INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	**POWER SYSTEM PROTECTION**				
Course Code	**AEE014**				
Programme	**B.Tech**				
Semester	VII	**EEE**			
Course Type	**Core**				
Regulation	**IARE - R16**				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	**Mr. P Shivakumar, Assistant Professor**				
Course Faculty	**Mr. P Shivakumar, Assistant Professor**				

I. COURSE OVERVIEW:

The main objective of the course is to provide an overview of the principles and schemes for protecting power lines, transformers, buses, generators. It provides in depth knowledge of various types of relays and circuit breakers. It includes protection against over voltages in power system using lighting arrestors and insulation co-ordination

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AEE004	III	DC machines and transformers	4
UG	AEE007	IV	AC machines	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Power system protection	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	Assignments
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
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	Assignments & Seminars

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**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.	3	Assignments & Seminars
PSO 2	**Problem-Solving 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.	-	-
PSO 3	**Successful Career and Entrepreneurship:** 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	Understand types of various circuit breakers.
II	Classify relays into various types such as of electromagnetic, static and numerical relays.
III	Evaluate the performance of protection schemes of generator and transformer.
IV	Analyze the performance of feeder and bus-bar protection.
V	Discuss the protection schemes against over voltages.

XI. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Understand the working of various types of circuit breakers and protective equipments of power systems.	CLO 1	Understand various types of faults in Power system.
		CLO 2	Apply the knowledge on different Protective Equipments of Power Systems.
		CLO 3	Understand concept of recovery and restriking voltages.
		CLO 4	Understand working of various protective systems.
		CLO5	Compare the different type of circuit breakers performance based on which selection of circuit breaker can be made for a given application.
		CLO 6	Discuss the construction and working of Fuse and circuit breakers.
CO 2	Understand the working of various protective relays.	CLO 7	Explain working of protective relays.
		CLO 8	Understand the concept of DMT, IDMT type relays.
CO 3	Discuss about various components of substation and understand protection of feeders and bus bars.	CLO 9	Understand layout of Substations.
		CLO 10	Understand layout of Substations, neutral earthling, testing of CB, CT and PT.
		CLO 11	Remember the faults and protection for the Feeders and Bus-Bars.
		CLO 12	Understand and justify a suitable protection system for a specified application.
CO 4	Understand the various faults and protection methods for the Generators and Transformers.	CLO 13	Understand the faults and protection for the Generators and Transformers.
		CLO 14	Understand Rotor, Stator Faults, inter turn faults and their protection.
CO 5	Understand the various protection schemes of power system against over voltages.	CLO 15	Understand the protection of power system against over voltages.

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
AEE014.01	CLO 1	Understand various types of faults in Power system.	PO1, PO3	2
AEE014.02	CLO 2	Apply the knowledge on different Protective Equipments of Power Systems.	PO2, PO3	2
AEE014.03	CLO 3	Understand concept of recovery and restriking voltages.	PO1, PO3	3
AEE014.04	CLO 4	Understand working of various protective systems.	PO1, PO3	3
AEE014.05	CLO 5	Compare the different type of circuit breakers performance based on which selection of circuit breaker can be made for a given application.	PO2, PO3	2
AEE014.06	CLO 6	Discuss the construction and working of Fuse and circuit breakers.	PO2, PO3	2
AEE014.07	CLO 7	Explain working of protective relays.	PO2, PO3	2
AEE014.08	CLO 8	Understand the concept of DMT, IDMT type relays.	PO1, PO2	3
AEE014.09	CLO 9	Understand layout of Substations.	PO2, PO3	2

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AEE014.10	CLO 10	Understand layout of Substations, neutral earthling, testing of CB, CT and PT.	PO1, PO2	3
AEE014.11	CLO 11	Remember the faults and protection for the Feeders and Bus-Bars.	PO2, PO3	2
AEE014.12	CLO 12	Understand and justify a suitable protection system for a specified application.	PO1, PO2	3
AEE014.13	CLO 13	Understand the faults and protection for the Generators and Transformers.	PO1, PO2	2
AEE014.14	CLO 14	Understand Rotor, Stator Faults, inter turn faults and their protection.	PO2, PO3	3
AEE014.15	CLO 15	Understand the protection of power system against over voltages.	PO1, PO2	2

3= High; 2 = Medium; 1 = Low

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

Course Outcomes (COs)	Program Outcomes (POs)			
	PO 1	PO 2	PO 3	PSO1
CO 1	3	3	2	3
CO 2	3	3	2	2
CO 3	3	3	3	2
CO 4	2	3	2	2
CO 5	2	3	3	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										3		
CLO 2		2	2										3		
CLO 3	3		3										3		
CLO 4	3		3												
CLO 5		2	2												
CLO 6		2	2												
CLO 7		2	2												
CLO 8	3	3													
CLO 9		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 10	3	3													
CLO 11		2	2										3		
CLO 12	2	2											3		
CLO 13	2	2													
CLO 14		3	3												
CLO 15	2	2													

3= High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1, PO2, PO3	SEE Exams	PO1, PO2, PO3	Assignments	PO1, PO2	Seminars	PO4
Laboratory Practices	PO3, PO4	Student Viva	PO1, PO2	Mini Project	-	Certification	-
Term Paper	-						

XIV. ASSESSMENT METHODOLOGIES – INDIRECT

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

XV. SYLLABUS

MODULE-I	CIRCUIT BREAKERS	Classes: 08
Circuit Breakers: Elementary principles of arc interruption, restriking and recovery voltages, restriking phenomenon, average, maximum and rate of rise of restriking voltage, current chopping and resistance switching, circuit breaker ratings and specifications, auto reclosures, description and operation of various types of circuit breakers, minimum oil circuit breakers, air blast circuit breakers, vacuum and SF6 circuit breakers, numerical problems.		
MODULE-II	**ELECTROMAGNETIC, STATIC AND NUMERICAL RELAYS**	**Classes: 14**
Electromagnetic relays: Principle of operation and construction of attracted armature, balanced beam, induction disc and induction cup relays; Relays classification: instantaneous, definite minimum time and inverse definite minimum time relays over current / under voltage relays, direction relays, differential relays and percentage differential relays, universal torque equation; Distance relays: Impedance, reactance, mho and offset mho relays, characteristics of distance relays; Static relays: Overview of static relay, block diagram, operating principle and comparison, static relays versus electromagnetic relays; Numerical relays: Introduction, block diagram of numerical relay, sampling theorem, anti aliasing filter, block diagram of phasor measurement unit and intelligent electronic device, data acquisition systems and numerical relaying algorithms, applications and numerical problems.		
MODULE-III	**SUBSTATIONS AND PROTECTION OF FEEDER / BUS BAR**	**Classes: 07**
Indoor and outdoor substations: Substations layout, bus bar arrangements like single, sectionalized, main		

and transfer bus bar system with relevant diagrams; Gas insulated substation (GIS): Types, single line diagram, constructional aspects of GIS, Installation, maintenance, advantages, comparison of GIS with air insulated substations. Protection of lines: Over current, carrier current and three zone distance relay protection using impedance relays, translay relay; Protection of bus bars: Differential protection, grounded and ungrounded neutral systems, effect of ungrounded neutral on system performance, methods of neutral grounding, solid, resistance, reactance arcing grounds and grounding practices, application of numerical relays.		
MODULE-IV	**GENERATOR AND TRANSFORMER PROTECTION**	**Classes: 08**
Generator protection: Protection of generators against stator faults, rotor faults, and abnormal conditions, restricted earth fault and inter turn fault protection, numerical problems on percentage winding unprotected; Transformer protection: Percentage differential protections, numerical problem on design of current transformers ratio, buchholz protection.		
MODULE-V	**PROTECTION AGAINST OVER VOLTAGES**	**Classes: 08**
Over voltages in power systems: Generation of over voltages in power systems, protection against lightning over voltages, valve type and zinc oxide lighting arresters, insulation coordination, basic insulation level, impulse ratio, standard impulse test wave, volt time characteristics.		
Text Books:		
1. Sunil S Rao, "Switchgear and Protection", Khanna Publishers, 1st Edition, 2013. 2. Badari Ram, D N Viswakarma, "Power System Protection and Switchgear", TMH Publications, 1st Edition, 2001. 3. A R van C Warrington, "Protective Relays: Their Theory and Practice", Springer Science & Business Media, Volume 2, 2nd Edition, 1977. 4. B L Soni, Gupta, Bhatnagar, Chakrabarthy, "Power System Engineering", Dhanpat Rai & Co, 3rd Edition, 2007. 5. T S Madhava Rao, "Power system protection: static relays", McGraw-Hill Companies, 2nd Edition, 1989.		
Reference Books:		
1. Paithankar, S R Bhide, "Fundamentals of Power System Protection", PHI, 1st Edition, 2003. 2. C LWadhwa, "Electrical Power Systems", New Age international (P) Limited, 6th Edition, 2010. 3. VK Mehta, "Principles of power systems", S Chand Publications, 4th Edition, 2009.		

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 the Elementary principles of arc interruption	CLO 1	T4,R3
2	Understand the concept restriking and recovery voltages, restriking phenomenon, average, maximum and rate of rise of restriking voltage	CLO 1	T4,R3
3	Analyze average, maximum and rate of rise of restriking voltage with examples	CLO 2	T4,R3
4	Explain concept of the current chopping.	CLO 2	T4,R3
5	Understand the concept of resistance switching	CLO 2	T4,R3
6	Understand the operation of various types of circuit breakers such as minimum oil circuit breakers.	CLO 2	T4,R3
7	Understand the operation air blast circuit breakers	CLO 2	T4,R3
8	Explain the concept of vacuum.	CLO 3	T4,R3
9	Explain the concept of SF6 circuit breaker.	CLO 3	T4,R3

Lecture No	Topics to be covered	CLOs	Reference
10	Analyze examples on recovery, rate of rise of restriking voltage	CLO 6	T4,R3
11	Understand the Principle of operation and construction of attracted armature.	CLO 6	T4,R3
12	Explain the operation of balanced beam.	CLO 7	T4,R3
13	Explain the operation induction disc.	CLO 6	T4,R3
14	Explain the operation of induction cup relays;	CLO 7	T4,R3
15	List out types of relays and discuss briefly on instantaneous, definite minimum time and inverse relay	CLO 4	T4,R3
16	Understand the concept of definite minimum time relays,	CLO 4	T4,R3
17	Understand the concept over current / under voltage relays.	CLO 5	T4,R3
18	Explain the working of direction relays.	CLO 5	T4,R3
19	Explain the working of differential relays	CLO 5	T4,R3
20	Explain the working of percentage differential relays.	CLO 5	T4,R3
21	Derive universal torque equation; and discuss briefly on distance relay.	CLO 5	T4,R3
22	Explain operation and characteristics of Impedance relay	CLO 8	T4,R3
23	Explain operation and characteristics reactance relay.	CLO 8	T4,R3
24	Explain operation and characteristics of mho and offset mho relays.	CLO 9	T4,R3
25	Overview of static relay, block diagram and operating principle	CLO 9	T4,R3
26	Differentiate between static relays versus electromagnetic relays	CLO 9	T4,R3
27	Understand the concept of numerical relay	CLO 8	T4,R3
28	Understand block diagram of numerical relay	CLO 8	T4,R3
29	Understand sampling theorem, anti aliasing filter	CLO 8	T4,R3
30	Explain the block diagram of phasor measurement MODULE and intelligent electronic device,	CLO 8	T4,R3
31	Analyze data acquisition systems and numerical relaying algorithms.	CLO 10	T4,R3
32	Layout substations and bus bar arrangements like single.	CLO 10	T4,R3
33	Layout substations and bus bar arrangements like sectionalized.	CLO 10	T4,R3
34	Explain main and transfer bus bar system with relevant diagrams	CLO 10	T4,R3
35	Explain the concept of gas insulated substations and , single line diagram.	CLO 10	T4,R3
36	Understand constructional aspects of GIS	CLO 10	T4,R3
37	Discuss installation, maintenance of gas insulated substation.	CLO 10	T4,R3
38	Give advantages of gas insulated substations	CLO 13	T4,R3
39	Differentiate GIS with air insulated substations	CLO 13	T4,R3
40	Understand the concept of protection of lines over current,	CLO 13	T4,R3
41	Understand the concept of carrier current.	CLO 13	T4,R3

Lecture No	Topics to be covered	CLOs	Reference
42	Explain the concept of three zone distance relay protection using impedance relays	CLO 11	T4,R3
43	Explain the concept of translay relay;	CLO11	T4,R3
44	Understand the protection of bus bars using Differential protection, grounded and ungrounded neutral systems and effect of ungrounded.	CLO 11	T4,R3
45	Explain the methods of neutral grounding	CLO 11	T4,R3
46	Overview of generator protection	CLO 12	T4,R3
47	Explain protection of generators against stator faults, rotor faults, and abnormal conditions	CLO 12	T4,R3
48	Analyze numerical problems on percentage winding unprotected	CLO12	T4,R3
49	Overview on transformer protection and design of current transformers ratio,	CLO 14	T4,R3
50	Understand working of percentage differential protections,	CLO 14	T4,R3
51	Analyze numerical problem on design of current transformers ratio	CLO 14	T4,R3
52	Understand working of buchholz protection.	CLO 14	T4,R3
53	Overview of over voltages in power systems,.	CLO 15	T4,R3
54	Discuss generation of over voltages in power systems,	CLO 15	T4,R3
55	Understand protection against lightning over voltages,	CLO 15	T4,R3
56	Explain valve type and zinc oxide lighting arresters	CLO 15	T4,R3
57	Explain the phenomenon of insulation coordination,	CLO 15	T4,R3
58	Understand basic insulation level, impulse ratio,	CLO 15	T4,R3
59	Understand the concept of standard impulse test wave,	CLO 15	T4,R3
60	Determine volt time characteristics	CLO 15	T4,R3

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

S No	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Case studies on Power systems protection	NPTEL/Guest lectures	PO1, PO2, PO3	PSO1

Prepared by:

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