INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	**POWER SYSTEM OPERATION AND CONTROL**				
Course Code	**AEE016**				
Programme	**B.Tech**				
	VII	**EEE**			
Course Type	**Core**				
Regulation	**IARE - R16**				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Mr. A Sathish Kumar, Assistant Professor				
Course Faculty	Mr. A Sathish Kumar, Assistant Professor				

I. COURSE OVERVIEW:

This electrical distribution course introduces the components of the distribution system and the way in which the system delivers power to end-use customers. Included in the course are descriptions of key system components including single and three phase lines as well as we and delta lines. The course also addresses the ways in which distribution systems are designed to serve various types of customer loads.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AEE011	V	Transmission and Distribution Systems	4
UG	AEE012	VI	Power System Analysis	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Power System Operation and Control	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 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	Presentation on real-world problems
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	3	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	Project Work / Assignment
PO11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	2	Project Work / Assignment

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.	3	Assignment and Seminar
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	Presentation on real-world problems
PSO 3	**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 (COs):

The course should enable the students to:	
I	Demonstrate economic operation of power systems, hydrothermal scheduling.
II	Illustrate modelling of turbines, generators and automatic controllers.
III	Discuss single area and two area load frequency control.
IV	Analyze reactive power control and load modeling

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Understand the optimal operation of generators in thermal power stations and their characteristics with and without transmission loss coefficient.	CLO 1	Understand optimal operation of generators in thermal power stations and their characteristics.
		CLO 2	Design an optimal operation setup of power system which minimizes operation costs and meet desired needs.
		CLO 3	Solve the unit Commitment problem with various constraints using conventional optimization techniques and general transmission line loss formula.
		CLO 4	Examine optimal scheduling of hydrothermal system characteristics and their economic operation.
CO 2	Design the mathematical models of the speed governing systems, turbine and excitation system	CLO 5	Design the mathematical models of the mechanical and electrical components involved in the operation of power systems.
		CLO 6	Understand the modeling of excitation systems and fundamental characteristics of an excitation system.
CO 3	Discuss single area load frequency control and two area load frequency control.	CLO 7	Design the single area and two area thermal power system
		CLO 8	Demonstrate the understanding of the open loop and closed loop control practices associated with the voltage and frequency control of single area or interconnected multi area power systems
CO 4	Discuss the need of power factor correction and voltage drop compensation and Identify the best methods for power factor improvement and voltage control	CLO 9	Understand the significance of reactive power control in power systems to maintain quality of power
		CLO 10	Design appropriate control scheme to compensate reactive power
		CLO 11	Describe the different methods of control and compensation to choose the best option so that social and environmental problems are minimized
		CLO 12	Describe the different methods of control and compensation recognize the need to continuously follow the advancements in technology and incorporate them in the present system to improve efficiency and increase the flexibility and quality of operation
CO 5	Understand the types of loads and their characteristics with specifications of load compensator.	CLO 13	Differentiate the types of loads and their characteristics
		CLO 14	Calculate the voltage drop and power loss in a distribution system.

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
AEE016.01	CLO 1	Understand optimal operation of generators in thermal power stations and their characteristics	PO1	3
AEE016.02	CLO 2	Design an optimal operation setup of power system which minimizes operation costs and meet desired needs.	PO1	3
AEE016.03	CLO 3	Solve the unit Commitment problem with various constraints using conventional optimization techniques and general transmission line loss formula	PO1, PO 2	3

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AEE016.04	CLO 4	Examine optimal scheduling of hydrothermal system characteristics and their economic operation.	PO1	3
AEE016.05	CLO 5	Design the mathematical models of the mechanical and electrical components involved in the operation of power systems	PO1, PO3	3
AEE016.06	CLO 6	Understand the modeling of excitation systems and fundamental characteristics of an excitation system	PO1, PO3	3
AEE016.07	CLO 7	Design the single area and two area thermal power system.	PO1, PO3	3
AEE016.08	CLO 8	Demonstrate the understanding of the open loop and closed loop control practices associated with the voltage and frequency control of single area or interconnected multi area power systems	PO1, PO3	3
AEE016.09	CLO 9	Understand the significance of reactive power control in power systems to maintain quality of power	PO1	3
AEE016.10	CLO 10	Design appropriate control scheme to compensate reactive power	PO1, PO3	3
AEE016.11	CLO 11	Describe the different methods of control and compensation to choose the best option so that social and environmental problems are minimized	PO1, PO3, PO11	3
AEE016.12	CLO 12	Describe the different methods of control and compensation recognize the need to continuously follow the advancements in technology and incorporate them in the present system to improve efficiency and increase the flexibility and quality of operation	PO1, PO2	3
AEE016.13	CLO 13	Differentiate the types of loads and their characteristics	PO1	3
AEE016.14	CLO 14	Calculate the voltage drop and power loss in a distribution system.	PO1	3
AEE016.15	CLO 15	Apply the concept of power systems and operation and control to solve real time world applications	PO1, PO2	3
AEE016.16	CLO 16	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 3	PO 11	PSO1	PSO2
CO 1	3	3			3	
CO 2	3		3		3	
CO 3	3		2			2
CO 4	3		3	2	3	2
CO 5	3				3	

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

3 = High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES – DIRECT:

CIE Exams	PO1, PO2, PO3, PSO1, PSO2	SEE Exams	PO1, PO2, PO3, PSO1, PSO2	Assignments	PO1	Seminars	PO1
Laboratory Practices	PO1	Student Viva	-	Mini Project	-	Certification	-
Term Paper	PO1						

XIV. ASSESSMENT METHODOLOGIES – INDIRECT:

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

XV. SYLLABUS

UNIT - I	ECONOMIC OPERATION OF POWER SYSTEMS
Optimal scheduling of thermal power system: Optimal operation of generators in thermal power stations, heat rate curve, cost curve, incremental fuel and production costs, input output characteristics, optimum generation allocation without and with transmission line losses coefficients, general transmission line loss formula, unit commitment; Optimal scheduling of hydrothermal system: Hydro electric power plant models, scheduling problems, short term hydro thermal scheduling problem.	
UNIT - II	**MODELING OF GOVERNOR, TURBINE AND EXCITATION SYSTEMS**
Modeling of governor: Mathematical modeling of speed governing system, derivation of small signal transfer function; Modeling of turbine: First order turbine model, block diagram representation of steam turbines and approximate linear models; Modeling of excitation system: Fundamental characteristics of an excitation system, transfer function, block diagram representation of IEEE type-1 model.	
UNIT - III	**SINGLE AREA AND TWO AREA LOAD FREQUENCY CONTROL**
Load frequency control of single area system: Necessity of keeping frequency constant, definitions of control area, single area control, block diagram representation of an isolated power system, steady state analysis, dynamic response, uncontrolled case. Load frequency control of two area system: Uncontrolled case and controlled case, tie line bias control; Load frequency controllers: Proportional plus integral control of single area and its block diagram representation, steady state response, load frequency control and economic dispatch.	
UNIT - IV	**COMPENSATION FOR POWER FACTOR IMPROVEMENT AND REACTIVE POWER CONTROL**
Voltage control: Equipment for voltage control, effect of series capacitors, line drop compensation, effect of AVR, power factor control using different types of power capacitors, shunt and series capacitors, effect of shunt capacitors (fixed and switched), power factor correction, capacitor allocation, economic justification, procedure to determine the best capacitor location; Reactive power control: Reactive power compensation in transmission systems, advantages and disadvantages of different types of compensating equipment for transmission systems; Uncompensated and compensated transmission lines: Shunt and series compensation.	
UNIT - V	**LOAD COMPENSATION**
Load Compensation: characteristics of loads, factors associated with loads, relation between the load factor and loss factor; specifications of load compensator; Classification of loads: Residential, commercial, agricultural and industrial and their characteristics.	
Text Books:	
1. Sivanagarju "Power system operation and control " Pearson Education India, 2009 2. "Electric Power Distribution system, Engineering" – by TuranGonen, McGraw-hill Book Company 3. T J E Miller, "Reactive power control in Electrical system", Wiley Interscience Publication, 1982. 4. V K Mehta and Rohit Mehta, "Principles of Power System", S Chand, 3rd revised Edition, 2015.	
Reference Books:	
1. Singh S N, "Electric Power Generation, Transmission and Distribution", Prentice Hall of India Pvt. Ltd., New Delhi, 2nd Edition, 2002. 2. Turan Gonen, "Electrical Power Distribution System Engineering", CRC Press, 3rd Edition, 2014. 3. V Kamaraju, "Electrical Power Distribution Systems", TMH, Publication, Edition, 2009 4. O I Elgerd, "Electrical Energy Systems Theory", Tata McGraw-Hill, 2nd Edition, 2007..	

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
1-2	Understand optimal operation of generators in thermal power stations and their characteristics	CLO1	T1:5-6
3	Understand the heat rate curve, cost curve, incremental fuel and production costs, input output characteristic	CLO2	T1: 25-26
4	Solve optimum generation allocation without transmission line losses coefficients, general transmission line loss formula,	CLO3	T1: 26-28
5	Solve optimum generation allocation with transmission line losses coefficients, general transmission line loss formula,	CLO3	T1: 26-28
6	Solve the unit Commitment problem with various constraints using conventional optimization techniques and general transmission line loss formula	CLO3	T1: 26-28
7-9	Examine optimal scheduling of hydrothermal system characteristics and their economic operation	CLO4	T1: 30-32
10-11	Design mathematical modeling of speed governing system and derive small signal transfer function	CLO5	T3:312-318
13-14	Design block diagram representation of steam turbines and approximate linear models	CLO5	T3:312-318
15	Design mathematical modeling of excitation system of steam turbine	CLO6	T3:322-326
16	Understand the fundamental characteristics of an excitation system	CLO6	T3:319
17	Understand the block diagram of an excitation system	CLO6	T2:11.5 R2:17.5
18-19	Understand block diagram representation of IEEE type-1 model.	CLO6	T1: 84-85
20	Study the definitions of control area and single area control	CLO7	T1: 327-330
21	Interpret the block diagram representation of an isolated power system for uncontrolled case	CLO7	T1: 327-330
22	Describe the steady state analysis and dynamic response for uncontrolled case	CLO7	T1: 327-330
23	Study the uncontrolled case and controlled case, tie line bias control for two area system	CLO8	T1: 327-330
24	Study the controlled case, tie line bias control for two area system	CLO8	T1: 58-59
25	Examine the proportional plus integral control of single area	CLO7	T1: 58-59
26-27	Study the Proportional plus integral control of single area and its block diagram representation	CLO7	T1 :60-62
28	Describe the steady state response, load frequency control and economic dispatch	CLO8	T1 :63-64
29	Study the steady state response, load frequency control and economic dispatch	CLO8	T1 :65-68
30	Understand the significance of reactive power control in power systems to maintain quality of power	CLO9	T1:296
31	Discuss equipment for voltage control, effect of series capacitors, line drop compensation, effect of AVR, power factor control using different types of power capacitors,	CLO9	T2:383 - 385
32	Describe the effect of series capacitors, line drop compensation, effect of AVR, power factor control using different types of power capacitors	CLO10	T2:383 - 385
33	Study the effect of series capacitors, line drop compensation,	CLO10	T2:383

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
	effect of AVR, power factor control using different types of power capacitors		
34	Learn the shunt and series capacitors, effect of shunt capacitors fixed and switched power factor correction,	CLO11	T 1: 330-345
35	Analyze the capacitor location and Reactive power control	CLO11	T2:337
36-37	Demonstrate the reactive power compensation in transmission systems	CLO11	T2:342-345
38	Distinguish between advantages and disadvantages of different types of compensating equipment for transmission systems	CLO11	T2:342-345
39	Describe the uncompensated and compensated transmission lines and shunt and series compensation.	CLO11	T2:337
40-42	Understand the uncompensated and compensated transmission lines and shunt and series compensation	CLO11	T2:325-327
43 - 44	Tutorial problems	CLO11	T2:325-327
45	Tutorial problems	CLO11	T2:325-327
46	Learn characteristics of loads and load compensation	CLO11	T2:25
47	Understand the significance of distribution systems and their characteristics	CLO12	T2:26-28
48	Illustrate the different types of loads and their characteristics	CLO12	T2:29-31
49	Derive the loss factor formula and load factor formula	CLO12	T2:29-31
50	Distinguish relation between the load factor and loss factor	CLO12	T2:29-31
51	Describe the specifications of load compensator	CLO12	T2:337
52	Understand the classification of loads (Residential, commercial, agricultural and industrial) and their characteristics.	CLO12	T2:31-35
53-55	Understand the classification of loads (Residential, commercial, agricultural and industrial) and their characteristics.	CLO12	T2:31-35
56-58	Tutorial Classes	CLO12	T2:31-35
59-60	Revision		

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

S No	Description	Proposed Actions	Relevance With POs	Relevance With PSOs
1	Designing of turbine model using digital simulation	Mat lab Demos / NPTEL	PO5	-
2	Optimum generation allocation without transmission line losses coefficients by using digital simulation	Mat lab Demos / NPTEL	PO5	-

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