INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	**POWER SYSTEM ANALYSIS**				
Course Code	AEE012				
Programme	B.Tech				
Semester	VI	EEE			
Course Type	Professional Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Mr. T. Anil Kumar, Assistant Professor				
Course Faculty	Mr. T. Anil Kumar, Assistant Professor Mr. P. Mabu Hussain, Assistant Professor				

I. COURSE OVERVIEW:

Power system analysis deals formation impedance and admittance matrices for power system network, finding different electrical parameters for various buses in power system, study fault analysis and represent power system using per unit system, understand steady state and transient stability of power system.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AEE002	II	Electrical Circuits	4
UG	AEE003	III	Power Generation Systems	4
UG	AEE011	V	Transmission And Distribution System	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Power System Analysis	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 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 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.	2	Assignment 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.	3	Assignment 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.	3	Assignment 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.	2	Assignment And Seminar

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO1	**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
PSO2	**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.	-	-
PSO3	**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	Determine the bus impedance and admittance matrices for power system network.
II	Calculate various electrical parameters at different buses using load flow studies and numerical methods.
III	Discuss the symmetrical component theory, sequence networks, short circuit calculations and per unit representation power system.
IV	Understand the steady state stability of power system and suggest methods to improve stability.
V	Analyze the transient stability of power system and check methods to improve the stability.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Formulate the bus impedance and admittance matrices for complex power system networks.	CLO 1	Define the basic terminology of graph theory to form bus impedance and admittance matrices..
		CLO 2	Determine the bus impedance and admittance matrices for power system.
		CLO 3	Draw the algorithms to form bus impedance and admittance matrices for configuration of primitive network.
CO 2	Identify unknown electrical quantity at various buses of power system and estimate.	CLO 4	Understand necessity of load flow studies and derive static load flow equations.
		CLO 5	Use different numerical methods to determine unknown parameters at various buses and to draw relevant algorithms.
		CLO 6	Compare various numerical methods of load flow studies and analyze DC load flow studies.
CO 3	Determine effect of symmetrical and unsymmetrical faults on power system in per unit system.	CLO 7	Draw the equivalent reactance network of three phase power system using per unit system.
		CLO 8	Calculate the electrical parameters under symmetrical fault conditions and understand symmetrical component theory.
		CLO 9	Compute the electrical parameters under unsymmetrical faults with and without fault impedance.
CO 4	Check the effect of slow and gradual change in load on power system and check the methods of improvement.	CLO 10	Discuss the steady state stability, dynamic stability and transient stability of power system.
		CLO 11	Describe steady state stability power limit, transfer reactance, synchronizing power coefficient, power angle curve.
		CLO 12	Determination of steady state stability and methods to improve steady state stability of power system.
CO 5	Discuss the characteristics of power system under large disturbances and methods to improve transient stability.	CLO 13	Derive the swing equation to study steady state stability of power system.
		CLO 14	Predict the transient state stability of power system using equal area criteria and solution of swing equation.
		CLO 15	Suggest the methods to improve transient stability, discuss application of auto reclosing and fast operating circuit breakers.

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
AEE012.01	CLO 1	Define the basic terminology of graph theory to form bus impedance and admittance matrices..	PO1	2
AEE012.02	CLO 2	Determine the bus impedance and admittance matrices for power system.	PO1,PO3	3
AEE012.03	CLO 3	Draw the algorithms to form bus impedance and admittance matrices for configuration of primitive network.	PO1,PO3	3
AEE012.04	CLO 4	Understand necessity of load flow studies and derive static load flow equations.	PO1,PO2	3

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AEE012.05	CLO 5	Use different numerical methods to determine unknown parameters at various buses and to draw relevant algorithms.	PO1,PO2, PO5	2
AEE012.06	CLO 6	Compare various numerical methods of load flow studies and analyze DC load flow studies.	PO2	2
AEE012.07	CLO 7	Draw the equivalent reactance network of three phase power system using per unit system.	PO1	2
AEE012.08	CLO 8	Calculate the electrical parameters under symmetrical fault conditions and understand symmetrical component theory.	PO1	3
AEE012.09	CLO 9	Compute the electrical parameters under unsymmetrical faults with and without fault impedance.	PO1,PO2	3
AEE012.10	CLO 10	Discuss the steady state stability, dynamic stability and transient stability of power system.	PO1,PO2	3
AEE012.11	CLO 11	Describe steady state stability power limit, transfer reactance, synchronizing power coefficient, power angle curve.	PO1,PO2, PO3	3
AEE012.12	CLO 12	Determination of steady state stability and methods to improve steady state stability of power system.	PO1,PO2, PO3	2
AEE012.13	CLO 13	Derive the swing equation to study steady state stability of power system.	PO1,PO3	2
AEE012.14	CLO 14	Predict the transient state stability of power system using equal area criteria and solution of swing equation.	PO1,PO2, PO3	2
AEE012.15	CLO 15	Suggest the methods to improve transient stability, discuss application of auto reclosing and fast operating circuit breakers.	PO1,PO2, PO3	2
AEE012.16	CLO 16	Apply the concept of graph theory, numerical methods, symmetrical and unsymmetrical fault to understand steady state and transient analysis.	PO1,PO2, PO3,PO5	2
AEE012.17	CLO 17	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations.	PO1,PO2, PO3,PO5, PO9,PO10, PO12	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	PO 5	PSO1
CO 1	2		3		2
CO 2	2	3		2	2
CO 3	2	3			3
CO 4	2	3	3		3
CO 5	1	3	2		3

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

Course Learning 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		3										2		
CLO 3	2		3										2		
CLO 4	2		3										3		
CLO 5	2	3			2								2		
CLO 6		2											2		
CLO 7	2												2		
CLO 8	3												3		
CLO 9	2	3											3		
CLO 10	2	3											3		
CLO 11	2	3	3										3		
CLO 12	1	2	2										3		
CLO 13	1		2										3		
CLO 14	1	3	3										3		
CLO 15	1	2	2										2		
CLO 16	1	3	3		2								3		
CLO 17	2	2	2		2				3	3		3	2		

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XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1,PO2 PO3,PO5	SEE Exams	PO1,PO2, PO3,PO5	Assignments	PO1,PO2 PO3,PO5	Seminars	PO1,PO2 PO3,PO5
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	POWER SYSTEM NETWORK MATRICES
Graph Theory: Definitions, bus incidence matrix, Y bus formation by direct and singular transformation methods, numerical problems; Formation of Z Bus: Partial network, algorithm for the modification of Z bus matrix for addition of element from a new bus to reference bus, addition of element from a new bus to an old bus, addition of element between an old bus to reference bus and addition of element between two old busses (Derivations and Numerical Problems), modification of Z bus for the changes in network (Numerical Problems).	
Unit-II	**POWER FLOW STUDIES AND LOAD FLOWS**
Load flows studies: Necessity of power flow studies, data for power flow studies, derivation of static load flow equations; Load flow solutions using Gauss Seidel method: Acceleration factor, load flow solution with and without PV buses, algorithm and flowchart; Numerical load flow solution for simple power systems (Max. 3 buses): Determination of bus voltages, injected active and reactive powers (Sample one iteration only) and finding line flows / losses for the given bus voltages; Newton Raphson method in rectangular and polar coordinates form: Load flow solution with or without PV busses derivation of Jacobian elements, algorithm and flowchart, decoupled and fast decoupled methods, comparison of different methods, DC load flow study.	
Unit-III	**SHORT CIRCUIT ANALYSIS PER UNIT SYSTEM OF REPRESENTATION**
Per unit system: Equivalent reactance network of a three phase power system, numerical problems; Symmetrical fault analysis: Short circuit current and MVA calculations, fault levels, application of series reactors, numerical problems; Symmetrical component theory: Symmetrical component transformation, positive, negative and zero sequence components, voltages, currents and impedances. Sequence networks: Positive, negative and zero sequence networks, numerical problems; Unsymmetrical fault analysis: LG, LL, LLG faults with and without fault impedance, numerical problems.	
Unit-IV	**STEADY STATE STABILITY ANALYSIS**
Steady state stability: Elementary concepts of steady state, dynamic and transient stabilities, description of steady state stability power limit, transfer reactance, synchronizing power coefficient, power angle curve and determination of steady state stability and methods to improve steady state stability.	
Unit-V	**TRANSIENT STATE STABILITY ANALYSIS**
Swing equation: Derivation of swing equation, determination of transient stability by equal area criterion, application of equal area criterion, critical clearing angle calculation, solution of swing equation, point by point method, methods to improve stability, application of auto reclosing and fast operating circuit breakers.	
Text Books:	
1. I J Nagrath & D P Kothari, "Modern Power system Analysis", Tata McGraw-Hill Publishing Company, 2nd Edition. 2. M A Pai, "Computer Techniques in Power System Analysis", TMH Publications. 3. B.R.Gupta, " power system analysis and design",S.CHAND publications 4. K Umarao, "Computer techniques and models in power systems", I K International Pvt. Ltd.	
Reference Books:	
1. Stagg , El Abiad, " Computer Methods In Power System". Tata McGraw-Hill.1968. 2. Grainger and Stevenson, "Power System Analysis", Tata McGraw-Hill, 3rd Edition, 2011. 3. J Duncan Glover and M S Sarma., THOMPSON, "Power System Analysis and Design", 3rd Edition 2006. 4. Abhijit Chakrabarthi and Sunita Haldar, "Power system Analysis Operation and control", 3rd Edition, PHI, 2010.	

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	Introduction to graph theory.	CLO1	T4:9.4.1 R1:3.1-3.2
2	Solve numerical problems on graph theory.	CLO1	T4:9.4.1 R1:3.1-3.2
3	Outline steps to form Building bus incidence matrix.	CLO2	T4:9.4.3 R1:3.3-3.5
4	Determination of Y bus using direct method.	CLO2	T4:9.2 R1:3.3-3.5
5,6	Derive expression for Y bus formation by singular transformation. methods,	CLO2	T4:9.2 R1:3.3-3.5
7	Solve numerical problems on bus matrices.	CLO2	T4:9.2 R1:3.3-3.5
8	Define Partial network and its importance.	CLO3	T4:9.4 R1:4.1
9	Develop algorithm for the Modification of Z Bus Matrix for addition element from a new bus to reference.	CLO3	T4:9.3&9.5 R1:4.2
10	Build algorithm for the Modification of Z Bus Matrix for addition element from a new bus to an old bus.	CLO3	T4: 9.3&9.5 R1:4.3-4.4
11,12	Structure algorithm for the Modification of Z Bus Matrix for addition element between an old bus to reference Addition of element	CLO3	T4: 9.3&9.5 R1:4.3-4.4
13	Study of necessity of power flow studies – Data for power flow studies – derivation of static load flow equations.	CLO4	T4:9.1 R1:8.1
14	Extract solution of load flow solutions using Gauss Seidel Method: Acceleration Factor.	CLO5	T4:9.8 R1:8.2
15	Develop load flow solution with and without P- V buses, Algorithm and Flowchart.	CLO5	T4:9.9.1 R1:9.2
16,17	Find numerical load flow solution for simple power systems (Max. 3- Buses): Determination of bus voltages, injected active and	CLO5	T4:9.8 R1:9.2
18,19	Discuss on newton raphson method in rectangular form: load flow, solution with or without PV busses- Derivation of jacobian elements.	CLO5	T4:9.10 R1:9.2
20	Discussion newton raphson method in polar co- ordinates form: load flow solution with or without pv busses-Derivation of jacobian	CLO5	T4:9.11.2 R1:9.2
21,22	Study on decoupled and fast decoupled methods for load flow solution.	CLO5	T4:9.12 R1:9.2
23	Comparison of Different Methods – DC load Flow.	CLO6	T4:9.4.12 R1:9.2
24,25	Summarize Short Circuit Current and MVA Calculations.	CLO7	T4:10.3 R1:6.1-6.3
26	Understand fault levels.	CLO7	T4:10.4 R1:6.1-6.3
27	Determine the application of series reactors.	CLO7	T4:10.4 R1:6.1-6.3
28	Solving numerical problems (Symmetrical fault Analysis).	CLO8	T4:10.4 R1:6.4
29	Understand symmetrical component transformation, positive, negative and zero sequence components.	CLO8	T4:10.5 R1:
30	Draw sequence networks.	CLO8	T4:10.6 R1:6.3
31	Derive sequence voltages, currents and impedances.	CLO08	T4:10.7 R1:6.3
32	Solving numerical problems on symmetrical components.	CLO8	T4:10.5 R1:6.3
33,34	Understand LG fault with and without fault impedance and numerical problems.	CLO9	T4:10.13 R1:6.3

Lecture No.	Topics to be covered	CLOs	Reference
35,36	Study fault with and without fault impedance and numerical problems.	CLO9	T4:10.13 R1:6.1-6.3
37,38	Determine LLG fault with and without fault impedance and numerical problems.	CLO09	T4:10.16 R1:6.1-6.3
39	Compare LG, LL, LLG faults with and without fault impedance and numerical problems.	CLO9	T4:10.17 R1:6.1-6.3
40,41	Introduction to steadystate, dynamic and transient stabilities.	CLO10	T4:13.1 R1:10.1
42,44	Description of steady state stability power limit, transfer reactance, synchronizing power coefficient.	CLO11	T4:13.2 R1:10.3
45,46	Plot Power Angle Curve and determination of steady state,. stability.	CLO11	T4:13.2 R1:
47,48	Explain methods to improve steady state stability.	CLO12	T4:13.2 R1:10.3
49	Derivation of swing equation.	CLO13	T4:13.3 R1:10.2
50,51	Determination of transient stability by equal area criterion.	CLO14	T4:13.6 R1:10.5
52	Application of equal area criterion to different cases.	CLO14	T4:13.7 R1:10.5
53	Discuss importance of critical clearing angle calculation.	CLO14	T4:13.6 R1:10.5
54,55	Solving numerical problems on equal area criteria.	CLO14	T4:13.7 R1:10.5
56	Solution of swing equation: point-by- point method.	CLO14	T4:13.8 R1:10.5
57	Explain methods to improve stability.	CLO15	T4:13.11 R1:10.6
58	Application of auto reclosing and fast operating circuit breakers.	CLO15	T4:13.11 R1:10.7

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

S. No	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Formation of bus impedance and admittance matrices using digital methods.	MATLAB Software	PO1, PO5	-
2	Power flow studies in integrated system.	Introduction To Distribution Generation	PO1, PO3	PSO1

Prepared by:
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