	

2. K R Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International (P) Ltd., Publishers, 1st Edition, 2008.
3. A T John, "Flexible AC Transmission System", Institution of Electrical and Electronic Engineers (IEEE), 2nd Edition, 1999.

Reference Books:

1. Narain G Hingorani, Laszio Gyugyl, "Understanding FACTS Concepts and Technology of Flexible AC Transmission System", Standard Publishers, 1st Edition, 2001.
2. K Sood, "HVDC and FACTS controllers - Applications of Static Converters in Power System", Kluwer Academic Publishers, 1st Edition, 2004.

XVI.COURSE PLAN:

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

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Introduction to FACTS and Power Systems Distribution	CLO 1	R1:1.1
2	Review Of Basics Of Power Transmission Networks	CLO 1	T2:1.2
3	Control of power flow in AC Transmission line	CLO 2	R1:1.2
4	Analysis Of Uncompensated AC Transmission Line	CLO 2	T1:2.1-2.2
5	Passive Reactive Power Compensation	CLO 2	T1:2.3
6	Effect Of Series Compensation At The Midpoint Of The Line On Power Transfer	CLO 2	T2:2.3
7	Effect of shunt compensation at the midpoint of the line on power transfer	CLO 2	T2:2.4
8	Types of facts controllers.	CLO 3	R1:1.6-1.7
9	Static Var Compensator: configuration of Static Var Compensator	CLO 4	T2:3.2
10	Voltage regulation by Static Var Compensator	CLO4	T2:3.4
11	Modeling of Static Var Compensator for load flow analysis	CLO 5	T1:4.7.1
12	Modeling of Static Var Compensator for load flow analysis	CLO 5	T1:4.7.1
13	Modeling of Static Var Compensator for stability studies	CLO 5	T1:4.7.4
14	Design of Static Var Compensator.	CLO6	T1:5.2.5
15	Static Var Compensator designing to regulate the midpoint voltage of SMIB system,	CLO 6	T1:5.2.5
16	Transient stability enhancement	CLO6	T1:6.3
17	Power oscillation damping of single machine infinite bus system with Static Var Compensator connected at the midpoint of the line	CLO 6	T1:6.7
18	Applications SVC	CLO 6	T2:3.8
19	Series Compensator	CLO 7	T1:7.1
20	Concepts of Controlled Series Compensation	CLO 7	T2:4.2
21	Operation of Thyristor Controlled Series Capacitor	CLO7	T2:4.3
22	Gate turn off Thyristor Controlled Series Capacitor	CLO 8	T2:4.3

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
23	Analysis of TCSC	CLO 8	T2:4.4
24	Analysis of GCSC	CLO 8	T2:4.7
25	Modeling of TCSC and GCSC for load flow studies	CLO 9	T2:4.8
26	Modeling TCSC and GCSC for stability studies	CLO 9	T2:4.8
27	Applications of TCSC and GCSC	CLO 9	T2:4.9
28	Static Synchronous Compensator (STATCOM)	CLO 10	T2:6.1
29	Static Synchronous Series Compensator (SSSC),	CLO 10	T2:7.1
30	Operation of STATCOM and SSSC power flow control	CLO 10	T2:7.2
31	Modeling of STATCOM and SSSC for power flow	CLO 11	T2:7.3
32	Modeling of STATCOM and SSSC for transient stability studies	CLO 11	T2:7.3
33	Introduction UPFC and IPFC	CLO 12	T2:8.2&8.5
34	Operation of unified and interline power flow controllers	CLO 12	T2:8.2&8.5
35	Modeling of UPFC and IPFC for load flow	CLO 12	T2:8.7
36	Modeling of UPFC and IPFC for transient stability studies	CLO 12	T2:8.7
37	Applications of UPFC and IPFC	CLO 12	T2:8.9
38	FACTS controller	CLO 13	T1:9.1
39	FACTS controller interactions	CLO 13	T1:9.2
40	FACTS controller interactions SVC	CLO 14	T1:9.2
41	SVC interaction	CLO 14	T1:9.3
42	Coordination of multiple controllers	CLO 15	T1 :9.8
43	Coordination using linear control techniques	CLO 15	T1:9.8.
44	Quantitative treatment of control co ordination	CLO 15	T1:9.9
45	Controller Coordination for Damping Enhancement	CLO 15	T1:9.9

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

S No	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	To improve standards and analyze the concepts.	Seminars	PO 1	PSO 1
2	Real Time applications of FACTS Devices	Seminars / NPTEL	PO 3	PSO 1
3	Encourage students to solve real time applications and prepare towards competitive examinations.	NPTEL	PO 2	PSO 1

Prepared by:
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