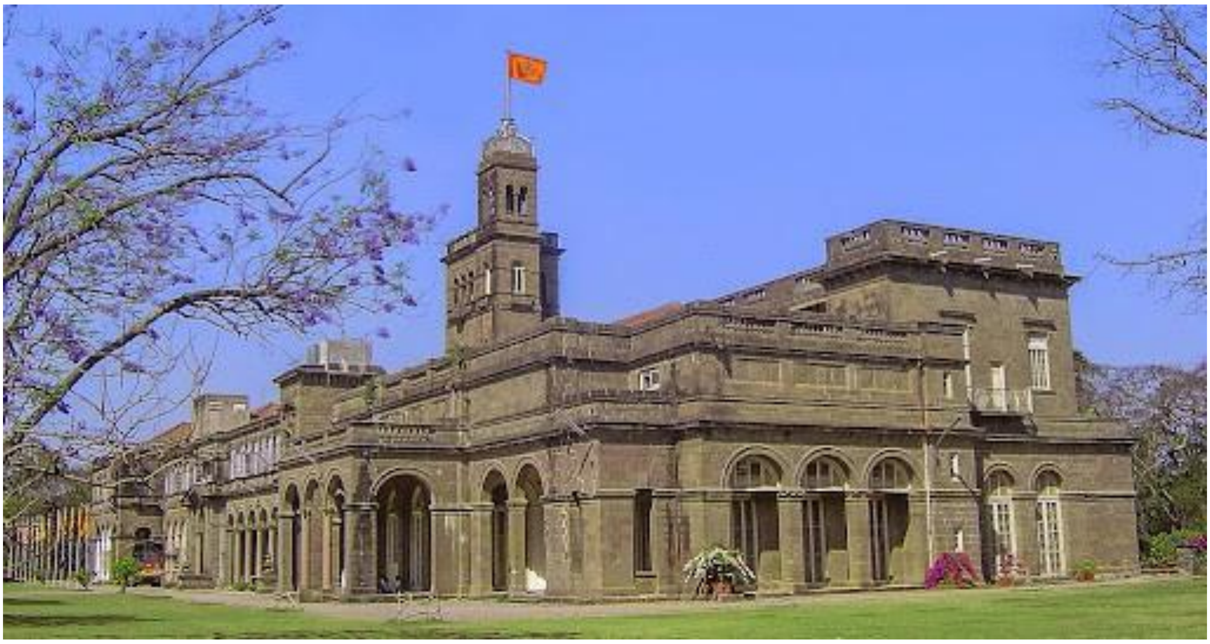
Savitribai Phule Pune University, Pune

Maharashtra, India

Faculty of Science and Technology



National Education Policy (NEP)-2020 Compliant Curriculum

TE-Third Year Engineering (2024 Pattern)

Electrical Engineering

(With effect from Academic Year: 2026-27)

Preface by Board of Studies

Dear Students and Teachers,

The Board of Studies-Electrical Engineering is pleased to present the revised Third Year Electrical Engineering curriculum under the 2024 Pattern, effective from the Academic Year 2026–27. The curriculum has been designed in alignment with the objectives of NEP-2020, AICTE, UGC, and Savitribai Phule Pune University, with emphasis on outcome-based education, multidisciplinary learning, and industry readiness.

The syllabus includes important core subjects such as Electrical Machines-II, Power Electronics, Electrical Installation Design & Condition Based Maintenance, Power System-II, and Control System Engineering along with associated laboratory courses to strengthen practical understanding and analytical skills. In addition, a wide range of elective courses including Embedded Systems, Solar Technology, Electric Vehicles, PLC & SCADA, Renewable Energy Systems, Energy Management, and Digital Signal Processing have been incorporated to address emerging technological advancements and industrial requirements.

The curriculum also focuses on innovation, skill development, and experiential learning through AI Applications in Electrical Engineering, Open Electives, Technical Seminar, Vocational Skill Courses, and Internship/On-Job Training. Students are encouraged to undertake self-learning through platforms such as NPTEL and SWAYAM to enhance their technical and professional competencies.

This curriculum is the result of extensive consultation with academic experts, industry professionals, and alumni to ensure relevance and excellence. It is designed not only to meet the current industry standards but also to prepare students for competitive exams, higher studies and research in the field of Electrical engineering.

We trust that this curriculum will inspire students to become competent professionals, responsible citizens, and contributors to the technological advancement of society.

Dr. Sanjay. A. Deokar
Chairman, Board of Studies (Electrical Engineering)
Savitribai Phule Pune University

Members of Board of Studies- Electrical Engineering	
Dr. B. E. Kushare	Dr. A. N. Sarwade
Dr. Mrs. A. G. Thosar	Dr. A. A. Kalage
Dr. Mrs. A. A. Godbole	Dr. D. M. Sonje
Dr. Rajendrakumar Sharma	Dr. A. R. Laware
Dr. Mrs. S. N. Chaphekar	Dr. S. S. Khule
Dr. Mrs. S. R. Deshmukh	Dr. D. P. Kadam
Dr. M. S. Thakare	

Nomenclature

CCE	Comprehensive Continuous Evaluation
ESE	End-Semester Examination
ELC	Experimental Learning Course
GAPC	Graduate Attributes and Professional Competencies
KAP	Knowledge and Attitude Profile
MDM	Multidisciplinary Minor
OE	Open Elective
OJT	On Job Training
PCC	Programme Core Course
PEC	Programme Elective Course
PEO	Programme Educational Objectives
PO	Program Outcomes
PSO	Program Specific Outcomes
QPD	Question Paper Delivery
SAR	Self-Assessment Report
SPPU	Savitribai Phule Pune University
SWAYAM	Study Webs of Active Learning for Young Aspiring Minds
UGC	University Grants Commission
VEC	Value Education Course
VSEC	Vocational and Skill Enhancement Course
VSC	Vocational Skill Courses
WK	Knowledge Profile

TE-Third Year of Engineering (2024 Course)

(With effect from Academic Year: 2026-27)

Table of Contents

Program Specific Outcomes (PSO)

Program Specific Outcomes (PSOs) refer to specific statements that describe what students are expected to know, think, or be able to do upon completion of a particular engineering program, reflecting the specialized knowledge and skills relevant to their field of study.

- **PSO1**: Test, operate, install & protect; AC/DC Electrical machines, power system and design of transformer & induction motor.
- **PSO2**: Select, measure, control, simulates & analyse; Systems in Electrical Engineering by using analog & digital circuits, power electronics, Microprocessor / Micro controllers, PLC / Scada and numerical methods

Program Educational Objectives (PEO)

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that engineering graduates are expected to achieve 4 to 5 years after completing the program.

PEO	PEO Focus	PEO Statements
PEO1	Core Technical Excellence	Graduates will establish themselves as competent professionals by applying core concepts of electrical engineering to analyze, design, and maintain electrical systems in industry, research, and academic settings
PEO2	Ethical, Social, and Global Responsibility	Graduates will exhibit professionalism, ethical behavior, and a commitment to societal and environmental responsibility while working in multidisciplinary teams and contributing to national and global development
PEO3	Professional Growth and Lifelong Learning	Graduates will pursue higher education, certifications, or self-directed learning to continuously enhance their knowledge and stay updated with evolving technologies in electrical and allied engineering domains.

Knowledge and Attitude Profile (WK)

A Knowledge and Attitude Profile (KAP), often represented as WK (Knowledge and Attitude Profile) In some contexts, is a framework or assessment tool used to evaluate an individual's knowledge and attitudes related to a specific area, topic, or domain.

WK1	A systematic, theory-based understanding of natural sciences applicable to the discipline and awareness of relevant social sciences.
WK2	Conceptually based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice are as in the engineering discipline; much is at the forefront of the discipline.
WK5	Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK9	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitudes.

Reference: Self-Assessment Report (SAR) Format Undergraduate Engineering Programs Graduate Attributes and Professional Competencies Version 4.0 (GAPCV4.0) -(August 2024) Page55.

Program Outcomes (POs)

POs are statements that describe what students are expected to know and be able to do upon graduating from the program. These relate to the skills, knowledge, attitude and behavior that students acquire through the program. On successful completion graduating students/graduates will be able to:

PO1	Engineering knowledge	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified inWK1 toWK4 respectively to develop to the solution of complex engineering problems
PO2	Problem analysis	Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1toWK4)
PO3	Design/Development of Solutions	Design creative solutions for complex engineering problems and design/develop systems/ components/ processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)
PO4	Conduct Investigations of Complex Problems	Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)
PO5	Engineering Tool Usage	Create, select and apply appropriate techniques, resources and modern engineering &IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 & WK6)
PO6	The Engineer and The World	Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).
PO7	Ethics	Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
PO8	Individual & Collaborative Team work	Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
PO9	Communication	Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences
PO10	Project Management and Finance	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.
PO11	Life-Long Learning	Recognize the need for and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)

Reference: Self-Assessment Report (SAR) Format Undergraduate Engineering Programs Graduate Attributes and Professional Competencies Version 4.0 (GAPCV4.0) -(August 2024) Page56.

General Rules and Guidelines

- **Course Outcomes (CO):** Course Outcomes are narrower statements that describe what students are expected to know and are able to do at the end of each course. These relate to the skills, knowledge and behaviour that students acquire in their progress through the course
- **Assessment**: Assessment is one or more processes, carried out by the institution, that identify, collect, and prepare data to evaluate the achievement of Program Educational Objectives and Program Outcomes.
- **Evaluation**: Evaluation is one or more processes, done by the Evaluation Team, for interpreting the data and evidence accumulated through assessment practices. Evaluation determines the extent to which Program Educational Objectives or Program Outcomes are being achieved, and results in decisions and actions to improve the program.

Guidelines for Examination Scheme

Theory Examination: The theory examination shall be conducted in two different parts Comprehensive Continuous Evaluation (CCE) and End-Semester Examination (ESE).

Comprehensive Continuous Evaluation (CCE):

1. CCE of 30 marks based on all the Units of course syllabus to be scheduled and conducted at institute level.
2. Case studies included under each unit are intended to support applied learning and are part of Comprehensive Continuous Evaluation
3. These case studies will be assessed through internal assessment components such as presentations, assignments, or group discussions. They shall not be included in the End-Semester Theory Examination.
4. To design a Comprehensive Continuous Evaluation scheme for a theory subject of 30 marks with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr.	Parameters	Marks	Coverage of Units
1	Unit Test	12 Marks	Units 1 & Unit 2 (6 Marks/Unit)
2	Assignments / Case Study	12 Marks	Units 3 & Unit 4 (6 Marks/Unit)
3	Seminar Presentation / Open Book Test/ Quiz	06 Marks	Unit 5

5. CCE of 15 marks based on all the Units of course syllabus to be scheduled and conducted at institute level. To design a CCE scheme for a theory subject of 15 marks with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr.	Parameters	Marks	Coverage of Units
1	Unit Test	10 Marks	Units 1 & Unit 2 (5 Marks/Unit)
2	Seminar Presentation / Open Book Test/ Assignments/Case Studies	05 Marks	Units 3 & Unit 4

Format and Implementation of Comprehensive Continuous Evaluation (CCE)

- **Unit Test**
  - **Format:** Questions designed as per Bloom's Taxonomy guidelines to assess various cognitive levels (Remember, Understand, Apply, Analyse, Evaluate, Create).
  - **Implementation:** Schedule the test after completing Units 1 and 2. Ensure the question paper is balanced and covers key concepts and applications.
- **Sample Question Distribution** [Topics from Units 1 and 2].
  - **Remembering (2 Marks):** Define related key terms.
  - **Understanding (2 Marks):** Explain the principle of [Concept] in [Context].
  - **Applying (2 Marks):** Demonstrate how [Concept] can be used in [Scenario].
  - **Analysing (3 Marks):** Compare & contrast [Two related concepts].
  - **Evaluating (3 Marks):** Evaluate the effectiveness of [Theory/Model] in [Situation].
- **Assignments / Case Study:** Students should submit one assignment, or one Case Study Report based on Unit 3 and one assignment, or one Case Study Report based on Unit 4.
  - **Format:** Problem-solving tasks, theoretical questions, practical exercises, or case studies that require in-depth analysis and application of concepts.
  - **Implementation:** Distribute the assignments or case study after covering Units 3 and 4. Provide clear guidelines and a rubric for evaluation.
- **Seminar Presentation**:
  - **Format:** Oral presentation on a topic from Unit 5, followed by a Q&A session.
  - **Deliverables:** Presentation slides, a summary report in 2 to 3 pages, and performance during the presentation.
  - **Implementation:** Schedule the seminar presentations towards the end of the course. Provide students with ample time to prepare and offer guidance on presentation skills.
- **Open Book Test:**
  - **Format:** Analytical and application-based questions to assess depth of understanding.
  - **Implementation:** Schedule the open book test towards the end of the course, ensuring it covers critical aspects of Unit 5.
- **Quiz:**
  - **Format:** Quizzes can help your students practice existing knowledge while stimulating interest in learning about new topic in that course. You can set your quizzes to be completed individually or in small groups.
  - **Implementation:** Online tools and software can be used create quiz. Each quiz is made up of a variety of question types including multiple choice, missing words, true or false etc
- **Example Timeline for conducting CCE:**
  - **Weeks 1-4** : Cover Units 1 and 2
  - **Week 5** : Conduct Unit Test (12 marks)

- **Weeks 6-9** : Cover Units 3 and 4
- **Week 10** : Distribute and collect Assignments / Case Study (12 marks)
- **Weeks 11-12** : Cover Unit 5
- **Week 13** : Conduct Seminar Presentations or Open Book Test or Quiz (6 marks)

- **Evaluation and Feedback:**
  - **Unit Test**: Evaluate promptly and provide constructive feedback on strengths and areas for improvement.
  - **Assignments / Case Study:** Assess the quality of submissions based on the provided rubric. Offer feedback to help students understand their performance.
  - **Seminar Presentation:** Evaluate based on content, delivery, and engagement during the Q&A session. Provide feedback on presentation skills and comprehension of the topic.
  - **Open Book Test:** Evaluate based on the depth of analysis and application of concepts. Provide feedback on critical thinking and problem-solving skills.

End-Semester Examination (ESE)

End-Semester Examination (ESE) of 70 marks written theory examination based on all the unit of course syllabus scheduled by university. Question papers will be sent by the University through QPD (Question Paper Delivery). University will schedule and conduct ESE at the end of the semester.

- **Format and Implementation:**
  - **Question Paper Design:** Below structure is to be followed to design an End Semester Examination (ESE) for a theory subject of 70 marks on all 5 units of the syllabus with questions set as per Bloom's Taxonomy guidelines and 14 marks allocated per unit.
  - **Balanced Coverage:** Ensure balanced coverage of all units with questions that assess different cognitive levels of Bloom's Taxonomy: Remember, Understand, Apply, Analyse, Evaluate, and Create. The questions should be structured to cover:
    - **Remembering**: Basic recall of facts and concepts.
    - **Understanding**: Explanation of ideas or concepts.
    - **Applying:** Use of information in new situations.
    - **Analysing:** Drawing connections among ideas.
    - **Evaluating**: Justifying a decision or course of action.
    - **Creating**: Producing new or original work (if applicable).

Unit wise marks allocation (for 70 Marks and 35 Marks Question Paper)

70 Marks Question Paper	35 Marks Question Paper
14 Marks per Unit	08 Marks for Unit1, 09 Marks for Unit 2, Unit 3 & Unit 4

Details: Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation

Curriculum Structure- Semester V

Third Year Engineering (2024 Pattern) – Electrical Engineering

Level 5.5

Course Code	Course Type	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credits			
			Theory	Tutorial	Practical	CCE	End-Sem	Term Work	Practical	Oral	Total	Theory	Tutorial	Practical	Total
PCC-301-ELE	Program Core Course	Electrical Machines-II	3	-	-	30	70	-	-	-	100	3	-	-	3
PCC-302-ELE	Program Core Course	Power Electronics	3	-	-	30	70	-	-	-	100	3	-	-	3
PCC-303-ELE	Program Core Course	Electrical Installation Design & Condition Based Maintenance	3	-	-	30	70	-	-	-	100	3	-	-	3
PCC-304-ELE	Program Core Course Lab	Electrical Machines-II Lab	-	-	2	-	-	25	25	-	50	-	-	1	1
PCC-305-ELE	Program Core Course Lab	Power Electronics Lab	-	-	2	-	-	25	25	-	50	-	-	1	1
PCC-306-ELE	Program Core Course Lab	Electrical Installation Design & Condition Based Maintenance Lab	-	-	2	-	-	25	-	25	50	-	-	1	1
PEC-321-ELE	Program Elective course	PEC-I	3	-	-	30	70	-	-	-	100	3	-	-	3
PEC-322-ELE	Program Elective course Lab	PEC-I Lab	-	-	2	-	-	25	-	-	25	-	-	1	1
MDM-331-ELE	Multidisciplinary minor	AI Applications in Electrical Engineering		2	2	-	-	25	-	25	50	-	2	1	3
	Open Elective*		2	-	-	15	35	-	-	-	50	2	-	-	2
ELC-342-ELE	Experimental learning course	Technical Seminar	-	-	2	-	-	-	-	25	25	-	-	1	1
Total			**14**	**02**	**12**	**135**	**315**	**125**	**50**	**75**	**700**	**14**	**02**	**06**	**22**

PEC-I (Theory)	PEC-I (Lab)	Course Name
PEC-321A-ELE	PEC-322A-ELE	Microcontroller and Embedded System
PEC-321B-ELE	PEC-322B-ELE	Renewable Energy systems
PEC-321C-ELE	PEC-322C-ELE	Computer aided design of Electric Machines

***Note**: Students can opt for Open Electives offered by different discipline/faculty like Law, Commerce and Management, Humanities or Inter-Disciplinary studies. Example - IPR and Cyber Laws, Sustainability Development, Digital Personal Data Protection, The Constitution of India, etc.

Curriculum Structure- Semester VI

Third Year Engineering (2024 Pattern) – Electrical Engineering

Level 5.5

Course Code	Course Type	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credits			
			Theory	Tutorial	Practical	CCE	End-Sem	Term Work	Practical	Oral	Total	Theory	Tutorial	Practical	Total
PCC-351-ELE	Program Core Course	Power System Engineering-II	3	-	-	30	70	-	-	-	100	3	-	-	3
PCC-352-ELE	Program Core Course	Control System Engineering	3	-	-	30	70	-	-	-	100	3	-	-	3
PCC-353-ELE	Program Core Course Lab	Power System Engineering-II Lab	-	-	2	-	-	25	25	-	50	-	-	1	1
PCC-354-ELE	Program Core Course Lab	Control System Engineering Lab	-	-	2	-	-	25	-	25	50	-	-	1	1
PEC-361-ELE	Program Elective course	PEC-II	3	-	-	30	70	-	-	-	100	3	-	-	3
PEC-362-ELE	Program Elective course Lab	PEC-II Lab	-	-	2	-	-	25	-	25	50	-	-	1	1
PEC-363-ELE	Program Elective course	PEC-III	3	-	-	30	70	-	-	-	100	3	-	-	3
MDM-371-ELE	Multidisciplinary minor	Evolutionary Algorithms in Electrical Engineering	-	1	2	-	-	25	-	25	50	-	1	1	2
VSEC-373-ELE	Vocational & skill Enhancement Course	Solar Technology and maintenance	-	-	2	-	-	25	-	25	50	-	-	1	1
ELC-381-ELE	Experimental learning course	Internship/OJT	-	-	8	-	-	-	-	50	50	-	-	4	4
Total			**12**	**1**	**18**	**120**	**280**	**125**	**25**	**150**	**700**	**12**	**01**	**09**	**22**

PEC-II (Theory)	PEC-II (Lab)	Course Name
PEC-361A-ELE	PEC-362A-ELE	Electric Vehicles-I
PEC-361B-ELE	PEC-362B-ELE	PLC and Scada
PEC-361C-ELE	PEC-362C-ELE	Energy Storage & Grid Interconnected Renewable Energy Systems

PEC-III (Theory)	Course Name
PEC-363A-ELE	Illumination Engineering
PEC-363B-ELE	Energy Management
PEC-363C-ELE	Digital Signal Processing

Savitribai Phule Pune University, Pune

Maharashtra, India

National Education Policy (NEP) Compliant Curriculum

SEMESTER-V

Third Year Engineering (2024 Pattern)

Electrical Engineering

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-301-ELE	**Course Name: Electrical Machines-II**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs	**03**	**CCE : 30 Marks**
Practical : 02 Hrs	**01**	**ESE : 70 Marks**

Prerequisites: Magnetic circuit fundamentals, Working principle and construction DC Machines, transformer & 3-ph induction motor, Phasor diagram and equivalent circuit of single-phase transformer, transmission line

Course Objectives:

1. To learn construction & working principle of three phase synchronous generator including cylindrical and salient pole type, effect of armature reaction on performance
2. To calculate voltage regulation of Alternator by direct and indirect methods
3. To study the operation, characteristics, performance analysis and applications of three phase synchronous motor
4. To understand speed control and applications of three phase induction motors, operation of induction generator and special purpose machine
5. To learn types, construction, working principle, performance analysis of single-phase induction motors

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Explain the construction and working principle of three-phase synchronous generator

CO2. Test and analyse the given 3-ph alternator by direct loading, EMF, MMF and potier methods for finding the voltage regulation.

CO3. Obtain the characteristics of a three-phase synchronous motor by varying excitation at constant mechanical load

CO4. Compare the 3-ph induction motor Vs induction generator, series motor on AC/DC supply & permanent Magnet motor AC Vs DC.

CO5. Compute the equivalent circuit parameters and efficiency of single- phase induction motor by conducting no load and blocked rotor test.

Course Contents

Unit No: I	**Three phase synchronous machines**	**08 Hours**

Three phase Synchronous machines: Construction, rotating-field type and rotating-armature type, salient-pole type and non-salient-pole type and their comparison. Excitation Methods for small, medium and large capacity synchronous generators

Three phase Synchronous generator (cylindrical rotor type): Principle of operation. Emf equation and winding factors (No derivation), rating of generator. Generator on no-load and on balanced load. Armature reaction and its effect under different load power factors. Voltage drop due to armature resistance, leakage flux and synchronous reactance. Per phase equivalent circuit and Phasor diagram. Power - power angle relation.

Three phase Synchronous generator (salient pole type): Armature reaction as per Blondel's two reaction theory for salient-pole machines, Direct-axis and quadrature-axis synchronous reactance's and their determination by slip test. Phasor diagram of Salient-pole generator and calculation of voltage regulation.

Reference Books	**T1, T2, T6, T7, T9, R3**

Unit No: II	**Voltage regulation of three phase synchronous generator**	**08 Hours**

Determination of voltage regulation by direct loading, Open circuit and short circuit test on synchronous generator, determination of voltage regulation by emf, mmf and Potier triangle methods. Short circuit ratio and its significance.

Parallel operation of 3-phase alternators: Necessity, conditions, Load sharing between two alternators in parallel (Descriptive treatment only). Process of synchronizing alternator with infinite bus-bar by one dark & two equally bright lamp method and by using synchroscope. Concept of synchronizing current, power and torque.

Reference Books	**T4, T6, T7, T9, R2**	
Unit No: III	**Three phase synchronous motor**	**08 Hours**

Principle of operation. Methods of starting. Equivalent circuit, significance of torque angle, Losses, efficiency and Power flow chart. Operation of 3-phase Synchronous motor with constant load and variable excitation (‘V’ Curves and ‘inverted V’ curves). Phenomenon of hunting and its remedies. Applications of 3-phase synchronous motors. Comparison of 3 phase synchronous motor with 3-phase induction motor.

Reference Books	**T1, T4, T6, T7, R2, R4**	
Unit No: IV	**Analysis of 3-ph induction motor, Induction generator and special purpose motors**	**08 Hours**

Speed control of three phase induction motor by various methods (Stator side and rotor side controls). Action of 3-phase induction motor as induction generator, applications of induction generator.

Operation of D.C. series motor on a.c. supply, nature of torque developed, problems associated with AC. operation and remedies, conductively and inductively compensated a c series motor. Applications, Introduction to Energy Efficient three phase Induction Motor.

Special Purpose Motors: Construction, principle of working, characteristics ratings and applications of Brush less D.C. motors, Stepper motors (permanent magnet and variable reluctance type only), Permanent Magnet motor (A.C. & D.C.).

Reference Books	**T3, T4, T6, T7, T9, R1, R2, R5**	
Unit No: V	**Single phase induction motor**	**08 Hours**

Construction of single-phase induction motor, double field revolving theory. Equivalent circuit and torque-slip characteristics on the basis of double revolving field theory. Tests to determine the parameters of equivalent circuit and calculation of performance characteristics of motor. Methods of self-starting. Types of single-phase induction motors: Split-phase motors (Resistor split-phase motor, Capacitor-start motor, Capacitor start and capacitor run motor and permanent capacitor motor). Comparison of 1-phase induction motor with 3-phase induction motor.

Reference Books	**T2, T3, T6, T7, T9, R2, R3**

Learning Resources

1. Text Books

[T1]. Nagrath and Kothari, Electrical Machines, 2nd Ed., Tata McGraw Hill.

[T2]. S. K. Bhattacharya, Electrical Machines, Tata McGraw Hill.

[T3]. A.S. Langsdorf, Theory of Alternating Current Machinery, Tata McGraw Hill

[T4]. P. S. Bimbhra, Electric Machinery, Khanna Publications.

[T5]. B.R. Gupta and Vandana Singhal -Fundamentals of Electric Machines, New Age International (P) Ltd.

[T6]. B. L Theraja –Electrical Technology vol II , S. Chand publication.

[T7]. V. K. Mehta and Rohit Mehta, Principles of Electrical Machines, S Chand Publication

[T8]. Krishna Reddy –Electrical Machines vol. II and III, SCITECH publications.

[T9]. Ashfaq Husain, Electrical Machines, Dhanpat Rai and Co.

[T10]. M V Deshpande, Electrical Machines, Prentice Hall of India

2. Reference Books

[R1]. M.G. Say, Performance and Design of A.C. Machines (3rd Ed.), ELBS

[R2]. J B Gupta - Theory and performance of Electrical Machines, S K Kataria Publications

[R3]. Samarjit Ghosh, Electrical Machines, Pearson Publication.

[R4]. Bhag S Guru and Huseyin R Hiziroglu, Electrical Machinary and Transformer, 3rd Edition, Oxford University Press.

[R5]. E G Janardanan, Special Electrical Machines, Prentice Hall of India.

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://www.youtube.com/watch?v=AWL-XQwxUdM

[M2]. Preview: Induction, Synchronous and Special Electrical Machines | SWAYAM

[M3]. nptel.ac.in/courses/108105131

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-302-ELE	**Course Name: Power Electronics**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs	**03**	**CCE : 30 Marks**
Practical : 02 Hrs	**01**	**ESE : 70 Marks**

Prerequisites: PN junction diodes, Zener diodes, BJTs, MOSFETs, and IGBTs. V–I characteristics. Resistors, inductors, capacitors, Ohm's law, Kirchhoff's laws. Transient, steady-state behavior of RL and RC circuits. Half-wave, full-wave, and bridge rectifiers, along with ripple, filtering, and efficiency concepts RMS and average values, power factor.

Course Objectives:

1. To introduce the fundamentals of solid-state power semiconductor devices, their construction, characteristics and ratings.
2. To develop understanding of the operating principles and performance of DC–DC, AC–DC and DC–AC power converters.
3. To analyze different converter control techniques, operating modes and power quality aspects.
4. To provide knowledge of modern inverter technologies, PWM techniques and multilevel converters used in industrial, renewable energy and electric vehicle applications.
5. To enable application of theoretical concepts through numerical problem solving.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Describe the construction, working principles, characteristics and ratings of solid-state power semiconductor devices.

CO2. Analyze the operating principles and performance of DC–DC converters (power choppers) under different configurations and control techniques.

CO3. Distinguish the operating modes and performance characteristics of single-phase and three-phase AC–DC power converters.

CO4. Explain the operating principles, circuit configurations and applications of single-phase and three-phase DC–AC inverters.

CO5. Summarize three-phase inverter operation, PWM techniques and the principle of operation of multilevel inverters for modern drive and EV applications.

Course Contents

Unit No: I	Power Semiconductor Devices and Protection	08 Hours

SCR – construction, static and dynamic characteristics, ratings and specifications, triggering circuits: R, RC and UJT. Commutation techniques: Class C and Class D. TRIAC – construction, four-quadrant operation (light dimmer). Transistor-based devices: MOSFET and IGBT – construction, working, static and dynamic characteristics. Introduction to wide band gap devices: Silicon Carbide (SiC) and Gallium Nitride (GaN) – features and applications (descriptive).

Exemplars/Case Studies	Design and analyze an RC triggering circuit for an SCR and study its effect on firing angle control.
Reference Books	**R1, R4**

Unit No: II	DC–DC Converters and Modern Control Techniques	08 Hours

Principle of DC–DC converters (choppers). Classification based on operating quadrants. Control techniques: PWM, CLC, TRC and FM (conceptual). Buck, boost and buck–boost converters – operation with R and RL loads. Bidirectional DC–DC converters and Dual Active Bridge (DAB) converter – concept, operation (descriptive).

Applications of DC-DC converters in battery management systems, electric vehicles and renewable energy systems.

Exemplars/Case Studies	**DC-DC converters in Electric Vehicles (EVs)** – Analyze how boost/buck converters regulate battery voltage for efficient EV operation.
Reference Books	**R1, R4**

Unit No: III	**AC–DC Converters (Controlled Rectifiers)**	**08 Hours**

Single-phase half-controlled and fully controlled converters. Operation with R and RL loads. Freewheeling diode. Performance parameters of fully controlled converters only: average and RMS output voltage, power factor, THD and TUF (conceptual). Single-phase dual converter (descriptive).

Applications in DC motor drives and EV battery chargers.

Exemplars/Case Studies	**EV battery charging system** – Study the use of controlled rectifiers for regulated DC charging of EV batteries.
Reference Books	**R1, R4**

Unit No: IV	**Three-Phase Converters and AC Voltage Controllers**	**08 Hours**

Three-phase half-controlled and fully controlled AC–DC converters. Operation with R and RL loads. Performance parameters of fully controlled converters, its characteristics and applications. Single-phase AC voltage controller with R and RL loads. Industrial and power conditioning applications.

Exemplars/Case Studies	**Industrial DC drives** – Analyze the use of three-phase converters in speed control of DC motors in industries.
Reference Books	**R1, R4**

Unit No: V	**DC–AC Inverters and Drive Applications**	**08 Hours**

Single-phase full-bridge VSI – operation and waveforms. Three-phase VSI. 120° and 180° modes – comparison. PWM techniques: single pulse modulation and sinusoidal PWM. Multilevel inverters – concept and classification (NPC and cascaded H-bridge). Applications in UPS, induction motor drives and electric vehicle traction systems

Exemplars/Case Studies	**UPS system using VSI inverter** – Study how inverters provide uninterrupted power supply during grid failure.
Reference Books	**R1, R4**

Learning Resources

1. Text Books

[T1]. Dr. P.S. Bimbhra, Power Electronics, Third Edition, Khanna Publication.
[T2]. K. Hari Babu, Power Electronics, Scitech Publication.
[T3]. M. D. Singh and K. B. Khandchandani, Power Electronics, Tata McGraw Hill.
[T4]. Ashfaq Ahmed- Power Electronics for Technology, LPE Pearson Edition.

2. Reference Books

[R1]. Vedam Subramanyam - Power Electronics , New Age International, New Delhi
[R2]. Dubey, Donalda, Joshi, Sinha, Thyristorised Power controllers, Wiley Eastern New Delhi.
[R3]. M. H. Rashid - Power Electronics 2nd Edition, Pearson publication.
[R4]. Ned Mohan, T.M. Undel and, W.P. Robbins - Power Electronics, 3rd Edition, John Wiley and Sons.

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/108105066
[M2]. https://nptel.ac.in/courses/108102145

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-303-ELE	**Course Name: Electrical Installation, Design and Condition Based Maintenance**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs	**03**	**CCE : 30 Marks**
Practical : 02 Hrs	**01**	**ESE : 70 Marks**

Prerequisites: Basic Electrical Engg, Power System 1, Electrical Machines I and Electrical Machines II

Course Objectives:

1. To classify different types of distribution supply system and determine economics of distribution system.
2. To compare and classify various substation equipment's and earthing systems.
3. To demonstrate the importance and necessity of maintenance.
4. To analyze and test different condition monitoring methods.
5. To carry out estimation and costing of internal wiring for residential and commercial installations.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Classify the types of distribution supply systems and determine economics of distribution system.
CO2. Enlist the equipment's used in the substation and analyze the earthing of substation as per IEEE standard 80-2013.
CO3. Demonstrate the breakdown maintenance, planned/preventive maintenance and condition-based maintenance of transformer, induction motors and alternators along with insulation level.
CO4. Prepare detailed estimates, analyze the rates of electrical wires, cables, equipments, and draft the tender documents for the purchase as per specifications.
CO5. Explain the procedure of insulation resistance & Earth resistance testing of residential and commercial installations with necessary safety measures.

Course Contents

Unit No: I	Economics of Distribution Systems	08 Hours

Classification of supply systems (State Only) (i)DC, 2-wire system, (ii) Single phase two wire ac system, (iii) Three phase three wire ac supply system, iv) Three phase four wire ac supply system. Comparison between overhead and underground systems (For above mentioned systems) on the basis of volume requirement for conductor. AC Distribution System: Types of primary and secondary distribution systems, calculation of voltage drops in ac distributors (Uniform and Non Uniform Loading) (Numerical) Economics of power transmission: Economic choice of conductor (Kelvin's law) (Derivation and Numerical) Distribution Feeders: Design considerations of distribution feeders; radial and ring types of primary feeder's voltage levels, energy losses in feeders.

Exemplars/Case Studies	
Reference Books	

Unit No: II	Substation and Earthing	08 Hours

Substation: classification of substations, various equipment's used in substation with their specifications, bus bar arrangements in the substation: simple arrangements like single bus bar, sectionalized single bus bar, main and transfer bus bar system with relevant diagrams. Earthing: necessity of earthing, types of earthing system (equipment and neutral), and maintenance free earthing system. Methods of testing earth resistance, different electrode configurations (plate and pipe electrode), tolerable step and touch voltages, steps involved in design of substation earthing grid as per IEEE standard 80 – 2013

Exemplars/Case Studies	
Reference Books	

Unit No: III	Maintenance and Condition Monitoring	08 Hours

Importance and necessity of maintenance, different maintenance strategies like breakdown maintenance, planned/preventive maintenance and condition-based maintenance. Planned and preventive maintenance of transformer, Induction motor and Alternators. Insulation stressing factors, Insulation deterioration, polarization index, dielectric absorption ratio. Concept of condition monitoring of electrical equipment's. Advanced tools and techniques of condition monitoring. Induction motor fault diagnostic methods – Vibration Signature Analysis, Motor Current Signature Analysis.

Hot Line Maintenance - Meaning and advantages, special types of non-conducting Materials used for tools for hot line maintenance

Exemplars/Case Studies	
Reference Books	**R1**

Unit No: IV	Basics of Estimation and Costing	08 Hours

Purpose of estimating and costing, qualities of good estimator, essential elements of estimating and costing, tender, guidelines for inviting tenders, quotation, price catalogue, labour rates, schedule of rates and estimating data (only theory)

Estimation of distribution system: Introduction cable sizing, Estimation and conductor size calculations of internal wiring for Residential and Commercial (Numerical) installations and estimate for underground LT service lines.

Exemplars/Case Studies	
Reference Books	**R6**

Unit No: V	Testing of Installation and Electrical Safety	08 Hours

Understanding CAT Ratings & Using CAT rated Instrument, Electrical Installation Testing Procedures- Insulation resistance test between installation and earth, Insulation resistance test between conductors (use of GUARD Terminal in IR test & Application) (methods used for IR Testing) Testing of polarity, Testing of earth continuity paths (Applications of PAT Tester "Portable Appliance Tester" in commercial like hotels hospital & Industry also) and Earth resistance test (methods for earth testing 2-pole,3-pole new methods clamp on type where we can performs test in Live)

Exemplars/Case Studies	
Reference Books	**T6**

Learning Resources

1. Text Books

[T1]. B. R. Gupta- Power System Analysis and Design, 3rd edition, Wheeler's publication.
[T2]. S. Rao, Testing Commissioning Operation and Maintenance of Electrical Equipment, Khanna publishers.
[T3]. S. L. Uppal - Electrical Power - Khanna Publishers Delhi.
[T4]. Handbook of condition monitoring by B. K. N. Rao, Elsevier Advance Tech., Oxford (UK).
[T5]. S. K. Shastri – Preventive Maintenance of Electrical Apparatus – Katson Publication House.
[T6]. B. V. S. Rao – Operation and Maintenance of Electrical Equipment – Asia Publication.

2. Reference Books

[R1]. P.S. Pabla –Electric Power Distribution, 5th edition, Tata McGraw Hill.
[R2]. S. L. Uppal, Electrical Wiring and Costing Estimation, Khanna Publishers, New Delhi.
[R3]. Surjit Singh, Electrical wiring, Estimation and Costing, Dhanpat Rai and company, New Delhi.

[R4]. Raina K.B. and Bhattacharya S.K., Electrical Design, Estimating and Costing, Tata McGraw Hill, New Delhi.

[R5]. B.D. Arora-Electrical Wiring, Estimation and Costing, - New Heights, New Delhi.

[R6]. M.V. Deshpande, Elements of Power Station design and practice, Wheelers Publication.

[R7]. S. Sivanagaraju and S. Satyanarayana, Electric Power Transmission and Distribution, Pearson Publication.

[R8]. Power Equipment Maintenance and Testing (Power Engineering Book 32) by Paul Gill

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://onlinecourses.nptel.ac.in/noc26_ee59/preview

[M2]. https://onlinecourses.nptel.ac.in/noc25_ee102/preview

[M3]. https://onlinecourses.nptel.ac.in/noc25_ee57/preview

[M4]. https://onlinecourses.nptel.ac.in/noc25_ge19/preview

[M5]. https://onlinecourses.nptel.ac.in/noc26_ee26/preview

Enlist the equipment's used in the substation and analyze the earthing of substation as per IEEE standard 80-2013. "Prepare detailed estimates, analyze the rates of electrical equipment's, and draft tender documents for purchase of equipment's as per specifications."

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-304-ELE	**Course Name: Electrical Machines-II Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**01**	**TW : 25 Marks**
		PR : 25 Marks

Prerequisites: Magnetic circuit fundamentals, Working principle and construction DC Machines, transformer & 3-ph induction motor. Phasor diagram and equivalent circuit of single-phase transformer, transmission line

Course Objectives:

1. To understand the construction, operation, and performance characteristics of cylindrical rotor and salient pole alternators through various regulation determination methods such as EMF, MMF, Potier, slip test, and direct loading.
2. To analyze the performance characteristics of synchronous motors by conducting load tests and studying V and inverted V curves at constant load conditions.
3. To study the operating principles and performance characteristics of single-phase and three-phase induction motors through load tests, no-load tests, and blocked rotor tests.
4. To investigate various speed control methods of three-phase induction motors, including V/f control and rotor resistance control techniques.
5. To understand synchronization techniques and modern motor control methods, including synchronization of alternators (lamp and synchroscope methods), MATLAB simulation of induction motors, and BLDC motor speed control.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Determine the voltage regulation of alternators using EMF, MMF, Potier, slip test, and direct loading methods and compare the results analytically and graphically

CO2. Analyze and interpret the performance characteristics of synchronous motors, including V-curves and inverted V-curves under constant load conditions

CO3. Evaluate the equivalent circuit parameters and performance of single-phase induction motor using experimental test data

CO4. Implement and compare different speed control techniques of three-phase induction motors, such as V/f control and rotor resistance control.

CO5. Perform synchronization of alternators and analyze motor performance using simulation tools like MATLAB and evaluate modern motor systems such as BLDC motors.

List of Experiments

Perform eight experiments from the following list:

Compulsory experiments:

1. Determination of voltage regulation of cylindrical rotor alternator by following methods
   a) EMF method b) MMF method.
2. Determination of regulation of cylindrical rotor alternator by Potier method.
3. Determination of regulation of salient pole alternator by slip test.
4. V and inverted V curve of synchronous motor at constant load.

5. Speed control of three phase induction motor by V/F method

Optional Experiments (Any three)

1. Determination of Regulation of alternator by direct loading.
2. Load test on three phase synchronous motor.
3. Load test on Single -phase induction motor.
4. Load test on Single-phase series motor.
5. No load and blocked-rotor test on a single-phase Capacitor-start induction motor and Determination of its equivalent circuit parameters.
6. Synchronization of three phase alternator by Lamp and Synchroscope methods.
7. Simulation of three phase induction motor on MATLAB to obtain its performance.
8. Speed control of three phase induction motor by rotor resistance control method.
9. Load test on BLDC Motor
10. Speed control of BLDC Motor

Guidelines for Instructor's Manual

The Instructor's Manual should contain the following related to every experiment:

- Prepare 3/4 sets of standard experiments. It must contain title of the experiment. Also, Aim, Apparatus including name of machines with their specifications, rheostats, ammeter, voltmeter, wattmeter if used along with their ratings / ranges etc.

Theory: Brief theory explaining the experiment

Circuit / connection diagram or construction diagram must be drawn either manually using geometrical instruments or using software on A-4 size quality graph paper / plain white paper.

Procedure: Write down step by step procedure to perform the experiment.

Observation table:

Sample calculation: For obs. number ---

Result table:

Nature of graph:

Conclusion:

Questions / Answers: Write minimum 4 /5, questions / answers based on each experiment.

Theory part must be typed on A-4 good quality paper on single side. Put these pages of experiments / circuit diagram in plastic folder and provide it to a group of 4/5 students.

Guidelines for Students Lab Manual

The student's Lab Journal should contain the following related to every experiment:

1. Students should write the journal in his own handwriting.
2. Circuit / Connection diagram or construction diagram must be drawn either manually using or using software. [Do not use Xerox copy of standard journal]
3. Handwriting must be neat and clean.
4. Journal must contain certificate indicating name of the institute, student, department, subject, class/ year, number of experiments completed, signature of staff, Head of the department and the Principal.
5. Index must contain sr. number, title of the experiment, page number, and the signature of staff along with date.
6. Put one blank page in between two experiments. Prepare the parallelogram at the center of page and write experiment number, date and title of the experiment in separate line.
7. (Use black or blue ink pen for writing.)

Guidelines for Lab conduction

1. Check whether the MCB / main switch is off.
2. Students should go through the name plates of machines.
3. Make connections as per circuit diagram. Use flexible wire for connection of voltmeter and pressure coil connection of wattmeter. For rest of the connections, use thick wire. Do not keep loose connection. Get it checked from teacher / Lab Assistant.
4. Perform the experiment only in presence of teacher or Lab Assistant.
5. Do the calculations and get it checked by the teacher.
6. After completion of experiment, switch off the MCB / main switch
7. Write the experiment in the journal and get it checked within week

Learning Resources

1. Text Books

[T1]. Nagrath and Kothari, Electrical Machines, 2nd Ed., Tata McGraw Hill
[T2]. S. K. Bhattacharya, Electrical Machines, Tata McGraw Hill.
[T3]. A.S. Langsdorf, Theory of Alternating Current Machinery, Tata McGraw Hill
[T4]. P. S. Bimbhra, Electric Machinery, Khanna Publications.
[T5]. B.R. Gupta and Vandana Singhal -Fundamentals of Electric Machines, New Age International (P) Ltd.
[T6]. B. L Theraja –Electrical Technologyvol II , S. Chand publication.
[T7]. V. K. Mehta and Rohit Mehta, Principles of Electrical Machines, S Chand Publication
[T8]. Krishna Reddy –Electrical Machines vol.II and III, SCITECH publications.
[T9]. Ashfaq Husain, Electrical Machines, Dhanpat Rai and Co
[T10]. M V Deshpande, Electrical Machines, Prentice Hall of India

2. Reference Books

[R1]. M.G. Say, Performance and Design of A.C. Machines (3rd Ed.), ELBS
[R2]. J B Gupta - Theory and performance of Electrical Machines, S K Kataria Publications
[R3]. Samarjit Ghosh, Electrical Machines, Pearson Publication.
[R4]. Bhag S Guru and Huseyin R Hiziroglu, Electrical Machinary and Transformer, 3rd Edition,Oxford University Press.
[R5]. E G Janardanan, Special Electrical Machines, Prentice Hall of India.

3. Links to online SWAYAM/NPTEL Courses

[M1]. Electrical Machines - II, IIT Kharagpur,Prof. Tapas Kumar Bhattacharya
https://nptel.ac.in/courses/108105131

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-305-ELE	**Course Name: Power Electronics Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**01**	**TW : 25 Marks** **PR : 25 Marks**

Prerequisites: PN junction diodes, Zener diodes, BJTs, MOSFETs, and IGBTs. V–I characteristics. Resistors, inductors, capacitors, Ohm's law, Kirchhoff's laws. Transient, steady-state behavior of RL and RC circuits. Half-wave, full-wave, and bridge rectifiers, along with ripple, filtering, and efficiency concepts RMS and average values, power factor.

Course Objectives:

1. To introduce the fundamentals of solid-state power semiconductor devices, their construction, characteristics and ratings.
2. To develop understanding of the operating principles and performance of DC–DC, AC–DC and DC–AC power converters.
3. To analyze different converter control techniques, operating modes and power quality aspects.
4. To provide knowledge of modern inverter technologies, PWM techniques and multilevel converters used in industrial, renewable energy and electric vehicle applications.
5. To enable application of theoretical concepts through numerical problem solving.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Describe the construction, working principles, characteristics and ratings of solid-state power semiconductor devices.

CO2. Analyze the operating principles and performance of DC–DC converters (power choppers) under different configurations and control techniques.

CO3. Distinguish the operating modes and performance characteristics of single-phase and three-phase AC–DC power converters.

CO4. Explain the operating principles, circuit configurations and applications of single-phase and three-phase DC–AC inverters.

CO5. Summarize three-phase inverter operation, PWM techniques and the principle of operation of multilevel inverters for modern drive and EV applications.

List of Experiments

Any four experiments from PART A (Hardware), any four experiments from PART B (Hardware/ simulation based) and any two experiments from PART C (VLAB) need to be conducted.

PART A: Hardware Experiments

1. Static V–I characteristic of SCR & TRIAC.
2. Single-phase half-controlled converter and fully controlled converter with R load.
3. Single-phase fully controlled converter with and without freewheeling diode with RL load
4. Three-phase AC–DC fully controlled bridge converter with R and RL load
5. Study of DC step-down and Step-up chopper.
6. Single-phase AC voltage regulator with R and RL load
7. Output and transfer characteristics of MOSFET and IGBT

8. Three-phase voltage source inverter using 120° and 180° modes of operation

PART B: Hardware/ Simulation Experiments

1. Fabrication of buck converter / inverter / AC voltage regulator *(Compulsory)*
2. Study of single-phase bridge inverter using SPWM
3. Design of SMPS
4. Power quality analysis at AC side of single-phase controlled converter
5. Power quality analysis at AC side of three-phase controlled converter
6. Performance analysis of three-phase diode-clamped multilevel inverter
7. Performance analysis of three-phase cascaded H-bridge multilevel inverter
8. Study of standalone / grid-connected converters for interfacing renewable energy sources
9. Industrial visit to power electronics manufacturing unit / renewable energy power plant. (Compulsory).

PART C: VLAB Experiments

Path:

- ⇨ **Type vlab.co.in**
- ⇨ **Scroll down and select Electrical Engineering**
- ⇨ **Select Power Electronics I Virtual Lab (New), IIT Delhi**
- ⇨ **Click on List of Experiments**

List of experiments

1. Characteristics of controlled switching power devices. (a) SCR (b) MOSFET (c) IGBT
2. Performance measurement and analysis of single-phase AC-DC controlled bridge rectifier
3. Performance measurement and analysis of single-phase AC voltage controller
4. Performance measurement and analysis of three-phase AC-DC Controlled bridge rectifiers
5. Single phase IGBT inverter under sinusoidal PWM control
6. Three phase IGBT inverter under sinusoidal PWM control

Guidelines for Instructor's Manual

The Instructor's Manual should contain the following related to every experiment:

- Include the title, aim, and objective of each experiment clearly.
- Provide neat and labeled circuit diagrams of the power electronic switching device or converter circuit.
- Explain the working principle and operating modes of the device/converter.
- Include theoretical background with relevant equations and operating conditions.
- Present expected output waveforms and V–I/output characteristics wherever applicable.
- Mention the list of required equipment and specifications such as ratings of SCR, MOSFET, IGBT, CRO, DC supply, etc.
- Provide a step-by-step experimental procedure for conducting the experiment safely and effectively.
- Include precautions and safety measures to avoid damage to devices and equipment.
- Add observation tables, sample calculations, and expected results for reference.
- Include viva questions and troubleshooting guidelines related to the experiment.
- Write a minimum of 4–5 questions and answers based on each experiment for better understanding and viva preparation.
- The theory part must be typed on good-quality A4 size paper on a single side only, and all experiment sheets/circuit diagrams should be arranged in a plastic folder and provided to a group of 4–5 students.

Guidelines for Students Lab Manual

The student's Lab Journal should contain the following related to every experiment:

1. Write the title, aim, and objectives of the experiment clearly at the beginning.
2. Include the circuit diagram with proper labelling of all components and ratings.
3. Write the theory related to the switching device or converter operation in brief.
4. Mention the equipment and instruments used along with their specifications.
5. Record the procedure in sequential steps before performing the experiment.
6. Maintain observation tables, calculations, and waveform sketches neatly on the left side of the journal.
7. Write aim, theory, procedure, and precautions on the right side of the journal.
8. Plot and analyze the obtained output characteristics or waveforms properly.
9. Interpret the experimental results and compare them with theoretical expectations.
10. Write a clear conclusion summarizing the outcome and learning from the experiment

Guidelines for Lab conduction

1. Each laboratory batch should consist of groups with a maximum of three students.
2. All students in the group must actively participate in circuit connections and experimentation.
3. The instructor should explain the objective, circuit operation, and safety precautions before starting the experiment.
4. Students must verify all circuit connections with the staff member before switching ON the supply.
5. Proper handling of power electronic devices and measuring instruments must be ensured during the experiment.
6. Staff members should monitor the experimental procedure and guide students during waveform observation and calculations.
7. Each group must record observations, waveforms, and readings systematically during the experiment.
8. The instructor should verify and validate the experimental results of every group.
9. Laboratory discipline, safety practices, and proper shutdown procedures must be strictly followed.
10. Students should submit completed lab records and analysis after every experiment for evaluation.

Learning Resources

1. Text Books

[T1]. Dr. P.S. Bimbhra, Power Electronics, Third Edition, Khanna Publication.

[T2]. K. Hari Babu, Power Electronics, Scitech Publication.

[T3]. M. D. Singh and K. B. Khandchandani, Power Electronics, Tata McGraw Hill.

[T4]. Ashfaq Ahmed- Power Electronics for Technology, LPE Pearson Edition

2. Reference Books

[R1]. Vedam Subramanyam - Power Electronics, New Age International , New Delhi

[R2]. Dubey, Donalda, Joshi, Sinha, Thyristorised Power controllers, Wiley Eastern New Delhi.

[R3]. M. H. Rashid - Power Electronics 2nd Edition, Pearson publication.

[R4]. Ned Mohan, T.M. Undel and, W.P. Robbins - Power Electronics, 3rd Edition, John Wiley and Sons

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/108105066

[M2]. https://nptel.ac.in/courses/108102145

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-306-ELE	**Course Name: Electrical Installation, Design and Condition Based Maintenance Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**01**	**TW : 25 Marks** **OR : 25 Marks**

Prerequisites: Basic Electrical Engg, Power System 1, Electrical Machines I and Electrical Machines II

Course Objectives:

1. To classify different types of distribution supply system and determine economics of distribution system.
2. To compare and classify various substation equipment's and earthing systems.
3. To demonstrate the importance and necessity of maintenance.
4. To analyze and test different condition monitoring methods.
5. To carry out estimation and costing of internal wiring for residential and commercial installations

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Classify the types of distribution supply systems and determine economics of distribution system.

CO2. Enlist the equipment's used in the substation and analyze the earthing of substation as per IEEE standard 80-2013.

CO3. Demonstrate the breakdown maintenance, planned/preventive maintenance and condition-based maintenance of transformer, induction motor and alternators along with insulation level.

CO4. Prepare detailed estimates, analyze the rates of electrical wires, cables, equipment's, and draft the tender documents for the purchase as per specifications.

CO5. Explain the procedure of insulation resistance & Earth resistance testing of residential and commercial installations with necessary safety measures.

List of Experiments

Perform eight experiments from the following list:

Compulsory experiments:

1. Single line diagram of 132 or 220 or 400 kv substation (based on actual field visit) symbols, plate or pipe earthing. (Drawing sheets using AutoCAD software).
2. Wiring and cabling on electrical lab (workshop) including MCCB, ELCB, MCB, distribution box. (Drawing sheets using AutoCAD software).
3. Measurement of soil resistivity by using 4 point Wenner method as per IEEE standard 81-2012.

Optional Experiments (Any five)

1. Measurement of dielectric absorption ratio and polarization index of insulation.
2. Study of thermograph images and preparation of thermograph report based on images taken.
3. Assignment on design of earthing grid for 132/220 kv substation.
4. Measurement of insulation resistance of motors and cables.
5. Estimation and costing for 11 kv feeders and substation. (voltage drop calculation, sld, substation layout).
6. Design, estimation and costing of earthing pit and earthing connection for computer lab, electrical

machines lab.

7. Use REVIT / any BOQ (bill of quantity) estimation software for estimation and costing.
8. Precautions from electric shock and method of shock treatment.

Beyond Syllabus

1. Inspection and testing of elevators.
2. Indian electricity rules of central electricity authority (CEA) 2024.
3. Study of bore well motor-pump and maintenance of bore well motor-pump.

Industrial visit: visit to any one of the following repair workshops.

(i) three phase induction motor (ii) transformer (iii) power cable.

Guidelines for Instructor's Manual

The Instructor's Manual should contain the following related to every experiment:

1. Provide structured guidance for conducting lab experiments.
2. Ensure uniform teaching methodology.
3. Maintain safety standards.
4. Help instructors evaluate students effectively.
5. Support outcome-based education (OBE) requirements.

Guidelines for Students Lab Manual

The student's Lab Journal should contain the following related to every experiment:

1. Experiment Title.
2. Aim.
3. Apparatus Required.
4. Theory.
5. Circuit Diagram.
6. Procedure.
7. Observations Table.
8. Calculations.
9. Result.

Learning Resources

1. Text Books

[T1]. B. R. Gupta- Power System Analysis and Design, 3rd edition, Wheeler's publication.
[T2]. S. Rao, Testing Commissioning Operation and Maintenance of Electrical Equipment, Khanna publishers.
[T3]. S. L. Uppal - Electrical Power - Khanna Publishers Delhi.
[T4]. Handbook of condition monitoring by B. K. N. Rao, Elsevier Advance Tech., Oxford (UK).
[T5]. S. K. Shastri – Preventive Maintenance of Electrical Apparatus – Katson Publication House.
[T6]. B. V. S. Rao – Operation and Maintenance of Electrical Equipment – Asia Publication.

2. Reference Books

[R1]. P.S. Pabla –Electric Power Distribution, 5th edition, Tata McGraw Hill.
[R2]. S. L. Uppal, Electrical Wiring and Costing Estimation, Khanna Publishers, New Delhi.
[R3]. Surjit Singh, Electrical wiring, Estimation and Costing, Dhanpat Rai and company, New Delhi.
[R4]. Raina K.B. and Bhattacharya S.K., Electrical Design, Estimating and Costing, Tata McGraw Hill, New

Delhi.

[R5]. B.D. Arora-Electrical Wiring, Estimation and Costing, - New Heights, New Delhi.

[R6]. M.V. Deshpande, Elements of Power Station design and practice, Wheelers Publication.

[R7]. S. Sivanagaraju and S. Satyanarayana, Electric Power Transmission and Distribution, Pearson Publication.

[R8]. Power Equipment Maintenance and Testing (Power Engineering Book 32) by Paul Gill

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://onlinecourses.nptel.ac.in/noc26_ee59/preview

[M2]. https://onlinecourses.nptel.ac.in/noc25_ee102/preview

[M3]. https://onlinecourses.nptel.ac.in/noc25_ee57/preview

[M4]. https://onlinecourses.nptel.ac.in/noc25_ge19/preview

[M5]. https://onlinecourses.nptel.ac.in/noc26_ee26/preview

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-321A-ELE	**Course Name: Microcontroller and Embedded Systems**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 3 Hrs	**3**	**CCE : 30 Marks**
Practical : 2 Hrs	**1**	**ESE : 70 Marks**

Prerequisite: Knowledge of Number system and Basic logic components. Programming basics of C language.

Course Objectives:

1. To develop understanding of PIC microcontroller architecture
2. To enhance ability to write and interpret programs in C language for PIC 18F458.
3. To train students to design and implement interfacing of PIC 18F458 with various peripherals
4. To equip students with the ability to build simple real-world applications with PIC 18F458
5. To develop understanding of serial communication protocols and sensor interfacing in embedded systems applications

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Explain architecture of PIC 18F458 microcontroller and embedded C concepts.

CO2. Generate time delays using PIC Timers, I/O Ports and C programming

CO3. Generate events using CCP module

CO4. Develop programs in C for internal and External interrupts and ADC

CO5. Use Serial Communication and various serial communication protocols.

Course Contents

Unit No: I	**PIC Architecture and embedded C**	**08 Hours**
Introduction to Microprocessor and Microcontroller, Pin diagram and architecture of P18F458 microcontroller, Comparison of CISC and RISC Architectures, Data and Program memory organization, Program Counter, Stack pointer, Status register, I/O Ports, their dual functions and related SFRs. Pre-processor directives for embedded C programming.		
Self-study	Embedded C concepts, Data types, Control loops, functions, bit operations.	
Reference Books	**T1, T2, R1, R2, M1**	

Unit No: II	**Port and Timer Programming**	**08 Hours**
I/O port programming in C. PIC 18 Timers with SFRs, Timer 0 details with Programing in C. Delay programming (with and without Timer0). Interfacing of LCD (16x2) in 4-bit mode theory & interfacing diagram.		
Exemplars/Case Studies	Experimental study of LED/buzzer Interfacing with different ports	
Reference Books	**T1, T2, T3, R1**	

Unit No: III	**CCP module and its applications**	**08 Hours**
CCP module in PIC 18 microcontroller, Timers required for CCP Applications, Generation of Square waveform using Compare mode of CCP module. Period measurement of unknown signal using Capture mode in CCP module, Speed control of DC motor using PWM mode of CCP module.		
Exemplars/Case Studies	Experimental study of DC motor speed control for various PWM frequency	
Reference Books	**T1, T2, T3, R1**	

Unit No: IV	**Interrupt Programming and PIC ADC**	**08 Hours**

Interrupt structure of PIC 18F458, SFRs related to Interrupts, Interrupt Programming using C, Programming of Timer0 interrupt, and External hardware interrupt INT0. Basics of ADC, On-chip ADC on PIC 18F458, Programming of ADC using interrupts.	
Self study	Study of DAC
Reference Books	**T1, T2, T3, R1, M2**

Unit No: V	**Serial Communication and Applications**	**08 Hours**
Serial Communication structure USART, SFRs related to serial communications. Programming serial port to transmit and receive data, Introduction to communication protocols as SPI MODBUS and CAN Bus. Types of sensors LM35, ACS712 (Hall-effect, ±5A to ±30A range), ZMPT101B for AC voltage. Measurement of temperature and Power using PIC microcontroller.		
Self study	Applications of SPI and MODBUS	
Reference Books	**T1, T2, T3, R1, R3**	

Learning Resources

1. Text Books

[T1]. PIC Microcontroller and Embedded Systems Using Assembly and C for PIC18 by Muhammad Ali Mazidi, Rolind D. McKinley, Danny Causey, Pearson Education.

[T2]. Fundamentals of Microcontrollers and Applications in Embedded Systems with PIC by Ramesh Gaonkar, Thomson and Delmar learning, First Edition.

[T3]. Programming and Customizing the PIC Microcontroller by Myke Predko, TATA McGraw-Hill.

2. Reference Books

[R1]. PIC18F458 datasheet

[R2]. MPLAB IDE user guides

[R3]. MICROCHIP Technical Reference Manual of 18F4520 Embedded Design with PIC 18F452 Microcontroller by John B. Peatman, Prentice Hall

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/108105102 **NOC: Microprocessors & Microcontrollers, IIT Kharagpur**

[M2]. https://nptel.ac.in/courses/106105193 **NOC: Embedded System Design, IIT Kharagpur**

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-321B-ELE	**Course Name: Renewable Energy Systems**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs	**03**	**CCE : 30 Marks**
Practical : 02 Hrs	**01**	**ESE : 70 Marks**

Prerequisites: Basic knowledge of electrical circuits, electrical machines, and power generation systems. Familiarity with fundamental concepts of energy conversion, basic thermodynamics, and engineering mathematics will help students understand renewable energy technologies and their applications effectively.

Course Objectives:

1. To study solar photovoltaic technologies and system configurations
2. To study solar thermal technologies and system configurations
3. To provide knowledge of development and operation of wind energy systems
4. To provide information of bio-energy resource assessment.
5. To introduce different storage systems; Integration methods and Economics of Renewable Energy Systems.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Explain solar energy systems and their performance analysis.
CO2. Determine wind turbine performance.
CO3. Explain and evaluate biomass resources in an Indian context.
CO4. Illustrate the importance of storage systems.
CO5. Analyze the economics of renewable energy sources.

Course Contents

Unit No: I	Solar Energy	08 Hours

Solar radiation: extra-terrestrial and terrestrial radiation, Solar angles, Measurement of solar radiation, Sun–earth geometry, Solar cell and PV module construction, I-V & P-V Characteristics of solar cell, fill factor, solar PV system component, Design and performance analysis of Solar PV system, Solar thermal collector & types, solar water heating system, its performance analysis.

Exemplars/Case Studies	
Reference Books	

Unit No: II	Wind Energy	08 Hours

Power Contained in Wind, Thermodynamics of Wind Energy, Efficiency Limit for Wind Energy Conversion, the maximum energy obtained for a Thrust-operated converter (Efficiency limit), Design of Wind Turbine Rotor, Power-Speed Characteristics, Torque-Speed Characteristics, Wind Turbine Control Systems: a) Pitch Angle Control, b) Stall Control, c) Power Electronics Control, d) Yaw Control, Control Strategy, Wind Speed Statistics, Site and Turbine Selection, Extraction of wind energy and wind turbine power.

Exemplars/Case Studies	
Reference Books	

Unit No: III	Biomass Energy	08 Hours

Biomass Classification, Biomass Resources and their Energy Potential, Biomass Conversion Technologies: Anaerobic Digestion, Ethanol Fermentation, Biomass Gasification: Gasifiers, Fluidized Bed Gasifier, Biogas Technologies and their factor affecting Biogas Production, Biogas Plants: Floating and Fixed Dome type, designing of biogas plant, Introduction to Biodiesel, Power Generation from Municipal Solid Waste (MSW), Landfill Gas, Liquid Waste.

Exemplars/Case Studies	
Reference Books	

Unit No: IV	Fuel Cells and Storage Systems	07 Hours

A. Fuel Cells: Operating principles of Fuel Cell, Fuel and Oxidant Consumption, Fuel Cell System Characteristics, Introduction to Fuel Cell Technology and its type, application and limits.

B. Storage systems: Hydrogen storage: Hydrogen production, relevant properties, Hydrogen as an Engine Fuel, methods of Hydrogen storage. Batteries: Introduction to Batteries, Elements of Electro-Chemical Cell, Battery classification, Battery Parameters, Factors affecting battery performance. Introduction to other storage technologies: pump storage, SMES, compressed air storage.

Exemplars/Case Studies	
Reference Books	

Unit No: V	Integration of RES	09 Hours

Integration of RES with grid, hybrid system, Grid codes, Concept of Net Metering, policies.

Economics of RES: Simple, Initial rate of return, time value, Net present value, Internal rate of return, Life cycle costing, Effect of fuel Escalation, Annualized and levelized cost of energy.

Exemplars/Case Studies	
Reference Books	

Learning Resources

1. Text Books

[T1]. G. N. Tiwari, Solar Energy, Fundamentals, Design, Modeling and Applications, Narosa, 2002.

[T2]. S. P. Sukhatme and J. K. Nayak, Solar Energy, McGraw Hill, 2017.

[T3]. Chetan Singh Solanki, "Solar Photovoltaics-Fundamentals, Technologies and Applications", PHI Second Edition.

[T4]. Mukund R. Patel, "Wind and Power Solar System", CRC Press

[T5]. Gilbert M. Masters, "Renewable and Efficient Electrical Power Systems", Wiley - IEEE Press, August 2004.

[T6]. H. P. Garg and J. Prakash, Solar Energy: Fundamentals and Applications, Tata McGraw Hill, 1997

2. Reference Books

[R1]. D.P.Kothari, K.C.Singal, Rakesh Rajan,"Renewable Energy Sources and Emerging Technologies", PHI Second Edition.

[R2]. Tapan Bhattacharya, "Terrestrial Solar Photovoltaics", Narosa Publishing House

[R3]. Paul Gipe, "Wind Energy Comes of Age", John Wiley & Sons Inc.

[R4]. B T.Nijaguna, "Biogas Technology", New Age International Publishers.

[R5]. Donald L.Klass, "Biomass for Renewable Energy, Fuels, and Chemicals, Elsevier, Academic Press

[R6]. Thomas Ackermann, "Wind Power in Power Systems", Wiley Publications.

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://onlinecourses.nptel.ac.in/noc25_ch40/preview

[M2]. https://onlinecourses.swayam2.ac.in/e-learning/preview/ntr25_ed119

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-321-ELE	**Course Name: Computer Aided Design of Electrical Machines**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs.	**3**	**CCE : 30 Marks**
Practical : 02 Hrs	**1**	**ESE : 70 Marks**

Prerequisites: Fundamentals of Electrical and Electronics Engineering, Knowledge of various materials used in electrical machines. Types, construction and working of transformer. Knowledge of types, construction and working of three phase induction motor.

Course Objectives:

1. Understand the principles, specifications, and design considerations of transformers as per relevant IS standards.
2. Apply analytical and empirical methods to design transformer components including core, windings, and cooling systems.
3. Analyze the design aspects and performance parameters of three-phase induction motors.
4. Develop the ability to design stator and rotor structures of induction machines using standard design procedures.
5. Introduce concepts of special electrical machines and utilize computer-aided tools for electrical machine design.

Course Outcomes:

CO1. Upon successful completion of this course, the students will be able to:

CO2. Design the core and overall structure of a three-phase transformer based on given specifications.

CO3. Calculate and evaluate transformer parameters such as resistance, reactance, losses, efficiency, and regulation.

CO4. Determine main dimensions and winding details of a three-phase induction motor.

CO5. Analyze performance characteristics of induction motors including losses, efficiency, and no-load current.

CO6. Apply fundamental design concepts of special machines (PMSM, SRM) and implement CAD tools for machine design.

Course Contents

Unit No: I	**Transformer Design: Part I**	**08 Hours**

Types and constructional features of core and windings used in transformer and auxiliaries. Heating and cooling time constants. Specifications of three phase transformers as per IS 2026(Part I), Output equation with usual notations, optimum design of transformer for minimum cost and loss. Design of core, estimation of overall dimensions of frame

Reference Books	**T1,T2, T3, T4, R1**

Unit No: II	**Transformer Design: Part II**	**08 Hours**

Design of windings of transformer. Estimation of resistance and leakage reactance of transformer. Estimation of no-load current, losses, efficiency and regulation of transformer. Calculation of mechanical forces developed under short circuit conditions, measures to overcome this effect. Methods of cooling of transformer. Design of tank with cooling tubes. Introduction to Computer aided design of transformer, generalized flow chart for design of transformer.

Reference Books	**T1,T2, T3, T4,R1**	
Unit No: III	**Three phase Induction Motor: Part I**	**08 Hours**
Specifications and constructional features. Types of ac windings. Specific electrical and magnetic loadings, ranges of specific loadings. Output equation with usual notations. Calculations for main dimensions, turns per phase and number of stator slots. Suitable combinations of stator and rotor slots. Selection of length of air gap, factors affecting length of air gap, Generalized flow chart for design of induction motor.		
Reference Books	**T2, R1**	
Unit No: IV	**Three phase Induction Motor: Part II**	**08 Hours**
Design of rotor slots, size of bars and end rings for cage rotor. Conductor size, turns and area of rotor slots for wound rotor. Leakage flux and leakage reactance: Slot, tooth top, zig - zag, overhang. Leakage reactance calculation for three phase machines. MMF Calculation for air gap, stator teeth, stator core, rotor teeth and rotor core, effect of saturation, effects of ducts on calculations of magnetizing current, calculations of no-load current. Calculations of losses and efficiency		
Reference Books	**T1,T2, T3, T4, R1**	
Unit No: V	**Introduction to Special machine design**	**08 Hours**
Brushless Motor Fundamentals- Torque equation, back emf, magnetic circuit, Multi phases radial flux machines inner rotor and outer rotor, Design Examples of PMSM, Switched Reluctance Machine (SRM) Sizing Equations, Stator and Rotor Design of SRM		
Reference Books	**R2**	

Learning Resources

1. Text Books

[T1]. M. G. Say–Theory and Performance and Design of A.C. Machines,3rd Edition, ELBS London.

[T2]. A.K. Sawhney–A Course in Electrical Machine Design, -Dhanpat Rai and sons New Delhi

[T3]. K. G. Upadhyay- Design of Electrical Machines, New age publication

[T4]. R. K. Agarwal–Principles of Electrical Machine Design, S. K. Katariya and sons.

2. Reference Books

[R1]. Vishnu Murti, "Computer Aided Design for Electrical Machines", B. S. Publications.

[R2]. Brushless permanent magnet motor design, Dr. Duane Hanselman, Second Edition, Magna Physics Publishing

[R3]. Krishnan, R., Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design, and Applications, CRC Press, USA.

3. Links to online SWAYAM/NPTEL Courses

[M1]. NPTEL Course on Design of Electric Motors By Prof. Prathap Reddy, IISc Bangalore

[M2]. NPTEL Course on Computer-Aided Design of Electrical Machines By Prof. Bhim Singh, IIT Delhi

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-322A-ELE	**Course Name: Microcontroller and Embedded Systems Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**1**	**TW : 25 Marks**

Prerequisite: Knowledge of Number system and Basic logic components. Programming basics of C language.

Course Objectives:

1. To develop ability to Write and Interpret C language programs for PIC 18F458
2. To interface various peripherals and sensors with PIC18F458
3. To develop understanding of performance analysis and design calculations of three-phase induction motors.
4. To enhance skills in preparing CAD drawings and design reports for electrical machines as per standard specifications.
5. To introduce computer-aided tools and modern techniques used in the design and analysis of electrical machines and special machines.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Use MPLAB IDE for programming PIC Microcontroller

CO2. Write programs for microcontroller applications in C language

CO3. Generate Time delays and LED Logics

CO4. Control DC Motor using PIC 18F458 microcontroller.

CO5. Interface devices and sensors with PIC 18F458 microcontroller

List of Experiments

Perform any eight experiments from the following list:

1. Introduction to MPLAB IDE
2. Interfacing of Switch and LED with P18F458
3. PIC 18F458 Port programming with generation of time delay using Timer 0
4. Interfacing of LCD [16 X 2] with P18F458 in 4 or 8 bit mode
5. Generation of square, positive ramp, negative ramp, triangular waveforms using DAC interface
6. Generating PWM waveform using PWM mode of P18F458
7. Driving relay from P18F458 using software and hardware interrupts
8. Interfacing DC motor / Stepper motor with P18F458
9. Using Serial Port of P18F458 to send and receive data
10. Interfacing of LM35 with P18F458 and displaying temperature
11. Measurement of power using PIC 18F458
12. Interfacing PIC18F458 microcontroller with a PC using serial communication and transmit/receive data.

Guidelines for Instructor's Manual

The Instructor's Manual should contain the following related to every experiment:

- Commands to be followed in order to operate the PIC18 micro controller kit.
- Detailed connection diagram / Circuit Diagram of the KIT
- Pin Diagram and PIN layout of PIC 18F458, all supporting ICs
- Manuals for interfacing of ADC, DAC, LCD etc.
- User manuals of all the interfacing kits such as stepper motor, DC motor etc.

Guidelines for Students Lab Manual

The student's Lab Journal should contain the following related to every experiment:

- Title of the program, Aim & Objectives, Brief theory related to the experiment, Embedded C Program, Input and Result of the program, Flow Chart for each program has to be drawn on separate page, Conclusion

Guidelines for Lab assessment

There should be continuous assessment.

- Assessment must be based on understanding of theory, attentiveness during practical session, how efficiently the student is able to do code and get the results.
- Timely submission of journal.

Guidelines for Lab conduction

- The first half hour should be utilized for explaining theory related to the experiment.
- Next one hour for code and interfacing of the experiment
- Remaining half hour for continuous assessment and timely checking of the experiment (This time slot can be adjusted as per convenience)
- Individual student should write and simulate the program using MPLAB IDE and C18 Compiler
- A separate Personal Computer should be provided to each student.
- The verified program should be run on the development kit of P18F458 microcontroller

Learning Resources

1. Text Books

[T1]. PIC Microcontroller and Embedded Systems Using Assembly and C for PIC18 by Muhammad Ali Mazidi, Roland D. McKinley, Danny Causey, Pearson Education.

[T2]. Fundamentals of Microcontrollers and Applications in Embedded Systems with PIC by Ramesh Gaonkar, Thomson and Delmar learning, First Edition.

[T3]. Programming and Customizing the PIC Microcontroller by Myke Predko, TATA McGraw-Hill.

2. Reference Books

[R1]. Muhammad Ali Mazidi, Rolin D. McKinlay, Danny Causey, PIC Microcontroller and Embedded Systems: Using Assembly and C for PIC18, 2008, Pearson Education

[R2]. Ramesh S. Gaonkar, Fundamentals of Microcontrollers and Applications in Embedded Systems with PIC Publisher: Cengage Learning / Thomson Delmar Learning, Publication Year: 2009

[R3]. Myke Predko, Programming and Customizing the PIC Microcontroller, Publisher: McGraw-Hill Education, Publication Year: 2000

[R4]. Tim Wilmshurst, Designing Embedded Systems with PIC Microcontrollers: Principles and Applications, Publisher: Newnes (Elsevier), Publication Year: 2007

[R5]. PIC18F458 datasheet

[R6]. MICROCHIP Technical Reference Manual of 18F4520 Embedded Design with PIC 18F452 Microcontroller by John B. Peatman, Prentice Hall

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/108105102 **NOC: Microprocessors & Microcontrollers, IIT Kharagpur**

[M2]. https://nptel.ac.in/courses/106105193 **NOC: Embedded System Design, IIT Kharagpur**

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-322B-ELE	**Course Name: Renewable Energy systems Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**01**	**TW : 25 Marks**
		OR : 25 Marks

Prerequisites: basic knowledge of electrical circuits, electrical machines, and conventional power generation systems. Familiarity with fundamental concepts of energy conversion, thermodynamics, and engineering mathematics will help in understanding renewable energy technologies, their operation, performance analysis, and grid integration aspects.

Course Objectives:

1. To study solar photovoltaic technologies and system configurations
2. To study solar thermal technologies and system configurations
3. To provide knowledge of development and operation of wind energy systems
4. To provide information on bio-energy resource assessment.
5. To introduce different storage systems; Integration methods and Economics of Renewable Energy Systems.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Explain solar energy systems and their performance analysis.
CO2. Determine wind turbine performance.
CO3. Explain and evaluate biomass resources in an Indian context.
CO4. Illustrate the importance of storage systems.
CO5. Analyze the economics of renewable energy sources.

List of Experiments

Perform minimum eight experiments from the following list.

Any three from 1-4, any one from 5-6, any two from 7-9, any one from 10-11, Field visit (12th) is compulsory.

1. To plot I-V and P-V characteristics with series and parallel combination of Solar PV Modules for different Insolation and temperature effects.
2. To evaluate effect of Shading and Tilt Angle on I-V and PV characteristics of Solar Module.
3. To estimate effect of sun tracking on energy generation by Solar PV Module.
4. To estimate efficiency of standalone Solar PV Module
5. To evaluate performance of Solar flat plate collector.
6. To plot characteristics of lead-acid / Lithium ion battery for various source and load condition
7. To analyze effect of blade angles on performance of wind turbine.
8. To evaluate performance of horizontal axis wind turbine.
9. To evaluate performance evolution of vertical axis wind turbine.
10. To study synchronization of wind electric generator.
11. Wind generation analysis using Matlab for variable wind speeds.
12. Field visit to Renewable Energy Technology installed locations or Manufacturing Industry.

Learning Resources

1. Text Books

[T1]. G. N. Tiwari, Solar Energy, Fundamentals, Design, Modeling and Applications, Narosa, 2002.

[T2]. S. P. Sukhatme and J. K. Nayak, Solar Energy, McGraw Hill, 2017.

[T3]. Chetan Singh Solanki, "Solar Photovoltaics-Fundamentals, Technologies and Applications", PHI Second Edition.

[T4]. Mukund R. Patel, "Wind and Power Solar System", CRC Press

[T5]. Gilbert M. Masters, "Renewable and Efficient Electrical Power Systems", Wiley - IEEE Press, August 2004.

[T6]. H. P. Garg and J. Prakash, Solar Energy: Fundamentals and Applications, Tata McGraw Hill, 1997

2. Reference Books

[R1]. D.P.Kothari, K.C.Singal, Rakesh Rajan,"Renewable Energy Sources and Emerging Technologies", PHI Second Edition.

[R2]. Tapan Bhattacharya, "Terrestrial Solar Photovoltaics", Narosa Publishing House

[R3]. Paul Gipe, "Wind Energy Comes of Age", John Wiley & Sons Inc.

[R4]. T.Nijaguna, "Biogas Technology", New Age International Publishers.

[R5]. Donald L.Klass, "Biomass for Renewable Energy, Fuels, and Chemicals, Elsevier, Academic Press

[R6]. Thomas Ackermann, "Wind Power in Power Systems", Wiley Publications.

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://onlinecourses.nptel.ac.in/noc25_ch40/preview

[M2]. https://onlinecourses.swayam2.ac.in/e-learning/preview/ntr25_ed119

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-321C-ELE	**Course Name: Computer Aided Design of Electrical Machines Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**01**	**TW : 25 Marks**

Prerequisite: fundamentals of electrical engineering, various materials used in electrical machines, types, construction and working of transformer. Types, construction and working of three phase induction motor.

Course Objectives:

1. To understand the principles, specifications, and design considerations of transformers as per relevant IS standards.
2. To apply analytical and empirical methods to design transformer components including core, windings, and cooling systems.
3. To analyze the design aspects and performance parameters of three-phase induction motors.
4. To develop the ability to design stator and rotor structures of induction machines using standard design procedures.
5. To introduce concepts of special electrical machines and utilize computer-aided tools for electrical machine design.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Design the core and overall structure of a three-phase transformer based on given specifications.

CO2. Calculate and evaluate transformer parameters such as resistance, reactance, losses, efficiency, and regulation.

CO3. Determine main dimensions and winding details of a three-phase induction motor.

CO4. Analyze performance characteristics of induction motors including losses, efficiency, and no-load current.

CO5. Apply fundamental design concepts of special machines (PMSM, SRM) and implement CAD tools for machine design.

List of Experiments

Perform eight experiments from the following list:

List of Experiment/Design Assignments: (1 to 4 and 7 compulsory)

1. CAD based sheet for transformer (3 phase)
2. Details and layout of single layer three phase winding and double layer three phase winding with design report. (Sheet in CAD) with report
3. CAD based sheet for three phase induction motor
4. Design Assignments for
   (a) Three phase transformer
   (b) Three phase induction motor
5. Finite element analysis by using available software **(Any 1 of below given)**
   (a) Three phase induction motor
   (b) Transformer
6. Computer aided design assignment’ **(Any 1 of below given)**
   (a) Main dimensions of special motors
   (b) Performance calculation of transformer and induction machine
7. Industrial Visit report on Transformer or Induction motor manufacturing/repairing unit.

Guidelines for Instructor's/ students Manual

1. **The Instructor's Manual should contain the following related to every experiment:**
2. Brief theory related to the concerned sheet.
3. Apparatus with their detail specification as per IS code.
4. Design as per problem statement.
5. Reference tables used for design purposes.
6. Design parameters details in tabular form.
7. Few short questions related to design.
8. A3 size sheet to be used for CAD drawing.

Guidelines for Lab assessment

There should be continuous assessment.

1. Assessment must be based on understanding of theory, attentiveness during practical session, how efficiently the student is able to design as per the problem statement.
2. Timely submission of design report and sheet.

Learning Resources

1. Text Books

[T1]. M. G. Say–Theory and Performance and Design of A.C. Machines,3rd Edition, ELBS London.
[T2]. A.K. Sawhney–A Course in Electrical Machine Design, -Dhanpat Rai and sons New Delhi
[T3]. K. G. Upadhyay- Design of Electrical Machines, New age publication
[T4]. R. K. Agarwal–Principles of Electrical Machine Design, S. K. Katariya and sons.

2. Reference Books

[R1]. Vishnu Murti, "Computer Aided Design for Electrical Machines", B. S. Publications.
[R2]. Brushless permanent magnet motor design , Dr. Duane Hanselman, Second Edition, Magna Physics Publishing
[R3]. Krishnan, R., Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design, and Applications, CRC Press, USA.

3. Links to online SWAYAM/NPTEL Courses

[M1] NPTEL Course on Design Of Electric Motors **By Prof. Prathap Reddy | IISc Bangalore**
[M2] NPTEL Course on Computer-Aided Design of Electrical Machines **By Prof. Bhim Singh | IIT Delhi**

Savitribai Phule Pune University Third Year of Electrical Engineering (2024 Course)		
Course Code: MDM-331-ELE	**Course Name: AI Applications in Electrical Engineering**	
Teaching Scheme	**Credits**	**Examination Scheme**
Tutorial : 02 Hrs	**2**	**TW : 25 Marks**
Practical : 02 Hrs	**1**	**OR : 25 Marks**

Prerequisite: Engineering Mathematics, Basics of Programming (Python/MATLAB preferred)

Course Objectives:

1. To understand fundamentals of AI and Soft Computing.
2. To learn Neural Networks, Fuzzy Logic
3. To apply AI techniques to solve electrical engineering problems.
4. To develop basic AI models using MATLAB/Python.
5. To analyze AI-based control and optimization in power & energy systems.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Apply AI methods to power systems, drives, and control problems

CO2. Design ANN models for prediction and classification

CO3. Develop fuzzy controllers for electrical systems

CO4. Apply GA for optimization in EE problems

CO5. Implement simple AI solutions using MATLAB/Python

Course Contents of Tutorials

Unit No: I	**Foundations of AI**	**06 Hours**

Introduction to Artificial Intelligence, Hard Computing vs Soft Computing, AI vs Conventional Programming, Role of AI in Electrical Engineering, various types of AI techniques, applications of AI in Electrical Engineering

Unit No: II	**Genetic Algorithm**	**06 Hours**

Genetic algorithm: Fundamentals, basic concepts, working principle, encoding, fitness function, reproduction, Differences & similarities between GA & other traditional method

Genetic modeling: Inheritance operator, cross over, inversion & deletion, mutation operator, Bitwise operator, Generational Cycle, Convergence of GA, Applications & Advances in GA

Unit No: III	**Artificial Neural Networks Fundamentals**	**06 Hours**

Biological vs Artificial Neuron, Structure of ANN, Difference between ANN and human brain, Types of Neural Networks, Activation functions, Learning paradigms, characteristics and applications of ANN

Unit No: IV	**ANN Learning Algorithms & Models**	**06 Hours**

Perceptron, ADALINE, MADALINE, Multilayer Perceptron (MLP), Backpropagation Algorithm, ANN vs Classical modeling

Unit No: V	**Fuzzy Logic Control**	**06 Hours**

Fuzzy Set Theory: Fuzzy set versus crisp set, Crisp relation & fuzzy relations, Fuzzy systems: crisp logic, fuzzy logic, introduction & features of membership functions

Fuzzy rule base system: fuzzy propositions, formation, decomposition & aggregation of fuzzy rules, fuzzy reasoning, fuzzy inference systems, fuzzy decision making, Applications of fuzzy logic in Electrical engineering

List of Tutorials

Unit No 1: Foundations of AI (Any three)

1. **Tutorial 1.1:** Comparative Analysis of Hard vs Soft Computing
   Group debate and case study analysis mapping traditional mathematical algorithms vs AI approaches in voltage control
2. **Tutorial 1.2:** Engineering Problem Identification for AI.
   Identifying electrical systems (drives, grid, protection) that fail under conventional programming and require AI solutions.
3. **Tutorial 1.3:** AI Software Ecosystem Setup.
   Hands-on session configuring Python (Anaconda/Jupyter) or MATLAB AI toolboxes for basic matrix operations.
4. **Tutorial 1.4:** Formulation of AI-Based Control Systems.
   Drafting a block diagram and flow execution chart for an AI agent regulating a closed-loop system.

Unit No 2: Genetic Algorithm (Any Three)

1. **Tutorial 2.1:** String Encoding and Chromosome Representation.
   Pen-and-paper exercise representing transmission line parameters into binary and real-coded chromosome formats.
2. **Tutorial 2.2:** Designing Fitness Functions.
   Mathematical formulation of a fitness function minimizing active power losses in a distribution line.
3. **Tutorial 2.3:** Manual Execution of GA Operators.
   Step-by-step tracing of single-point crossover, bit-inversion, and mutation on a small sample population.
4. **Tutorial 2.4:** Convergence and Tuning Parameter Analysis.
   Evaluating how changing mutation rates and population sizes impacts optimization speed and local minima traps.

Unit No 3: Artificial Neural Networks Fundamentals (Any Three)

1. **Tutorial 3.1:** Mathematical Modeling of a Neuron.
   Manual calculation of weighted sums, bias additions, and structural inputs for a single artificial node.
2. **Tutorial 3.2:** Activation Function Mapping.
   Plotting and comparing Sigmoid, Tanh, and ReLU functions to see their response to negative motor parameters.
3. **Tutorial 3.3:** Designing Multi-Layer Network Architectures.
   Sizing the input layer, hidden layer nodes, and output layer configurations based on a given dataset layout.
4. **Tutorial 3.4:** Selection of Learning Paradigms.
   Categorizing power system problems into supervised (fault prediction) or unsupervised (load clustering) categories.

Unit No 4: ANN Learning Algorithms & Models (Any Three)

1. **Tutorial 4.1:** Perceptron Learning Rule Execution.
   Adjusting weights manually using the delta rule to classify a binary logic gate sequence.
2. **Tutorial 4.2:** Backpropagation Error Computation.
   Working through a single reverse pass calculation to find partial derivatives of error with respect to weights.
3. **Tutorial 4.3:** Preventing Overfitting and Underfitting
   Evaluating learning curves and configuring data splitting rules (Training, Validation, Testing) for load forecasting.
4. **Tutorial 4.4:** ANN Model vs Classical Regression.

Comparing performance metrics (RMSE, MAE) of an ANN model against classical numerical models for data estimation

Unit No: 5 **Fuzzy Logic Control (Any Three)**

1. **Tutorial 5.1:** Crisp to Fuzzy Set Mapping.
   Designing triangular and trapezoidal membership functions for linguistic variables like "High Temperature" or "Low Voltage".
2. **Tutorial 5.2:** Fuzzy Composition Matrix Operations
   Solving max-min and max-product composition exercises using relational fuzzy matrices.
3. **Tutorial 5.3:** Building an IF-THEN Rule Base.
   Drafting a comprehensive matrix of conditional logic rules to control a DC motor's speed based on Error and Change-in-Error.
4. **Tutorial 5.4:** Defuzzification Method Evaluation.
   Calculating the exact crisp control outputs using the Centroid method (Center of Gravity) vs Mean of Maxima.

List of Experiments (Any Eight)

1. Introduction to MATLAB/Python for AI. Data handling and plotting using MATLAB / Python.
2. Design membership functions, Fuzzification and defuzzification and Rule base creation using Fuzzy Logic Toolbox.
3. Classification of transmission line faults using ANN.
4. Design fuzzy controller for speed control DC Motor.
5. Solve a single-objective optimization problem using GA.
6. Load Forecasting using Artificial Neural Network (ANN)
7. Power System Fault Detection using AI Techniques
8. Comparative Study of Classical and AI-Based Controllers
9. Implementation of Perceptron and ADALINE Networks
10. Application of AI for Economic Load Dispatch (ELD)
11. Building's electricity demand prediction based on outdoor temperature using linear regression.

Guidelines for Instructor's/ Students Manual

The Instructor's Manual should contain the following related to every experiment:

- Aim, Apparatus/Software, Theory, Algorithm, MATLAB/Python Code, Sample Input / Output, Result Viva Questions

Learning Resources

1. Text Books

[T1]. Dr. D.K. Chaturvedi, Soft Computing Techniques and its Applications in Electrical Engineering, , Springer-Verlag Berlin Heidelberg, 2008.

[T2]. S. Rajasekaran, G.A. Vijayalakshmi Pai, Neural Networks, Fuzzy Logic and Genetic Algorithm, Synthesis and Applications, PHI Learning Pvt. Ltd., 2017.

2. Reference Books

[R1]. S.N. Sivananda, S.N. Deepa, Principles of Soft Computing, Wiley India Pvt. Ltd., 2nd Edition, 2011.

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/106105173

[M2]. https://nptel.ac.in/courses/111105614

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Open Electives		
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 2 Hrs	**2**	**CCE : 15 Marks**
		ESE : 35 Marks

Open Electives (OE) are multidisciplinary courses allowing students to study subjects outside their core discipline to foster holistic development and skill enhancement. Students pick subjects outside their core specialization from the following list to broaden their knowledge base.

Sr. No.	Open Elective Course Name	Offering Discipline
1	IPR and Cyber Laws	Law / Faculty of Humanities
2	Agri Business Management: Banking Operation and finance	Commerce & Management
3	Product Costing for Mechanical Engineering	Commerce & Management
4	Sustainability Development	Commerce & Management
5	Material and Logistics	Management
6	The Constitution of India	Law / Faculty of Humanities
7	Digital Personal Data Protection	Law / Faculty of Humanities
8	Environmental Law	Law / Faculty of Humanities
9	Construction Law and Contracts	Law / Faculty of Humanities
10	Human Resource Management	Management
11	Statistics and Computer Applications	Commerce & Management
12	Business Administration	Commerce & Management
13	Business Marketing	Commerce & Management
14	Entrepreneurship Development	Commerce & Management
15	Banking, Finance & Insurance	Commerce & Management
16	Cost & Works Accounting	Commerce & Management

*Detailed syllabus for above open elective courses is available on university website.

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: ELC-342-ELE	**Course Name: Technical Seminar**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 2 Hrs	**1**	**OR/Presentation : 25 Marks**

The "Technical Seminar" course is a critical milestone designed to bridge the gap between structured classroom learning and independent research. It prepares students for Final Year Projects by developing literature survey, technical analysis, presentations, and report writing skills in emerging electrical engineering domains.

Course Objectives:

1. To develop research orientation and technical communication skills in emerging Electrical Engineering domains
2. To enable students to critically review, analyze, and synthesize contemporary research papers, white papers, patents, and technical standards.
3. To promote interdisciplinary thinking aligned with NEP-2020 multidisciplinary philosophy.
4. To inculcate ethical awareness, sustainability perspective, and societal impact analysis of electrical systems and technologies
5. To prepare students for industry, higher education, entrepreneurship, and innovation ecosystems.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Identify and select emerging and relevant technical topics through literature surveys.
CO2. Analyze and synthesize information from research papers, journals, and credible sources.
CO3. Demonstrate effective technical communication skills through oral presentation.
CO4. Prepare a structured technical report following academic writing standards.
CO5. Use modern tools for seminar preparation, referencing, plagiarism checking, and presentation.

Guidelines for Conduct of Technical Seminar

- Topic must be from emerging Electrical Engineering domains (preferably last 3–5 years).
- Suggested domains include Smart Grid, Renewable Energy Systems, Electric Vehicles, Power Electronics, Industrial Automation, Energy Storage Systems, High Voltage Engineering, AI applications in Power Systems, IoT in Electrical Systems, and Sustainable Energy Technologies.
- The seminar must involve a minimum of 5 recent research papers from IEEE, Springer, Elsevier, ACM, or other reputed sources.
- Students should summarize the papers by understanding the objectives, methodology, results, advantages, and limitations of the proposed approaches.
- Practical sessions on how to read, analyse and summarize research papers should be arranged.
- Topics should not be a basic textbook topic.
- Must include, Problem statement, State-of-the-art analysis, Comparative study, Ethical & societal impact, Interdisciplinary themes aligned with NEP encouraged.
- Topic should be approved by a faculty panel/ Seminar coordinator/ Head of the department.

Seminar Process

- **Orientation, Topic Finalization and Guide allocation (Week 1–2)**
  - ⇨ Conduct an orientation session explaining: Objectives of the technical seminar, Evaluation criteria and expected outcomes
  - ⇨ Each student must submit: Title of the seminar, Problem statement, Relevance to current technology trends. Approval by guide is mandatory before proceeding
  - ⇨ The precise topic is finalized and approved by a departmental seminar committee.
- **Literature Survey & Problem Understanding (Week 2–4)**
  - ⇨ Students must: Refer minimum 5–8 recent research papers (IEEE, Springer, Elsevier, or other reputed

sources).
- ⇨ Use scholarly databases like IEEE Xplore, Google Scholar, ScienceDirect
- ⇨ Prepare a literature survey matrix, including: Author/year, Methodology used, Key findings, Limitations
- ⇨ Identify: Research gaps and Challenges in existing approaches.

- **Synopsis Preparation & Presentation (Week 4–5)**
  - ⇨ Submit a 2–3 page synopsis including: Introduction, Literature insights, Objectives, Proposed seminar scope
  - ⇨ Conduct a Synopsis Presentation (5–7 minutes): Evaluate clarity of understanding, Receive feedback for improvement
  - ⇨ Approval required before proceeding to full report
- **In-depth Study & Content Development (Week 5–8)**
  - ⇨ Students should: Deeply analyze concepts, models, architectures, or case studies, Include diagrams, flowcharts, and comparative tables
  - ⇨ Weekly review meetings with guide: Track progress, Ensure conceptual clarity.
  - ⇨ Emphasis on: Critical analysis (not just description), Real-world applications
- **Draft Report Submission & Review (Week 8–10)**
  - ⇨ Submit first draft of the report
  - ⇨ Guide provides feedback on: Technical content quality, Structure and coherence, Referencing and plagiarism,
  - ⇨ Students must revise based on suggestions by the guide
- **Pre-Seminar Presentation (Mock Evaluation) (Week 10–11)**
  - ⇨ Conduct a mock presentation simulating final evaluation
  - ⇨ Focus on: Presentation skills, Time management, Handling questions.
  - ⇨ Peer and faculty feedback should be incorporated
- **Final Report Submission (Week 11–12)**
  - ⇨ Submit: Final hard copy (if required), Soft copy (PDF format)
  - ⇨ Ensure: Proper formatting, Plagiarism compliance (<20%), Correct referencing using reference managers like Zotero and Mendeley Desktop
- **Final Seminar Presentation & Viva Voce (Week 12–13)**
  - ⇨ Presentation duration: 10–15 minutes, Followed by Q&A session (5–10 minutes)
  - ⇨ Evaluation based on: Depth of understanding, Analytical ability, Communication skills

Method of Evaluation

- During the seminar session each student is expected to prepare and present a topic on engineering/ technology, for duration of about 12 to 15 minutes.
- Each student is expected to present at least twice during the semester, and the student is evaluated based on that.
- At the end of the semester, he / she can submit a report on his / her topic of seminar and marks are given based on the report.
- A Faculty guide is to be allotted, and he / she will guide and monitor the progress of the student and maintain attendance.

Seminar Report

The final technical report should be highly structured (20 to 25 pages), strictly technical, and clear of marketing jargon. The recommended structure includes

- **Cover Page & Certificates**: Standard institutional format.
- **Abstract**: A single, dense paragraph (200–250 words) capturing the domain background, problem identified, state-of-the-art solutions analysed, and key takeaways.
- **Chapter 1**: Introduction: Overview of the technology, historical context, motivation, and scope.

- **Chapter 2**: Literature Survey: A comprehensive critical analysis of the referred papers. It is highly recommended to synthesize this into a structured matrix, tabular form
- **Chapter 3**: System Architecture / Technical Core: Detailed breakdown of algorithms, mathematical formulations, protocols, or structural pipelines.
- **Chapter 4**: Comparative Analysis / Applications: Deep dive into current real-world deployment challenges, performance metrics (latency, accuracy, scale), and limitations.
- **Chapter 5**: Conclusion & Future Scope: Summarizing the insights gleaned and highlighting concrete pathways for prospective final-year project extensions.
- **References**: Strictly formatted in standard IEEE

Rubrics for Technical Seminar Assessment			
Content	**Does not meet Criterion (0)**	**Meets criterion somewhat (1)**	**Meets criterion fully (2)**
Background/Intro is sufficient to understand how this project fits into larger field	0	1	2
Description of methodology is sufficient for audience to understand the procedure	0	1	2
Explanations are understandable/clear	0	1	2
Conclusions stated are supported to topic	0	1	2
References/Sources are cited correctly	0	1	2
Audience questions are answered honestly (i.e. no bluffing or guessing)	0	1	2
Presentation Quality			
Speaking is understandable/clear	0	1	2
Speaker can answer questions professionally	0	1	2
Speaker makes eye contact with audience	0	1	2
Speaker uses professional body language	0	1	2
Visuals/PPT are clear and readable	0	1	2
Visuals/PPT have appropriate amount of text, diagrams	0	1	2
Visuals/PPT are free of errors/typos	0	1	2
Report Writing			
Abstract is meaningful	0	1	2
Graphs/diagrams are labeled completely	0	1	2
References/Sources are cited correctly	0	1	2
At least one reference is from a journal	0	1	2
Grammar is correct	0	1	2
Spelling is correct	0	1	2
Report format is clear	0	1	2
Total		**_____/40 (convert to 50)**	

Learning Resources

1. Reference Books

[R1]. Raman, M., & Sharma, S. (2015). Technical Communication: Principles and Practice (3rd ed.). Oxford University Press.

[R2]. Kothari, C. R. (2014). Research Methodology: Methods and Techniques (3rd ed.). New Age

[R3]. IEEE Xplore Digital Library – Research Articles in Electrical Engineering.

[R4]. NPTEL and SWAYAM Courses related to Smart Grid, Electric Vehicles, Renewable Energy, and Power Electronics.

Savitribai Phule Pune University, Pune

Maharashtra, India

National Education Policy (NEP) Compliant Curriculum

SEMESTER-VI

Third Year Engineering (2024 Pattern)

Electrical Engineering

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-351-ELE	**Course Name: Power System Engineering-II**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs	**03**	**CCE : 30 Marks**
Practical : 02 Hrs	**01**	**ESE : 70 Marks**

Prerequisites: Knowledge of Power generation techniques, two port network and ABCD parameters of short and medium lines, working of Power system components

Course Objectives:

1. To develop analytical ability to estimate power flow analysis of transmission line.
2. To demonstrate different computational methods for load flow analysis.
3. To analyse the power system under symmetrical fault conditions.
4. To analyse the power system under Unsymmetrical fault conditions.
5. To understand concept of reactive power compensation and FACTs devices.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Estimate ABCD constants and power flow in long transmission line.

CO2. Determine per unit values and develop Y bus matrix for load flow analysis.

CO3. Evaluate fault current and short circuit MVA for Symmetrical fault condition.

CO4. Evaluate fault current and short circuit MVA for unsymmetrical fault condition.

CO5. Interpret reactive power compensation and classify FACTS devices.

Course Contents

Unit No: I	Power Flow Analysis of long transmission Lines	08 Hours

Evaluation of ABCD constants of long transmission lines, Concept of complex power, power flow using generalized constants, Characteristic Impedance and Surge impedance loading, Numerical based on: Calculation of ABCD constants of Long transmission line, Complex power flow calculation at sending end and receiving end.

Exemplars/Case Studies	
Reference Books	**T2, T3, R1, R3, R4**

Unit No: II	Per Unit System & Load Flow Analysis	08 Hours

A) Per Unit (PU) System: SLD of a typical power system network, Impedance and reactance diagram, per unit quantities, relationships, selection of base, change of base, reduction to common base, advantages and application of per unit system. Numerical based on: Network reduction by using per unit system.

B) Load Flow Analysis: Network topology, driving point and transfer admittance, concept of Z-bus and formulation of Y-bus matrix using bus incidence matrix method, Generalized power- flow equations for n bus systems, classification of buses, Newton- Raphson method (polar method) for 3 bus system.

Numerical based on: Y Bus Matrix formation

Exemplars/Case Studies	
Reference Books	**T1, T2, T3, R1, R2, R3**

Unit No: III	Symmetrical Fault Analysis	07 Hours

3-phase short-circuit analysis of unloaded alternator, sub-transient, transient and steady state current and impedances, Estimation of fault current without pre-fault current for simple power systems, selection of circuit-breakers and current limiting reactors and their location in power system (Descriptive treatment Only)

Numerical based on: Symmetrical fault analysis (Fault Current and Short Circuit MVA).

Exemplars/Case Studies	
Reference Books	**T1, T2, T3, R1, R2, R3, R4**

Unit No: IV	**Un-symmetrical fault Analysis**	**09 Hours**

Symmetrical components, sequence components, power in terms of symmetrical components, sequence impedance of transmission line and zero sequence networks of transformer, solution of unbalances by symmetrical components, L-L, L-G, and L-L-G fault analysis of unloaded alternator and simple power systems with and without fault impedance. Numerical based on: Symmetrical components, Fault Current and Short Circuit MVA.

Exemplars/Case Studies	
Reference Books	**T1, T2, T3, R1, R2, R3, R4**

Unit No: V	**Reactive Power Compensation and FACTS Devices**	**08 Hours**

Necessity of reactive power compensation, production and absorption of reactive power, Types of compensation – series and shunt. Introduction to FACTS devices, Types of FACTS devices - Series compensation: TCSC, Shunt compensation: STATCOM. circuit diagram, working principle, VI characteristics, applications.

Exemplars/Case Studies	
Reference Books	**T2, T3, T6, T7, T9, R2, R3**

Industrial Visit:

Visit to EHV-AC substation (400 kV) / HVDC substation is recommended

Learning Resources

1. Text Books

[T1]. I.J. Nagrath and D.P. Kothari – Modern Power System Analysis – TMH New Delhi.

[T2]. Dr B R Gupta - “Power System Analysis and Design”, S. Chand.

[T3]. C.L. Wadhwa - “Power System Analysis”, New Age International.

2. Reference Books

[R1]. Stevenson W.D. Elements of Power System Analysis (4th Ed.) Tata McGraw Hill, New Delhi.

[R2]. Hadi Sadat: Power System Analysis, Tata McGraw-Hill New Delhi.

[R3]. J. B. Gupta - “A course in power systems” S.K. Kataria Publications.

[R4]. Ashfaq Hussain - “Electrical Power Systems”, CBS Publication 5th Edition.

[R5]. V. K. Chandana, Power Systems, Cyber tech Publications.

3. Links to online SWAYAM/NPTEL Courses

[M1]. NPTEL Course on Power System Engineering: Debpriya Das
https://nptel.ac.in/courses/108/105/108105104/

[M2]. NPTEL Course on Power System Analysis by Dr. A.K. Sinha
https://nptel.ac.in/courses/108/105/108105067/

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-352-ELE	**Course Name: Control System Engineering**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs	**03**	**CCE : 30 Marks**
Practical : 02 Hrs	**01**	**ESE : 70 Marks**

Prerequisites: Laplace Transform, ordinary differential equations

Course Objectives:

1. To understand the foundational principles and terminologies of control systems and develop mathematical models of physical systems.
2. To analyze time-domain behavior of the system.
3. To assess system stability and root locus behavior.
4. To perform frequency-domain analysis for system evaluation
5. To design and tune PID controllers to meet desired specifications and determine transfer function of lead and lag compensator networks.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Explain the basic principles, terminologies, classifications of control systems, and develop mathematical models of physical systems using transfer function approach.

CO2. Analyse the time-domain response of control systems and evaluate performance indices such as rise time, settling time, peak time, delay time, overshoot and steady-state error.

CO3. Determine the stability of control systems using analytical methods and construct and interpret root locus plots to assess system behaviour.

CO4. Analyse the control system in the frequency domain using Bode plot to assess stability and robustness.

CO5. Design and tune PID controllers to meet desired performance specifications in time-domain Determine transfer functions of lead and lag compensator networks.

Course Contents

Unit No: I	Basics of Control System	08 Hours

Basic concepts of control system, classification of control systems (open loop systems, closed-loop systems, linear time-variant systems, linear time-invariant systems, servo systems, regulatory systems, SISO and MIMO systems), transfer function with poles and zeros, modelling of electrical networks (up to two loops) and Mechanical systems, analogy between electrical and mechanical systems, signal flow graph, Mason's gain formula.

Exemplars/Case Studies	
Reference Books	**[T1, T2, T3] [R1, R2]**

Unit No: II	Time-Domain Analysis	08 Hours

Concept of transient and steady state response, standard test signals: step, ramp, parabolic and impulse signal, type and order of control system, time response of first and second order systems to unit step input, time domain specifications of second order systems, steady state error and static error coefficients.

Exemplars/Case Studies	
Reference Books	**[T1, T2, T3] [R1, R3]**

Unit No: III	Stability Analysis and Root Locus	08 Hours

Concept of stability, nature of system response for various locations of poles in S-plane. Routh's-Hurwitz

criterion. Root Locus: Angle and magnitude condition, Basic properties of root locus. Construction of root locus, Stability analysis using root locus.		
Exemplars/Case Studies		
Reference Books	**[T1, T2, T3] [R2, R3]**	
Unit No: IV	**Frequency Domain Analysis**	**08 Hours**
Introduction, Frequency domain specifications, correlation between time and frequency domain specifications, introduction to Bode plot, sketching of Bode plot, stability analysis using Bode plot, introduction to polar plot.		
Exemplars/Case Studies		
Reference Books	**[T1, T2, T3] [R1, R3]**	
Unit No: V	**Design of PID Controller**	**08 Hours**
Basic concept of P, PI, PID controller, design specifications in time domain, tuning of PID controllers using Ziegler-Nichol methods (two methods), transfer function of lag network and lead network		
Exemplars/Case Studies		
Reference Books	**[T1, T2, T3] [R1, R3]**	

Industrial Visit:

Visit to EHV-AC substation (400 kV) / HVDC substation is recommended

Learning Resources

1. Text Books

[T1]. I.J. Nagrath, M. Gopal, "Control System Engineering", New Age International Publishers, 6th edition, 2017.

[T2]. Katsuhiko Ogata, "Modern control system engineering", Prentice Hall, 2010.

[T3]. Nise N. S. "Control Systems Engineering", John Wiley & Sons, Incorporated, 2011

2. Reference Books

[R1]. B. C. Kuo, "Automatic Control System", Wiley India, 8th Edition, 2003. Hadi Sadat: Power System Analysis, Tata McGraw-Hill New Delhi.

[R2]. Richard C Dorf and Robert H Bishop, "Modern control system", Pearson Education, 12th edition, 2011.

[R3]. B. Wayne Bequette, "Process Control: Modeling, Design and Simulation", PHI, 2003

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/108106098

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-353-ELE	**Course Name: Power System Engineering-II Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**01**	**TW : 25 Marks**
		PR : 25 Marks

Prerequisites: Knowledge of Power generation techniques, two port network and ABCD parameters of short and medium lines, working of Power system components

Course Objectives:

1. To develop analytical ability to estimate power flow analysis of transmission line.
2. To demonstrate different computational methods for load flow analysis.
3. To analyse the power system under symmetrical fault conditions.
4. To analyse the power system under Unsymmetrical fault conditions.
5. To understand concept of reactive power compensation and FACTs devices.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Estimate ABCD constants and power flow in long transmission line.

CO2. Determine per unit values and develop Y bus matrix for load flow analysis.

CO3. Evaluate fault current and short circuit MVA for Symmetrical fault condition.

CO4. Evaluate fault current and short circuit MVA for unsymmetrical fault condition.

CO5. Interpret reactive power compensation and classify FACTS devices.

List of Experiments

Perform eight experiments from the following list:

Compulsory experiments:

1. Measurement of ABCD parameters of a medium transmission line with magnitude and angle.
2. Measurement of ABCD parameters of a long transmission line with magnitude and angle.
3. Study of the effect of VAR compensation using capacitor bank on the transmission line.
4. Formulation and calculation of Y- bus matrix of a given system using software.
   (Solve at least one / two problems for 3 bus system and calculate Y bus matrix analytically. Verify the result by software coding)
5. Static measurement of sub-transient reactance of a salient-pole alternator.
6. Measurement of sequence reactance of a synchronous machine (Negative and zero).

Optional Experiments (Any Two)

1. Plot receiving end circle diagram to evaluate the performance of medium transmission line.
2. Solution of a load flow problem using Newton-Raphson method using software.
   (Solve one problem for NR method for 3 bus system up to one iteration and verify the result with software.)
3. Simulation of Symmetrical fault of single machine connected to infinite bus.
   (Solve one problem for Symmetrical fault conditions and verify the result with simulation)
4. Simulation of Unsymmetrical fault of single machine connected to infinite bus.
   (Solve one problem for Unsymmetrical fault conditions and verify the result with simulation)

Guidelines for Instructor's Manual

The Instructor's Manual should contain the following related to every experiment:

- The circuit diagram of the experiment should be drawn at the start.
- Aim, apparatus, and theory related to that experiment should be written.
- One sample calculation should be shown, result table should be made, and graph should be plotted if required.
- Conclusion based on calculations, result and graph (if any) should be written.
- Five - six questions based on that experiment should be written at the end.

Guidelines for Students Lab Manual

Student's Lab Journal should be Handwritten/ Drawn containing, following things related to every experiment-

1. The circuit diagram of the experiment should be drawn on the graph paper at the start of the experiment.
2. Aim, apparatus, and theory related to that experiment should be written.
3. One sample calculation should be shown, result table should be made and graph should be plotted if required.
4. Conclusion based on calculations, result and graph (if any) should be written.
5. Students should write answers to five - six questions based on that experiment at the end.

Guidelines for Lab conduction

1. The circuit diagram should be explained to students in such a way that they should be able to develop it at their own.
2. Detail explanation of the experiment along with its circuit diagram, observation table, calculations, result table and plotting of graphs (if any).
3. While conducting new experiments, assessment of previous experiments should be carried out by its checking along with its mock oral session (minimum 4 -5 questions to each student).

Learning Resources

1. Text Books

[T1]. I.J. Nagrath and D.P. Kothari – Modern Power System Analysis – TMH New Delhi.
[T2]. Dr B R Gupta - "Power System Analysis and Design", S. Chand.
[T3]. C.L. Wadhwa - "Power System Analysis", New Age International.

2. Reference Books

[R1]. Stevenson W.D. Elements of Power System Analysis (4th Ed.) Tata McGraw Hill, New Delhi.
[R2]. Hadi Sadat: Power System Analysis, Tata McGraw-Hill New Delhi.
[R3]. J. B. Gupta - "A course in power systems" S.K. Kataria Publications.
[R4]. Ashfaq Hussain - "Electrical Power Systems", CBS Publication 5th Edition.
[R5]. V. K. Chandana, Power Systems, Cyber tech Publications.

3. Links to online SWAYAM/NPTEL Courses

[M1]. NPTEL Course on Power System Engineering: Debpriya Das
https://nptel.ac.in/courses/108/105/108105104/
[M2]. NPTEL Course on Power System Analysis by Dr. A.K. Sinha
https://nptel.ac.in/courses/108/105/108105067/

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PCC-354-ELE	**Course Name: Control System Engineering Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**01**	**TW : 25 Marks**
		OR : 25 Marks

Prerequisites: Ordinary Differential Equations, Basic Control System concepts (transfer function, time response, stability)

Course Objectives:

1. To experimentally validate control system concepts studied in theory
2. To develop mathematical models of physical systems
3. To analyze time-domain and frequency-domain responses
4. To study performance of controllers (P, PI, PID)
5. To use simulation tools (MATLAB/Simulink) for control analysis

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Determine transfer function of physical systems experimentally

CO2. Analyze time response of second-order systems

CO3. Perform frequency response analysis (Bode plot, compensators)

CO4. Study stability using root locus and frequency methods

CO5. Evaluate effects of P, PI, PID controllers on system.

List of Experiments

Minimum 8 experiments should be conducted. 4 experiments from Part (A) and 4 experiments from Part (B). Virtual Laboratory experiments are considered as experiments beyond syllabi.

Part (A) experiments:

1. Experimental determination of DC servo motor parameters for mathematical modelling and transfer function.
2. Experimental study of time response characteristics of R-L-C second order system. Validate the results using software simulation.
3. Experimental determination of frequency response of Lead compensator.
4. Experimental determination of frequency response of Lag compensator.
5. PID control of level/ Temperature/speed control system.
6. Experimental determination of transfer function of any one physical systems (AC Servomotor/ Two Tank System/ Temperature control/ Level control)
7. Experimental analysis of D.C. Motor Position control System.

Part (B) Experiments:

1. Stability analysis using a) Bode plot and b) Root locus.
2. Effect of P, PI and PID controllers on time response of second order system.
3. Analysis of closed loop DC position control system using PID controller.
4. Effect of addition of pole-zero on root locus of second order system.

5. Effect of addition of dominant and non-dominant poles on step response of second order system.
6. Stability analysis using Root Locus.

Part (C) Experiments:

Virtual Laboratory (V-Lab) Experiments

Guidelines for Instructor's Manual

The Instructor's Manual should contain the following related to every experiment:

- Theory related to the experiment
- Apparatus with their detailed specifications.
- Connection diagram /circuit diagram
- Basic MATLAB instructions for control system/ Simulink basics
- Observation table/ Expected simulation results
- Sample calculations for one/two reading
- Result table

Guidelines for Students Lab Manual

The student's Lab Journal should contain the following related to every experiment:

1. Apparatus with their detailed specifications.
2. Connection diagram /circuit diagram/ Simulink diagram/MATLAB program
3. Observation table/ simulation results
4. Sample calculations for one/two reading
5. Result table, Conclusion
6. Software program and result (if applicable)
7. Few short questions related to the experiment.

Guidelines for Lab assessment

There should be continuous assessment.

1. Continuous assessment is mandatory throughout the semester.
2. Evaluation should not be based on a single exam but on overall performance during lab sessions.
3. Assessment must consider the following aspects:
   - Understanding of theoretical concepts related to each experiment
   - Preparation before performing the experiment
   - Active participation and attentiveness during lab sessions
   - Accuracy in performing experiments and simulations
   - Ability to analyze results and draw meaningful conclusions
   - Timely completion and submission of lab journal
4. Regular monitoring of student progress should be carried out by the instructor.
5. Both experimental work and simulation (MATLAB/Simulink) should be considered during evaluation.
6. Internal assessment should reflect consistency, practical skills, and conceptual clarity.

Guidelines for Lab conduction

1. Assessment must be based on understanding of theory, attentiveness during practical session.
2. Assessment should be done how efficiently student is able to perform experiment/simulation and get the results. Understanding fundamentals and objective of experiment, timely submission of journal

Learning Resources

1. Text Books

[T1]. I.J. Nagrath, M. Gopal, "Control System Engineering", New Age International Publishers, 6th edition, 2017.

[T2]. Katsuhiko Ogata, "Modern control system engineering", Prentice Hall, 2010

[T3]. Nise N. S. "Control Systems Engineering", John Wiley & Sons, Incorporated, 2011

2. Reference Books

[R1]. B. C. Kuo, "Automatic Control System", Wiley India, 8th Edition, 2003.

[R2]. Richard C Dorf and Robert H Bishop, "Modern control system", Pearson Education, 12th edition, 2011

[R3]. B. Wayne Bequette, "Process Control: Modeling, Design and Simulation", PHI, 2003.

3. Links to online SWAYAM/NPTEL Courses

[M1]. NPTEL LINK: **https://nptel.ac.in/courses/108106098**

Savitribai Phule Pune University Third Year of Engineering (2024 Course)			
Course Code: PEC-361A-ELE	**Course Name: Electric Vehicles-I**		
Teaching Scheme	**Credits**	**Examination Scheme**	
Theory : 03 Hrs	**03**	**CCE**	**: 30 Marks**
Practical : 02 Hrs	**01**	**ESE**	**: 70 Marks**

Prerequisites: Battery fundamentals, DC and AC machines, DC–DC converters, inverters, and pulse width modulation (PWM) techniques. single-phase and three-phase systems, power, energy, and efficiency calculations is necessary. Fundamentals of mechanics, including force, torque, power, and motion.

Course Objectives:

1. To provide understanding to analyze the fundamental concepts, architecture and classification of Hybrid and Electric Vehicles.
2. To enable students to describe different types of energy storage systems and battery technologies used in electric and hybrid vehicles.
3. To develop knowledge to explain vehicle dynamics, driving resistances, traction and braking principles influencing the performance and efficiency of electric vehicles.
4. To impart analytical skills to analyze different powertrain configurations, modes of operation and electric drive systems used in hybrid electric vehicles.
5. To create awareness to differentiate Vehicle-to-Home (V2H), Vehicle-to-Vehicle (V2V) and Vehicle-to-Grid (V2G) concepts and evaluate their applications

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Analyze the fundamental concepts, architecture and classification of Hybrid and Electric Vehicles.

CO2. Describe different types of energy storage systems and battery technologies used in electric and hybrid vehicles.

CO3. Explain vehicle dynamics, driving resistances, traction and braking principles influencing the performance and efficiency of electric vehicles.

CO4. Analyze different powertrain configurations, modes of operation and electric drive systems used in hybrid electric vehicles.

CO5. Differentiate Vehicle-to-Home (V2H), Vehicle-to-Vehicle (V2V) and Vehicle-to-Grid (V2G) concepts and evaluate their applications.

Course Contents

Unit No: I	Introduction to Hybrid and Electric Vehicles	08 Hours

Need for electric mobility, energy and environmental issues, Basic components of electric vehicles and their functions. Classification of electric vehicles: BEV, HEV, PHEV and FCEV. Evolution of hybrid and electric vehicles. Comparison of electric vehicles, hybrid vehicles and internal combustion engine vehicles. Advantages, challenges and limitations of electric vehicles. Overview of global electric mobility trends and future EV roadmap (descriptive).

Exemplars/Case Studies	Study the growth of electric vehicles in India and compare them with petrol vehicles. Identify benefits like low pollution and challenges like charging availability.
Reference Books	**R1**

Unit No: II	Energy Storage and Battery Management Systems	08 Hours

Energy storage requirements for electric vehicles. Battery technologies used in EVs such as Lithium-ion batteries and their characteristics. Battery performance parameters including voltage, capacity, C-rate and efficiency. Battery Management System (BMS): functions, block diagram and protection features. State of Charge (SOC), State of Health (SOH) and State of Function (SOF) estimation (conceptual). Cell balancing techniques and thermal management. Battery aging, degradation and fast-charging challenges (introductory). Overview of AI-based battery management systems. (Self-Study)

Exemplars/Case Studies	Analyze how a battery management system monitors battery safety and performance in EVs. Understand basic concepts like SOC, charging, and temperature control.
Reference Books	**R1, R3**

Unit No: III	**Vehicle Dynamics**	**08 Hours**

Tire and wheel fundamentals including tire construction and components, radial and non-radial tires, and wheel and rim fundamentals. Tire–road interaction covering tire footprint, rolling resistance and hydroplaning (aquaplaning). Vehicle classification based on ISO and FHWA standards, passenger car classification and vehicle body styles. Forces acting on a vehicle under stationary conditions, during acceleration and braking. Driving resistances including rolling resistance, aerodynamic drag, gradient resistance and acceleration resistance. Vehicle motion and performance involving conceptual understanding of equation of motion, power and torque requirement, and performance parameters such as speed, gradeability and acceleration. Braking and traction dynamics covering longitudinal tire force, slip, traction and braking force generation with applications in electric vehicles.

Exemplars/Case Studies	Study how forces like rolling resistance and air drag affect an electric vehicle's motion. Understand how speed, load, and road conditions influence performance.
Reference Books	**R4, R5, R6**

Unit No: IV	**EV Drives and Charging Infrastructure**	**07 Hours**

Electric motors used in electric vehicles. BLDC, SRM and PMSM motors for EV applications. Comparison of BLDC, SRM and PMSM motors. Power electronics interface for EV drives. EV charging methods: AC and DC charging. EV charging levels and charging standards. Overview of EV supply equipment (EVSE). Introduction to wide band-gap power devices (SiC and GaN) for EV drives and chargers. Thermal challenges in EV drives and charging systems

Exemplars/Case Studies	Compare different motors used in EVs and their performance. Study basic EV charging methods and types of charging stations.
Reference Books	**R1, R3, R4, R5. R6**

Unit No: V	**V2H, V2V and V2G Technologies**	**09 Hours**

Concept of Vehicle-to-Home (V2H), Vehicle-to-Vehicle (V2V) and Vehicle-to-Grid (V2G). Smart charging concepts and demand response. Electric vehicles as distributed energy resources (DERs). Grid interaction of electric vehicles and impact on power systems. Aggregator concept and coordinated EV charging. Communication standards for EV–grid interaction. Cybersecurity issues in EV charging infrastructure. Future trends in EV–grid integration.

Exemplars/Case Studies	Understand how electric vehicles can supply power to homes or the grid. Study the concept of smart charging and its benefits to the power system.
Reference Books	**R2**

Learning Resources

1. Text Books

[T1]. I James Larminie and John Lowry, "Electrical Vehicle", John Wiley and Sons, 2012.
[T2]. Ronald K. Jurgen, "Electric and Hybrid-Electric Vehicles", SAE InternationalPublisher.
[T3]. K T Chau, "Energy Systems for Electric and Hybrid Vehicles", The institution of
[T4]. Engineering and Technology Publication
[T5]. D.A.J Rand, R Woods, R M Dell, "Batteries for Electric Vehicles", Research studies
[T6]. press Ltd, New York, John Willey and Sons

[T7]. Electric and Hybrid Vehicles-Design Fundamentals, CRC press

[T8]. Mark Warner, The Electric Vehicle Conversion handbook –HP Books, 2011.

2. Reference Books

[R1]. Mehrdad Ehsani, Yimin Gao and Ali Emadi, "Modern Electrical Hybrid Electric and Fuel Cell Vehicles: Fundamental, Theory and design", CRC Press, 2009.

[R2]. Junwei Lu, Jahangir Hossain, "Vehicle-to-Grid: Linking Electric Vehicles to the

[R3]. Smart Grid", IET Digital Library.

[R4]. "Automobile Electrical and Electronic systems", Tom Denton, SAE International publications.

[R5]. "Automotive handbook 5th edition", Robert Bosch, SAE international publication.

[R6]. Vehicle dynamics martin meywerk new york, john willey and sons

[R7]. Vehicle dynamics: theory and application, reza n. Jazar,springer publications.

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://auece.digimat.in/nptel/courses/video/108106170/L01.html

[M2]. https://archive.nptel.ac.in/courses/108/106/108106182/

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-361B-ELE	**Course Name: PLC and SCADA**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs	**03**	**CCE : 30 Marks**
Practical : 02 Hrs	**01**	**ESE : 70 Marks**

Prerequisites: Basic knowledge of Electrical and Electronic circuits including Relays, Contactors, Power supplies. Understanding of Digital Electronics including Logic Gates, Timers, Counters. Introductory knowledge of Microcontrollers and Basic programming Logic. Fundamentals of industrial Sensors, Transducers, and Electrical Machines.

Course Objectives:

1. To introduce fundamentals, architecture, and industrial applications of PLCs.
2. To develop PLC programming skills using ladder logic and standard instruction sets.
3. To enable students to design real-time industrial automation solutions using PLC.
4. To introduce SCADA systems, communication protocols, and industrial applications.
5. To explain Distributed Control Systems (DCS) and compare PLC, SCADA and DCS.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Describe the architecture of Programmable Logic Controller (PLC). (BTL-2: Understand).
CO2. Explain the interfacing of PLCs with Analog and Digital Input/Output devices. (BTL-2: Understand).
CO3. Implement PLC programs using ladder logic, timers, counters, and comparison instructions.
CO4. Describe Supervisory Control and Data Acquisition (SCADA) system architecture and its applications.
CO5. Describe industrial communication protocols and fundamentals of Distributed Control Systems (DCS).

Course Contents

Unit No: I	**Introduction to Industrial Automation and Programmable Logic Controller**	**08 Hours**

Introduction to Industrial Automation, Need and Role of Industrial Automation, Evolution of Industrial Automation, Types of Industrial Automation (Fixed Automation, Flexible Automation, Programmable Automation, and Integrated Automation), Benefits and Challenges of Industrial Automation, Applications of Industrial Automation. Necessity of Programmable Logic Controller (PLC), History and Evolution of PLC, Definition as per NEEMA (National Electrical Engineering Manufacturers Association), Types of PLC - Fixed/Modular/Dedicated, Overall PLC system, PLC Input and output modules (along with Interfaces), CPU, programmers and monitors, power supplies, selection criterion, advantages and disadvantages, specifications, comparison of various PLCs.

Exemplars/Case Studies	Automation of Conveyor System, Bottle Filling System.
Reference Books	**R2, R4.**

Unit No: II	**Programming of PLC**	**07 Hours**

Input ON/OFF Switching Devices (Push button, Limit switch, Selector switch, Proximity sensors, Level, Flow, Temperature, switches), Input Analog Devices (LVDT, Load cell, RTD, Transmitters, Incremental and Absolute Encoders), Output ON/OFF Devices (Relays, Contactors, Solenoids), Output Analog Devices (I/P converter, Variable Frequency Drive (VFD), Servo drive), Actuators (Electrical, Pneumatic, Hydraulic)

Exemplars/Case Studies	PLC Based Motor Control, Tank Level Monitoring System.
Reference Books	**R1, R2**

Unit No: III	**Programming of PLC**	**08 Hours**

Programming languages for PLC, Ladder Diagram fundamentals, Rules for proper construction of ladder diagram, Timer and counter- types along with timing diagrams, Reset instruction, Latch/Unlatch instruction, Master Control Relay (MCR) and control zones. Introduction to Compare instructions (“EQUAL." Or "EQU", "NOT EQUAL" or "NEQ", "LESS THAN" or "LES", "LESS THAN OR EQUAL" or "LEQ", GREATER THAN" or "GRT", "GREATER THAN OR EQUAL TO" or "GRQ", "MASKED COMPARISON FOR EQUAL" or "MEQ", "LIMIT TEST" or "LIM"), Analog Operation of PLC, PID module using PLC.

Exemplars/Case Studies	Traffic Light Control, Motor Sequencing.
Reference Books	**R1, R2**

Unit No: IV	**Supervisory Control and Data Acquisition Systems**	**07 Hours**

Introduction, Definitions and History of Supervisory Control and Data Acquisition, Typical SCADA system architecture, Important definitions HMI, MTU, RTU, Communication means, Desirable properties of the SCADA system, Advantages, Disadvantages, and Applications of SCADA. SCADA generations (First Generation - Monolithic, Second Generation - Distributed, Third Generation – Networked Architecture), SCADA systems in Operation and Control of Interconnected Power System, Functions and Features of SCADA systems, Automatic Substation Control, Energy Management Systems (EMS), System Operating States, SCADA systems in Critical Infrastructure: Petroleum Refining Process, Conventional Electric power generation, Water Purification System, Chemical Plant.

Exemplars/Case Studies	SCADA in Substation Automation.
Reference Books	**R1, R3.**

Unit No: V	**Industrial Communication Protocols and Distributed Control Systems**	**07 Hours**

Open Systems Interconnection (OSI) Model, TCP/IP protocol, Modbus model, DNP3 protocol, Industrial Ether Net protocol, Flexible Function Block process (FFB), Process Field bus (Profibus). Distributed Control System: Introduction to DCS - its working & operation, Architecture, Features, Advantages & Applications of DCS, and Comparison between DCS & PLC.

Exemplars/Case Studies	DCS in Process Industry.
Reference Books	**R3, R4.**

Learning Resources

1. Text Books

[T1]. J. W. Webb and R. A. Reis, Programmable Logic Controllers: Principles and Applications, 5th ed., Prentice Hall, 2015.

[T2]. Garry Dunning, Introduction to Programmable Logic Controllers, 2nd ed., Thomson Learning, 2003.

[T3]. F. D. Petruzella, Programmable Logic Controllers, 4th ed., McGraw-Hill Education, 2016.

2. Reference Books

[R1]. J. R. Hackworth and F. D. Hackworth Jr., Programmable Logic Controllers: Programming Methods and Applications, PHI Learning, 2003.

[R2]. C. D. Johnson, Process Control Instrumentation Technology, 8th ed., Pearson Education, 2014.

[R3]. G. Clarke and D. Reynders, Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems, 1st ed., Newnes (Elsevier), 2004.

[R4]. R. L. Krutz, Securing SCADA Systems, Wiley, 2010.

3. Links to online SWAYAM/NPTEL Courses

[M1]. NPTEL Course on “Industrial Automation and Control” By, Prof. Siddhartha Mukhopadhyay, IIT Kharagpur – Course Link: https://nptel.ac.in/courses/108105088

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-361C-ELE	**Course Name: Energy Storage & Grid Interconnected Renewable Energy Systems**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 3 Hrs	**03**	**CCE : 30 Marks**
		ESE : 70 Marks

Prerequisites: Basic knowledge of electrical quantities like voltage, current, power, energy etc.

Course Objectives:

1. To understand the role of energy storage systems in renewable energy applications.
2. To learn the operation of grid-connected renewable energy systems.
3. To study battery technologies and energy management systems.
4. To understand power electronic converters and protection methods used in renewable integration.
5. To explore smart grid, microgrid, and electric vehicle applications.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Explain the basics of energy storage systems and grid integration.
CO2. Understand operation of battery energy storage systems.
CO3. Analyze grid-connected renewable energy systems.
CO4. Understand power quality and protection issues in renewable energy systems.
CO5. Apply concepts of smart grid and microgrid systems

Course Contents

Unit No: I	**Introduction to Energy Storage Systems**	**08 Hours**

Need for energy storage systems, Applications of energy storage in renewable energy systems,
Types of energy storage systems: Battery storage, Supercapacitor, Flywheel storage, Hydrogen storage
Comparison of energy storage systems, Advantages and limitations of energy storage systems, Introduction to Battery Energy Storage System (BESS)

Exemplars/Case Studies: Solar power plants, wind farms, backup systems, electric vehicles

Reference Books:

Unit No: II	**Battery Technologies and Battery Management System**	**08 Hours**

Introduction to batteries, Types of batteries: Lead-acid battery, Lithium-ion battery, Sodium-ion battery
Battery charging and discharging characteristics, State of Charge (SOC) and Depth of Discharge (DOD)
Battery Management System (BMS): Monitoring, Protection, Cell balancing
Thermal management of batteries, Applications of battery energy storage systems

Exemplars/Case Studies: Electric vehicles, UPS systems, renewable energy storage systems

Reference Books

Unit No: III	**Grid Connected Renewable Energy Systems**	**08 Hours**

Basic concept of grid-connected renewable energy systems, Grid synchronization basics
Grid-connected solar PV system: Basic block diagram, Working principle
Grid-connected wind energy system: Basic block diagram, Working principle,
Hybrid renewable energy systems, Net metering concept, Advantages of grid-connected renewable systems

Exemplars/Case Studies: Rooftop solar systems, solar farms, wind power plants, smart grids

Reference Books		
Unit No: IV	**Power Electronics and Protection in Renewable Energy Systems**	**08 Hours**
Role of power electronics in renewable energy systems, Introduction to: DC-DC converters, Inverters PWM control technique, Power quality issues: Harmonics, Voltage fluctuations Reactive power compensation, Islanding and anti-islanding protection, Grounding and safety practices		
Exemplars/Case Studies: Grid-connected renewable plants, battery storage systems		
Reference Books		
Unit No: V	**Smart Grid and Modern Energy Applications**	**08 Hours**
Introduction to smart grid, Smart meters and monitoring systems, Basic concept of microgrid, Modes of operation of microgrid, Electric vehicle charging systems, Vehicle-to-Grid (V2G) concept, Energy management system, Recent trends: AI in energy systems, Smart energy monitoring, Hydrogen energy applications		
Exemplars/Case Studies: Smart cities, EV charging stations, industrial microgrids		
Reference Books		

Learning Resources

1. Text Books

[T1]. Renewable and Efficient Electric Power Systems, Gilbert M. Masters, Wiley-IEEE Press.

[T2]. Power Electronics for Renewable Energy Systems, Bimal K. Bose, Wiley Publication.

[T3]. Solar Photovoltaics: Fundamentals, Technologies and Applications, Chetan Singh Solanki, PHI Learning Ltd.

[T4]. Energy Storage Systems, S. K. Khaitan and James D. McCalley, Wiley Publication.

[T5]. Smart Grid Technology and Applications, Lars T. Berger and Krzysztof Iniewski, Wiley Publication.

2. Reference Books

[R1]. Renewable Energy Sources and Emerging Technologies, D. P. Kothari, K. C. Singal and Rakesh Ranjan, PHI Learning.

[R2]. Battery Management Systems, Gregory L. Plett, Artech House.

[R3]. Grid Integration of Wind Energy, Siegfried Heier, Wiley Publication.

[R4]. Smart Grid, Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu and Akihiko Yokoyama, Wiley Publication.

[R5]. Electrical Energy Storage, Benoit Robyns, Bruno François and Philippe Degobert, Wiley Publication.

[R6]. Introduction to Modern Power Electronics, Andrzej M. Trzynadlowski, Wiley India.

[R7]. Understanding Smart Grids, Yang Xiao, CRC Press.

[R8]. Fundamentals of Electric Drives, G. K. Dubey, Narosa Publishing House.

3. Links to online SWAYAM/NPTEL Courses

[M1]. Introduction to Smart Grid – SWAYAM NPTEL (IIT Roorkee), Prof. N. P. Padhy and Prof. Premalata Jena, covers smart grid, renewable integration, microgrid and energy management concepts.

[M2]. Smart Grid: Basics to Advanced Technologies – NPTEL, Prof. N. P. Padhy and Prof. Premalata Jena, IIT Roorkee, includes smart grid technologies, distributed generation and renewable energy integration.

[M3]. Introduction to Smart Grid – NPTEL Archive Course, archived course covering smart grid fundamentals, renewable integration and monitoring systems.

[M4]. Sustainable Energy Technology – SWAYAM NPTEL (IIT Hyderabad), Prof. Sayak Banerjee, covers sustainable energy technologies, smart grids and energy storage systems

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-362A-ELE	**Course Name: Electric Vehicles Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs	**01**	**TW : 25 Marks**
		OR : 25 Marks

Prerequisites: Ohm's law, Kirchhoff's laws, power calculations, and AC/DC circuit behavior, BLDC, PMSM, or induction motors, battery fundamentals—such as voltage, current, capacity (Ah), energy (Wh), state of charge (SOC), state of health (SOH), and charging methods like constant current (CC) and constant voltage (CV), MATLAB/Simulink, PSIM and ANSYS tools.

Course Objectives:

1. To provide understanding to analyze the fundamental concepts, architecture and classification of Hybrid and Electric Vehicles.
2. To enable students to describe different types of energy storage systems and battery technologies used in electric and hybrid vehicles.
3. To develop knowledge to explain vehicle dynamics, driving resistances, traction and braking principles influencing the performance and efficiency of electric vehicles.
4. To impart analytical skills to analyze different powertrain configurations, modes of operation and electric drive systems used in hybrid electric vehicles.
5. To create awareness to differentiate Vehicle-to-Home (V2H), Vehicle-to-Vehicle (V2V) and Vehicle-to-Grid (V2G) concepts and evaluate their applications

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Analyze the fundamental concepts, architecture and classification of Hybrid and Electric Vehicles.

CO2. Describe different types of energy storage systems and battery technologies used in electric and hybrid vehicles.

CO3. Explain vehicle dynamics, driving resistances, traction and braking principles influencing the performance and efficiency of electric vehicles.

CO4. Analyze different powertrain configurations, modes of operation and electric drive systems used in hybrid electric vehicles.

CO5. Differentiate Vehicle-to-Home (V2H), Vehicle-to-Vehicle (V2V) and Vehicle-to-Grid (V2G) concepts and evaluate their applications.

List of Experiments

Perform eight experiments from the following list.

Four hardware experiments and four software experiments will be compulsory.

Hardware experiments (Any four):

1. Study of basic components of Electric Vehicles (motor, controller, battery, charger, transmission)
2. Estimation of Battery capacity calculation and it's validation for a specific EV application.
3. Demonstration of Battery pack performance characteristics: variation of voltage, current and SOC with time
4. Study of basic components of Hybrid Electric Vehicles and their configuration
5. Case study of 2-W / 3-W / 4-W Electric or Hybrid Vehicle (design, specifications and performance)

6. Demonstration and study of Battery Management System (BMS) and its functions

Software Experiments (Any Four)

1. Simulation of first- and second-order electrical circuits to evaluate EV component dynamics
2. Simulation of Equivalent Circuit Battery model (2RC / 3RC) for EV applications.
3. Estimation of vehicle longitudinal dynamics to estimate driving resistances (rolling, aerodynamic and gradient)
4. Estimation of traction and braking performance of an electric vehicle under different road conditions (upward, downward, horizontal etc.)
5. Effect of tractive effort on different load condition
6. Simulation of complete EV powertrain and evaluation of performance parameters

Learning Resources

1. Text Books

[T1]. James Larminie and John Lowry, "Electrical Vehicle", John Wiley and Sons, 2012.

[T2]. Ronald K. Jurgen, "Electric and Hybrid-Electric Vehicles", SAE International Publisher.

[T3]. K T Chau, "Energy Systems for Electric and Hybrid Vehicles", The institution of Engineering and Technology Publication

[T4]. D.A.J Rand, R Woods, R M Dell, "Batteries for Electric Vehicles", Research studies press Ltd, New York, John Willey and Sons

[T5]. Electric and Hybrid Vehicles-Design Fundamentals, CRC press

[T6]. Mark Warner, The Electric Vehicle Conversion handbook –HP Books, 2011.

2. Reference Books

[R1]. Mehrdad Ehsani, Yimin Gao and Ali Emadi, "Modern Electrical Hybrid Electric and Fuel Cell Vehicles: Fundamental, Theory and design", CRC Press, 2009.

[R2]. Junwei Lu, Jahangir Hossain, "Vehicle-to-Grid: Linking Electric Vehicles to the Smart Grid", IET Digital Library.

[R3]. "Automobile Electrical and Electronic systems", Tom Denton, SAE International publications.

[R4]. "Automotive handbook 5th edition", Robert Bosch, SAE international publication.

[R5]. Vehicle dynamics martin meywerk new york, john willey and sons

[R6]. Vehicle dynamics: theory and application, reza n. Jazar,springer publications.

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/108106170

[M2]. https://onlinecourses.nptel.ac.in/noc22_ee53/preview

Savitribai Phule Pune University Third Year of Engineering (2024 Course)			
Course Code: PEC-362B-ELE	**Course Name: PLC and SCADA Lab**		
Teaching Scheme	**Credits**	**Examination Scheme**	
Practical : 02 Hrs	**1**	**TW**	**: 25 Marks**
		OR	**: 25 Marks**

Prerequisite: Basic knowledge of PLC and SCADA theory and ladder logic programming, Understanding of sensors, actuators and motor control circuits, Fundamentals of digital logic and control systems

Course Objectives:

1. To provide hands-on experience in PLC programming using simulation tools.
2. To develop skills in interfacing field devices with PLC.
3. To implement real-time industrial control applications using PLC logic.
4. To introduce SCADA configuration, monitoring, alarm handling and data logging.
5. To integrate PLC and SCADA for supervisory control applications.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Develop and simulate PLC programs for industrial applications.
CO2. Interface digital and analog I/O devices in PLC environment.
CO3. Design motor control and process control applications using PLC.
CO4. Configure SCADA for monitoring, alarm handling and data logging.
CO5. Implement PLC–SCADA integrated supervisory control systems.

List of Experiments

At least one experiment must be performed using hardware (sensor-based) from Experiments 6 to 9

PLC Based Experiments (Any 5 Experiments)

1. Interfacing of lamp and push button with PLC for ON and OFF operation. Verification of basic logic gates using ladder logic.
2. Set/Reset operation using PLC: One push button for ON (SET) and another push button for OFF (RESET) operation with emergency interlock condition.
3. Delayed operation of lamp using push button: Implementation using ON-delay and OFF-delay timer instructions with sequential lamp operation.
4. UP/DOWN counter implementation with RESET instruction for counting applications.
5. Combination of counter and timer for sequential lamp ON/OFF control operation.
6. DOL starter and Star–Delta starter control using PLC logic with proper interlocking.
7. PLC-based thermal ON/OFF control system using temperature input simulation.
8. Interfacing of encoder (Incremental type) with PLC for pulse counting and position monitoring.
9. PLC-based measurement system for speed/position/flow/ level/ pressure using analog inputs.

SCADA Based Experiments (Any 3 experiments)

10. Parameter reading and monitoring of PLC variables using SCADA software.
11. Alarm configuration and annunciation using SCADA system.
12. Reporting and trend analysis in SCADA system for process parameters.

13. Tank level control and monitoring using SCADA.
14. Temperature monitoring system using SCADA.
15. Speed control of machine using SCADA supervisory control.
16. Pressure monitoring and control using SCADA.

Guidelines for Instructor's Manual

The Instructor's Manual should contain the following related to every experiment:

- Aim and objectives of the experiment
- Hardware/software requirements
- Brief theory and industrial relevance
- Circuit/logic diagram
- Stepwise procedure for implementation
- Expected output/results
- Troubleshooting guidelines
- Assessment rubric

Guidelines for Students Lab Manual

The student's Lab Journal should contain the following related to every experiment:

- Title and Aim
- Problem statement
- PLC addressing table
- Ladder logic/program screenshots
- SCADA screen design (where applicable)
- Observations and result
- Conclusion
- Viva questions

Guidelines for Lab assessment

There should be continuous assessment.

- Timely completion of experiments
- Understanding of ladder logic and SCADA configuration
- Lab journal maintenance
- Mini-application development
- Viva voce performance
- Final practical examination

Guidelines for Lab conduction

- Use PLC simulation software (e.g., Siemens/Allen-Bradley/Delta or equivalent)
- SCADA software (e.g., WinCC, Wonderware, FactoryTalk, or open-source tools)
- Each experiment should include demonstration and verification
- Encourage industrial case-based implementation
- Maintain safety practices while handling hardware (if available)

Learning Resources

1. Text Books

[T1]. John W. Webb & Ronald A. Reis, *Programmable Logic Controllers: Principles and Applications*

[T2]. Frank D. Petruzella, *Programmable Logic Controllers*

2. Reference Books

[R1]. Gary Dunning, *Introduction to Programmable Logic Controllers*

[R2]. Stuart A. Boyer, *SCADA: Supervisory Control and Data Acquisition*

3. Links to online SWAYAM/NPTEL Courses (virtual lab)

[M1]. https://ial-coep.vlabs.ac.in/List%20of%20experiments.html

[M2]. https://plc-coep.vlabs.ac.in/List%20of%20experiments.html

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-362C-ELE	**Course Name: Energy Storage & Grid Interconnected Renewable Energy Systems Lab**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 02 Hrs/Week	**01**	**TW : 25 Marks**

Prerequisites: Basic knowledge of Electrical Engineering fundamentals, Basic understanding of renewable energy systems, Fundamentals of Power Electronics, Basic knowledge of Electrical Measurements and Instrumentation, Basic understanding of MATLAB/Simulink software

Course Objectives:

1. To understand the operation and characteristics of energy storage devices used in renewable energy systems.
2. To study battery technologies, Battery Management Systems (BMS), and supercapacitors.
3. To analyze operation of grid-connected solar PV systems and renewable energy converters.
4. To study power quality issues and harmonic analysis in renewable-integrated systems.
5. To understand microgrid operation, net metering, and energy management techniques.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Perform testing and analysis of batteries and energy storage devices.
CO2. Analyze characteristics of lithium-ion batteries and supercapacitors.
CO3. Understand operation of Battery Management System (BMS) and SOC estimation methods.
CO4. Study operation of grid-connected renewable energy systems and inverters.
CO5. Analyze harmonics, net metering systems, and microgrid operation using practical and simulation tools.

List of Experiments

Any Eight Experiments has to be performed

1. Study of charging and discharging characteristics of battery
2. Study of lithium-ion battery characteristics
3. State of Charge (SOC) estimation using Battery Management System (BMS)
4. Study of supercapacitor characteristics
5. Study of grid-connected solar PV system
6. Study of inverter operation for renewable energy systems
7. Harmonic analysis in grid-connected renewable systems
8. Study of net metering system
9. Simulation of battery energy storage system using MATLAB/Simulink
10. Study of microgrid operation and control

Learning Resources

1. Text Books

[T1]. Renewable and Efficient Electric Power Systems, Gilbert M. Masters, Wiley-IEEE Press.
[T2]. Solar Photovoltaics: Fundamentals, Technologies and Applications, Chetan Singh Solanki, PHI Learning Pvt. Ltd.

[T3]. Power Electronics for Renewable Energy Systems, Bimal K. Bose, Wiley Publication.
[T4]. Energy Storage Systems, S. K. Khaitan and James D. McCalley, Wiley Publication.
[T5]. MATLAB and Simulink for Engineers, Agam Kumar Tyagi, Oxford University Press.

2. Reference Books

[R1]. Battery Management Systems, Gregory L. Plett, Artech House.
[R2]. Renewable Energy Sources and Emerging Technologies, D. P. Kothari, K. C. Singal and Rakesh Ranjan, PHI Learning.
[R3]. Smart Grid, Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu and Akihiko Yokoyama, Wiley Publication.
[R4]. Electrical Energy Storage, Benoit Robyns, Bruno François and Philippe Degobert, Wiley Publication.
[R5]. Understanding Smart Grids, Yang Xiao, CRC Press.

3. Links to online SWAYAM/NPTEL Courses

[M1]. Introduction to Smart Grid – SWAYAM NPTEL (IIT Roorkee), Prof. N. P. Padhy and Prof. Premalata Jena, covers smart grid, renewable integration, microgrid and energy management.
[M2]. DC Microgrid and Control System – SWAYAM NPTEL (IIT Roorkee), Prof. Avik Bhattacharya, covers DC microgrid architecture, operation and control strategies.
[M3]. Physics of Renewable Energy Systems – SWAYAM NPTEL (IIT Kharagpur), Prof. Amreesh Chandra, includes renewable energy sources, batteries and supercapacitors.
[M4]. Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems – NPTEL, Prof. Vaibhav Vasant Goud and Prof. R. Anandalakshmi, covers renewable energy conversion and applications.
[M5]. Energy Materials and Devices – SWAYAM NPTEL (IIT Delhi), Prof. Santanu Ghosh, covers batteries, supercapacitors, fuel cells and hydrogen energy systems.
[M6]. Energy Storage Options – NPTEL Learning Resource, Prof. Kaushal Kumar Jha, IIT Madras, covers battery technologies and energy storage methods used in renewable energy systems.

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-363A-ELE	**Course Name: Illumination Engineering**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 3 Hrs	**03**	**CCE : 30 Marks**
		ESE : 70 Marks

Prerequisite: Electrical Engineering fundamentals, physics concepts (light, optics, energy), electrical circuits and measurements

Course Objectives:

1. To introduce the importance of lighting in human life and develop understanding of visual performance, properties, and measurement of light..
2. To familiarize students with various light sources, their operating principles, materials, and methods of electrical and photometric control.
3. To develop the ability to apply design principles and methods for calculating illumination levels in indoor environments.
4. To enable students to design practical lighting schemes for different applications such as residential, commercial, and special-purpose installations.
5. To introduce modern trends in illumination, including LED technologies and human-centric lighting concepts with their impact on health and well-being.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Explain the role of lighting in human life, visual perception, and evaluate light properties and measurement techniques.

CO2. Analyze different light sources, their characteristics, and methods of electrical and photometric control used in lighting systems.

CO3. Apply illumination design methods such as the zonal cavity method to determine lighting requirements for indoor spaces.

CO4. Design appropriate lighting schemes for various real-world applications considering technical and aesthetic requirements.

CO5. Evaluate modern lighting technologies and human-centric lighting principles for energy-efficient and user-friendly illumination systems.

Course Contents

Unit No: I	**Importance of Lighting in Human Life**	**08 Hours**

Optical systems of human eye, Dependence of human activities on light, performance characteristics of human visual system, External factors of vision-visual acuity, contrast, sensitivity, time illuminance, colour, visual perception, optical radiation hazards, Good and bad effects of lighting and perfect level of illumination, Artificial lighting as substitute to natural light, Ability to control natural light, Production of light, physics of generation of light, Properties of light, Quantification and Measurement of light.

Exemplars/Case Studies	
Reference Books	**T1, T2, T3, T4, T5, R1, R3, R4, R5**

Unit No: II	**Light Sources and Electrical Control of Light Sources**	**08 Hours**

Light Sources- Lamp materials: Filament, glass, ceramics, gases, phosphors and other metals and non-metals.

Discharge Lamps: Theory of gas Discharge phenomena, lamp design considerations, characteristics of low- and high-pressure mercury and Sodium vapour lamps, Low Vapour Pressure discharge lamps - Mercury Vapour lamp, Fluorescent Lamp, Compact Fluorescent Lamp (CFL)
High Vapour Pressure discharge lamps - Mercury Vapour lamp, Sodium Vapour lamp, Metal halide Lamps, Solid Sodium Argon Neon lamps, SOX lamps, Electro luminescent lamps, Induction lamps.
Ballast, ignitors and dimmers for different types of lamps

Control of Light Sources

Photometric Control of Light Sources and their Quantification: Types of Luminaries, factors to be considered for designing luminaries Types of lighting fixtures. Optical control schemes, design procedure of reflecting and refracting type of luminaries. Lighting Fixture types, use of reflectors and refractors, physical protection of lighting fixtures, types of lighting fixtures according to installation type, types of lighting fixtures according to photometric usages, luminaries standard (IEC-598-Part I).

Exemplars/Case Studies	
Reference Books	**T1, T2, T3, T4, T5, R1, R3, R4, R5**

Unit No: III	**Design Considerations for illumination schemes**	**08 Hours**

Zonal cavity method for general lighting design, determination for zonal cavities and different shaped ceilings using COU (coefficient of utilization), beam angles and polar diagrams. Factors to be considered for design of indoor illumination scheme

Exemplars/Case Studies	
Reference Books	**T2, T3, T4, T5, R1, R3, R4, R5**

Unit No: IV	**Design of lighting schemes**	**08 Hours**

Indoor illumination design for following installations -Residential (Numerical), Educational institute Commercial installation Hospitals, Special purpose lighting schemes Decorative lighting, Theatre lighting Aquarium, swimming pool lighting

Exemplars/Case Studies	An indoor illumination scheme design project to a group of students may be assigned.
Reference Books	**T2, T3, T4, R1, R3, R4, R5**

Unit No: V	**Modern trends in illumination**	**08 Hours**

Intelligent LED fixtures, Natural light conduiting, Organic lighting system, Optical fiber, its construction as a light guide, features and applications.
Introduction to Human-Centric Lighting (HCL), Definition and concept of HCL, Evolution from conventional lighting to smart and adaptive lighting, Biological and Psychological Effects of Light, Human circadian rhythm and its relation to light Lighting Parameters for HCL-Illuminance (lux levels) ,Correlated Color Temperature (CCT) ,Color Rendering Index (CRI) ,iming, intensity, and spectral distribution.Effect of light on sleep, alertness, mood, and well-being.
HCL design principles for indoor environments

Exemplars/Case Studies	
Reference Books	**T1, T3, T4, T5, T6, R4, R5, R6, R7**

Learning Resources

1. Text Books

[T1]. H. S. Mamak, “Book on Lighting”, Publisher International lighting Academy..
[T2]. Joseph B. Murdoch, “Illumination Engineering from Edison’s Lamp to Lasers” Publisher -York, PA : Visions Communications

[T3]. M. A. Cayless, A. M. Marsden, "Lamps and Lighting", Publisher-Butterworth Heinemann (ISBN 978-0-415-50308-2)

[T4]. B.R. Gupta and Vandana Singhal -Fundamentals of Electric Machines, New Age International (P) Ltd

[T5]. Tran Quoc Khanh, Peter Bodrogi, Trinh Quang Vinh, "Human Centric Integrative Lighting: Technology, Perception, Non-Visual Effects", Wiley-VCH (2023)

[T6]. Kevin W. Houser, "Human-Centric Lighting: Foundational Considerations and a Five-Step Design Process", Frontiers in Neurology

2. Reference Books

[R1]. "BIS, IEC Standards for Lamps, Lighting Fixtures and Lighting", Manak Bhavan, New Delhi.

[R2]. D. C. Pritchard, "Lighting", 4th Edition, Longman Scientific and Technical, ISBN 0-582-23422-0

[R3]. "IES Lighting Handbook", (Reference Volume 1984), Illuminating Engineering Society of North America.

[R4]. "IES Lighting Handbook", (Application Volume 1987), Illuminating Engineering Society of North America.

[R5]. IESNA lighting Handbook., Illuminating Engineering Society of North America 9th edition 2000

[R6]. Applied Illumination Engineering, Jack L. Lindsey FIES (Author), Scott C. Dunning PHD PECEM (Author) ,ISBN-13: 978-0824748098 ISBN-10: 0824748093, 3rdEdition.

[R7]. Organic Light Emitting Diodes (OLEDs): Materials, Devices and Applications, Alastair Buckley, University of Sheffieid, UK, ISBN: 978-0-85709-425-4

3. Links to online SWAYAM/NPTEL Courses

[M1]. Illumination Engineering, IIT Kharagpur by Prof. N.K. Kishore
Link- https://nptel.ac.in/courses/108105060

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-363B-ELE	**Course Name: Energy Management**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 3 Hrs	**3**	**CCE : 30 Marks**
		ESE : 70 Marks

Prerequisites: Construction, and operation of various electrical equipment, Construction, and operation of different equipment/ industrial process like HVAC, Pumps, Compressors etc.

Course Objectives:

1. To understand importance of energy Conservation and energy security and impact of energy use on environment.
2. To comprehend format of energy management, energy policy.
3. To understand demand side management tools and impact of tariff on demand management.
4. To use simple data analytics in Energy audit and audit process.
5. To calculate energy consumption and saving options with economic feasibility.
6. To use of appropriate energy conservation measure in field applications or industry.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Describe environmental impacts of energy and means to reduce it

CO2. Apply appropriate demand management measures for managing utility systems.

CO3. Elaborate Energy management principles and strategy.

CO4. Analyze energy audit data for assessing energy conservation potential.

CO5. Evaluate economic feasibility of energy conservation projects or energy conservations measures.

Course Contents

Unit No: I	**Energy Scenario and Sustainability**	**08 Hours**

Classification of Energy resources, commercial energy production, Indian and Global energy scenario, final energy consumption. Energy needs of growing economy, short terms and long terms policies, energy sector reforms, energy security, energy and environmental impacts, Global Warming and Climate Change: Causes, Effects, and Mitigation. Carbon Footprint Calculation and Reduction Strategies, Environmental Risk Assessment. Salient features of Energy Conservation Act 2001 and Electricity Act 2003. Energy Conservation Building Code (ECBC).

Exemplars/Case Studies	Study of CDM, UNFCCC, Paris treaty
Reference Books	**T1, M1**

Unit No: II	**Demand Response and management**	**08 Hours**

Supply side management (SSM), constraints on SSM. Demand side management (DSM), advantages and barriers, implementation of DSM. Use of demand side management in agricultural, domestic, and commercial consumers. Demand management through tariffs (TOD). Role of renewable energy sources in energy management, Net metering, Role of Energy storage in demand management.

Exemplars/Case Studies	Study ISO 50001- Energy Management.
Reference Books	T1

Unit No: III	**Energy Management**	**08 Hours**

Definition, Objectives and Principles of Energy Management, Energy

Management Strategy, Energy Manager Skills, key elements in energy management, force field analysis, energy policy, Responsibilities and duties of energy manager under the latest Act. Organizational structure, Energy Efficiency Programs., Energy monitoring systems, Role of IoT in demand management, Advance metering infrastructure

Exemplars/Case Studies	Latest Energy Efficiency Programs in India
Reference Books	**T1, R4, R5**

Unit No: IV	**Energy Audit**	**08 Hours**

Definition, need of energy audits, types of audits, steps in audit, data and information analysis, Introduction to Data Analytics, data quality processing, clustering techniques, pattern mining, regression and classification. energy audit instrumentation, energy consumption-production relationship, pie charts. Sankey diagram, Cusum technique, least square method and numerical based on it. Outcome of energy audit and energy saving potential, action plans for implementation of energy conservation options. Bench-marking energy performance of an industry. Energy Audit reporting format-Executive Summary and report

Exemplars/Case Studies	Energy Audits case studies – Sugar Industry/Steel Industry
Reference Books	**T1, R4, R5, R6**

Unit No: V	**Financial Analysis and Energy Conservation area**	**08 Hours**

Financial appraisals; criteria, simple payback period, return on investment, net present value method, time value of money, break even analysis, numerical based on it.

Energy Conservation in Commercial and Industrial sector: a) Motive power (motor and drive system). b) Boiler and steam systems c) Cogeneration and waste heat recovery systems d) Utility industries (T and D Sector)

Exemplars/Case Studies	Energy Audits case studies – Paper and Pulp
Reference Books	**T2, T3, T4, R1, R2, R3, R4, M2**

Learning Resources

1. Text Books (available online)

[T1]. Guidebooks for National Certification Examination for Energy Managers/Energy Auditors Book 1, General Aspects

[T2]. Guidebooks for National Certification Examination for Energy Managers/Energy Auditors Book 2 – Thermal Utilities

[T3]. Guidebooks for National Certification Examination for Energy Managers/Energy Auditors Book 3- Electrical Utilities

[T4]. Guidebooks for National Certification Examination for Energy Managers/Energy Auditors Book 4

2. Reference Books

[R1]. Success stories of Energy Conservation by BEE (www. Bee-india.org)

[R2]. Utilization of electrical energy by S.C. Tripathi, Tata McGraw Hill.

[R3]. Energy Management by W.R. Murphy and Mackay, B.S. Publication.

[R4]. Generation and utilization of Electrical Energy by B.R. Gupta, S. Chand Publication

[R5]. Energy Auditing made simple by Balasubramanian, Bala Consultancy Services.

[R6]. A General Introduction to Data Analytics by Andre Carvalho and Tomáš Horváth Wiley Inc First Edition

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/109106161 **NOC: Energy Economics and Policy**

[M2]. https://nptel.ac.in/courses/112105221 **NOC: Energy Conservation and Waste Heat Recovery**

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: PEC-363C-ELE	**Course Name: Digital Signal Processing**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03 Hrs	**03**	**CCE : 30 Marks**
		ESE : 70 Marks

Prerequisite: Fundamentals of Electrical and Electronics Engineering, Z-transform, ROC and inverse Z-transform, Fourier transform, IIR Systems: direct form, cascade form, Basic Structures for FIR Filters

Course Objectives:

1. To introduce the fundamental concepts of discrete-time signals and systems used in digital signal processing.
2. To develop the ability to analyze discrete-time signals and systems using DTFT and DFT techniques.
3. To provide knowledge of FFT algorithms and their applications for efficient frequency domain analysis.
4. To impart skills for the design and realization of IIR and FIR digital filters using standard techniques.
5. To enable students to apply DSP concepts in electrical engineering applications such as harmonic analysis, power measurement, and power quality improvement.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Analyze discrete time signals and systems

CO2. Obtain frequency response of LTI system using DTFT

CO3. Obtain frequency response of LTI system using DFT

CO4. Design and realize IIR and FIR filters

CO5. Apply concepts of DSP in various applications of electrical engineering

Course Contents

Unit No: I	**Discrete time signal and system**	**08 Hours**

Discrete-time and Digital signals, Basic sequences and sequence operations, Discrete time systems, Properties of D. T. Systems, Linear Time Invariant Systems, impulse response, linear convolution and its properties, properties of LTI systems: stability, causality, Periodic Sampling, Sampling Theorem, reconstruction of a band limited Signal, A to D conversion Process: Sampling, quantization and encoding. Linear constant coefficient difference equations, Solution of difference equation using Z-transform.

Exemplars/Case Studies	
Reference Books	**T2, T3, M2**

Unit No: II	**Discrete Time Fourier Transform**	**08 Hours**

Representation of Sequences by Fourier Transform, Symmetry properties of D. T., F. T. theorems: Linearity, time shifting, frequency shifting, time reversal, differentiation, convolution theorem, Frequency response analysis of first and second order system, steady state and transient response

Exemplars/Case Studies	
Reference Books	**T1, T2, T3, R1, M1**

Unit No: III	**Discrete Fourier Transform**	**08 Hours**

Sampling in frequency domain, The Discrete Fourier Transform, Relation with z transform Properties of DFT: Linearity, circular shift, duality, symmetry, Circular Convolution, Linear Convolution using DFT, Effective computation of DFT and FFT, DIT FFT, DIF FFT

Exemplars/Case Studies	
Reference Books	

Unit No: IV	Design of IIR filter	08 Hours
Ideal frequency selective filters, Concept of filtering, specifications of filter, IIR filter design from continuous time filters: Characteristics of Butterworth and impulse invariant techniques, Design examples (Butterworth low pass filter)		
Exemplars/Self Studies		
Reference Books	**T2, T3, R2, M1, M3**	

Unit No: V	Design of FIR Filter and DSP Applications	08 Hours
A) Specifications of properties of commonly used windows, Design Examples using rectangular and hanning windows. Comparison of IIR and FIR Filters **B)** Applications: Measurement of magnitude and phase of voltage, current, power, frequency. Power factor correction, harmonic Analysis and measurement.		
Exemplars/Self Studies		
Reference Books	**T2, T3, R2, M1, M3**	

Learning Resources

1. Text Books

[T1]. Proakis J., Manolakis D., "Digital signal processing", 3rd Edition, Prentice Hall, ISBN 81- 203-0720-8

[T2]. P. Ramesh Babu, "Digital Signal Processing", 4th Edition Scitech Publication

[T3]. Dr. S. D. Apte, "Digital Signal Processing",2nd Edition Wiley India Pvt. Ltd ISBN: 97881-265-2142-5

2. Reference Books

[R1]. Mitra S., "Digital Signal Processing: A Computer Based Approach", Tata McGrawHill, 1998, ISBN 0-07-044705-5

[R2]. A.V. Oppenheim, R. W. Schafer, J. R. Buck, "Discrete Time Signal Processing", 2nd Edition Prentice Hall, ISBN 978-81-317-0492-9

[R3]. Steven W. Smith, "Digital Signal Processing: A Practical Guide for Engineers and Scientists",1st Edition Elsevier, ISBN: 9780750674447

3. Links to online SWAYAM/NPTEL Courses

[M1]. NPTEL Course on Digital Signal Processing and its Applications, IIT Bombay – https://nptel.ac.in/courses/108101174

[M2]. NPTEL Course on Digital Signal Processing, IIT Madras - https://nptel.ac.in/courses/108106151

[M3]. NPTEL Course on Digital Signal Processing, IIT Delhi - https://nptel.ac.in/courses/117102060

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: MDM-371-ELE	**Course Name: Evolutionary Algorithms in Electrical Engineering**	
Teaching Scheme	**Credits**	**Examination Scheme**
Tutorial : 01 Hr	**1**	**TW : 25 Marks**
Practical : 02 Hrs	**1**	**OR : 25 Marks**

Prerequisite: Engineering Mathematics, Basics of Programming (MATLAB / Python), Power Systems / Control Systems (desirable)

Course Objectives:

1. To understand fundamentals of evolutionary and nature-inspired algorithms.
2. To learn working principles of PSO, DE, and modern optimization techniques.
3. To formulate electrical engineering problems as optimization problems.
4. To apply evolutionary algorithms to power systems, power electronics, and electrical machine.
5. To implement algorithms using MATLAB/Python for EE applications.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

1. CO1: Explain principles of evolutionary computation and swarm intelligence
2. CO2: Formulate EE problems as optimization problems
3. CO3: Implement GA, PSO, DE algorithms
4. CO4: Apply evolutionary algorithms to solve EE optimization problems
5. CO5: Analyze and compare performance of different algorithms

Course Contents for Tutorials

Unit No: I	**Optimization Basics**	**3 Hours**

Need for optimization in Electrical Engineering, Mathematical formulation of optimization problems, Single-objective and multi-objective optimization, Constraints handling, Classical vs modern optimization techniques

Unit No: II	**Evolutionary Algorithms Overview**	**3 Hours**

Evolutionary Algorithms: concept & history, Hard computing vs evolutionary computing, Components of evolutionary algorithms, Fitness function design, Constraint handling techniques, Overview of popular algorithms

Unit No: III	**Differential Evolution**	**3 Hours**

Mutation strategies, Crossover schemes, Selection mechanism, DE algorithm, Comparison: GA vs PSO vs DE EE applications

Unit No: IV	**Particle Swarm Optimization**	**3 Hours**

Concept of swarm intelligence, Particle, velocity, position pbest and gbest, PSO algorithm, Parameter selection, Application of PSO

Unit No: V	**Modern Nature-Inspired Algorithms**	**3 Hours**

JAYA Algorithm, Grey Wolf Optimizer (GWO), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC)

List of Tutorials (Any Six)

1. **Introduction to Optimization Problems in Electrical Engineering**
   Identify simple electrical engineering problems that can be solved using optimization techniques.
2. **Comparison of Classical and Evolutionary Algorithms**
   Study the differences between conventional optimization methods and evolutionary algorithms.
3. **Basic Concepts of Evolutionary Algorithms**
   Understand population, chromosome, fitness function, mutation, crossover, and selection using simple examples.
4. **Fitness Function Formulation for Simple EE Problems**
   Write objective/fitness functions for simple problems such as minimizing power loss or tuning controller gains.
5. **Manual Execution of Differential Evolution (DE)**
   Perform mutation, crossover, and selection operations manually for a small sample problem.
6. **Understanding Particle Swarm Optimization (PSO)**
   Calculate particle position and velocity updates for a simple optimization example.
7. **Comparison of GA, PSO, and DE Algorithms**
   Compare the working principles and applications of different evolutionary algorithms.
8. **Study of Nature-Inspired Algorithms**
   Introduction and flowchart study of JAYA, Grey Wolf Optimizer (GWO), Ant Colony Optimization (ACO), and Artificial Bee Colony (ABC) algorithms.

List of Experiments

Perform any eight experiments from the following list:

1. Formulate an electrical engineering problem as an optimization problem
2. Implement DE for a benchmark optimization problem
3. Apply DE to solve Economic Load Dispatch (ELD)
4. Implement PSO on a standard test function
5. Use PSO for PI/PID controller gain tuning
6. Implement JAYA algorithm for a constrained optimization problem
7. Apply ABC to solve an optimization problem
8. Compare PSO, DE, and JAYA for the same EE optimization problem
9. Solve a multi-objective EE problem

Guidelines for Instructors/Students Lab Manual

The student's Lab Journal should contain the following related to every experiment:

- Aim, Problem formulation, Algorithm, Flowchart, MATLAB/Python code, Input parameters, Output results & convergence plot, Result & inference, Viva questions

Learning Resources

1. Text Books

[T1]. Singiresu S. Rao, Nitin Kumar, D. Sumitha, Engineering Optimization: Theory and Practice, 5ed , Wiley
[T2]. Godfrey C. Onwubolu, B. V. Babu ·, New Optimization Techniques in Engineering, 2013, Springer

2. Reference Books

[R1]. S.N. Sivanandam , S.N.Deepa, Principles of Soft Computing, Wiley India Pvt. Ltd., 2nd Edition, 2011.
[R2]. Altaf Q. H. Badar , Evolutionary Optimization Algorithms, 2021, CRC Press

3. Links to online SWAYAM/NPTEL Courses

[M1]. https://nptel.ac.in/courses/112105235
[M2]. https://nptel.ac.in/courses/112103301
[M3]. https://nptel.ac.in/courses/111105039
[M4]. https://nptel.ac.in/courses/106106245
[M5]. https://nptel.ac.in/courses/111104644

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: VSEC-373-ELE	**Course Name: Solar Technology and maintenance**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 2 Hrs	**1**	**TW : 25 Marks**
		OR : 25 Marks

Prerequisite: Basic knowledge of Physics, Electrical Engineering, Basic Electronics, Semiconductor Devices, Energy Conversion, Electrical Measurements, and Renewable Energy concepts.

Course Objectives:

1. To apply safe installation, wiring, testing, and commissioning practices for solar PV systems
2. To analyze the impact of environmental and operational conditions on solar PV system performance.
3. To evaluate maintenance and troubleshooting procedures for solar photovoltaic systems and associated equipment.
4. To develop practical solutions and technical documentation for improving solar energy system efficiency and reliability.
5. To introduce students to modern monitoring, data acquisition, and smart management techniques used in solar photovoltaic systems.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Apply safe installation, wiring, commissioning, and performance measurement techniques for solar PV systems.

CO2. Analyze the effect of irradiance, temperature, shading, and environmental conditions on solar PV performance.

CO3. Evaluate maintenance procedures, inverter health, battery performance, and troubleshooting methods in solar systems.

CO4. Create simple practical solutions or documentation for improving solar system performance via mini projects.

CO5. Demonstrate the use of monitoring and data analysis tools for performance assessment and smart operation of solar PV systems.

List of Practical's

- **Perform 8 experiments, Experiment No 1, 2 and 10 are compulsory. Perform any 2 Experiments from 3 to 5. Perform any 3 Experiments from 6 to 9.**

1. Measurement of solar irradiance using pyrometer/lux meter at different times and tilt angles.
   Real-World Assignment: Survey solar irradiance on the college rooftop and estimate daily energy generation for a 100 W solar panel.
2. Plot I-V and P-V characteristics of solar PV module under varying light & temperature.
   Real-World Assignment: Simulate cloudy/rainy day conditions. Calculate module efficiency and estimate annual energy loss in local area climate.
3. Survey and Comparative Analysis of Solar PV Installation Systems: Grid-Tied, Hybrid, and Off-Grid Configurations.
   Real-World Assignment: Survey 2–3 real solar installations (e.g., college rooftop, nearby home/business, or online/virtual)
4. Series and parallel connection of PV modules, observe mismatch issues.
   Real-World Assignment: Design a small array for 12V/24V system (e.g., for small electrical loads). Calculate total power and suggest suitable protection.

5. Installation and wiring of standalone solar PV system (PV ⇨ Charge controller ⇨ Battery ⇨ Load/Inverter)
   Real-World Assignment: Prepare a complete wiring diagram and BOM for a 1kW standalone system.
6. Preventive maintenance: Cleaning, visual inspection, corrosion/loose connection check.
   Real-World Assignment: Inspect any existing rooftop solar panel instalation. Prepare a 6-month maintenance schedule with cost estimation (dust cleaning, tightening)
7. Grid-Related Maintenance Checks for Grid-Tied Solar PV Systems: Inverter Health, Performance Monitoring, and Fault Diagnosis.
   Real-World Assignment: Survey a real grid-tied installation, Prepare a maintenance schedule: Monthly inverter check, quarterly visual, annual professional inspection.
8. Mounting structure assembly: Rooftop/ground mount, tilt adjustment, stability check
   Real-World Assignment: Design a simple mounting frame for local area wind load conditions. Calculate wind load and suggest material/cost for a 5kW residential installation.
9. IoT-Based Real-Time Solar PV System Monitoring and Performance Dashboard.
   Real-World Assignment: Develop a simple dashboard for real-time monitoring of solar energy generation.
10. Industrial Visit to Solar power plant/ solar installation in local area:
    Real-World Assignment: Prepare a technical report on solar PV system operation, maintenance practices, and safety measures.

Learning Resources

1. Text Books

[T1]. L. Ashok Kumar and K. Mohana Sundaram, Solar PV System: Design, Installation, Operation and Maintenance, PHI Learning Pvt. Ltd., 1st Edition, 2020.C.S. Solanki, Solar Photovoltaics

[T2]. John A. Duffie, William A. Beckman, Nathan Blair, Solar Engineering of Thermal Processes, Photovoltaics and Wind, Wiley, 5th Edition, 2020.

[T3]. D. Yogi Goswami, Frank Kreith, Jan F. Kreider, Principles of Solar Engineering, CRC Press, 3rd Edition, 2000.

[T4]. S. P. Sukhatme and J. K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, McGraw Hill Education, 4th Edition, 2017.

2. Reference Books

[R1]. Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and Engineers Author: Chetan Singh Solanki.

[R2]. Solar PV System: Design, Installation, Operation and Maintenance, Authors: L. Ashok Kumar and K. Mohana Sundaram.

[R3]. Solar Engineering of Thermal Processes, Photovoltaics and Wind (5th Edition) Authors: John A. Duffie, William A. Beckman (updated with Nathan Blair).

[R4]. Principles of Solar Engineering (3rd Edition) Authors: D. Yogi Goswami, Frank Kreith, Jan F. Kreider

3. Links to online SWAYAM/NPTEL Courses

[M1]. Solar Photovoltaics: Fundamentals, Technology and Applications: https://onlinecourses.nptel.ac.in/noc

[M2]. SkillCat or Other Free Solar Training (Installation Focus).
https://www.skillcatapp.com/solarinstallation-training

[M3]. SWAYAM – Solar Energy and Solar PV Systems

[M4]. NPTEL – Power Electronics Applications in Renewable Energy Systems

Savitribai Phule Pune University Third Year of Engineering (2024 Course)		
Course Code: ELC-381-ELE	**Course Name: Internship/On Job Training**	
Teaching Scheme	**Credits**	**Examination Scheme**
Practical : 8 Hrs	**4**	**OR : 50 Marks**

Internships are educational and career development opportunities, providing practical experience in a field or discipline. Internships are far more important as the employers are looking for employees who are properly skilled and have awareness about industry environment, practices and culture. Internship is structured, short-term, supervised training often focused on particular tasks or projects with defined time scales. Core objective is to expose technical students to the industrial environment, which cannot be simulated/experienced in the classroom and hence creating competent professionals in the industry and to understand the social, economic and administrative considerations that influence the working environment of industrial organizations. Engineering internships are intended to provide students with an opportunity to apply theoretical knowledge from academics to the realities of the field work/training.

Course Objectives:

1. To expose students to real-world industry practices.
2. To bridge the gap between academic learning and practical implementation.
3. To develop professional competency, ethics, communication, and teamwork skills.
4. To encourage self-learning and problem-solving abilities.
5. To encourage innovation, entrepreneurship, and research aptitude.

Course Outcomes:

Upon successful completion of this course, the students will be able to:

CO1. Apply theoretical knowledge to solve real-world engineering problems.
CO2. Demonstrate technical competency in tools/technologies used in industry.
CO3. Exhibit professional ethics and teamwork.
CO4. Prepare technical reports and deliver effective presentations on industrial training experience.
CO5. Analyse industrial processes and suggest feasible improvements or innovations.

Guidelines

1. Students should opt for an internship/OJT that would provide them to gain ample field knowledge in the relevant field of engineering such that theoretical knowledge gained in the class can be applied to solve the practical/ field problem.
2. Students must have to opt for technical internship after VI semester and before VII semester, preferably during summer break.
3. **Undergoing a training programme / Course at a particular organization for specified duration is NOT considered as summer internship**
4. However, student can attend such programs mentioned in above to learn new tools for short duration that would help for solving the problem undertaken in the internship
5. Students should take a challenging task, may be a small portion, and apply the knowledge gained to solve it.
6. Internship may involve field visits, industrial maintenance activities, testing, commissioning, performance analysis, data collection, simulation, and experimental work. The data may be analysed later.
7. Internships may be carried out in industries, power plants, substations, manufacturing industries, research organizations, government organizations, PSUs, renewable energy industries, automation industries, electrical consultancy firms, and reputed institutions.
8. Students need to submit Synopsis, Permission letter and offer letter to Internship coordinator before proceeding to internship.

9. Internship completion will be considered only after submission of valid documents at the end of internship like Completion certificate, Report and presentation of work done, feedback from industry etc.
10. Student will appear for term work evaluation where he/she will present the work done before mentor(s) at the end of internship.

Suggested Internship Activities

Students are expected to perform the following activities during internship:

- **Phase I – Orientation and Requirement Study**
  - ⇨ Understanding organization structure
  - ⇨ Study of workflow and operational processes
  - ⇨ Requirement analysis and project allocation
  - ⇨ Understanding tools and technologies used
- **Phase II – Technical Learning and Development**
  - ⇨ Electrical wiring and installation practices
  - ⇨ Testing and commissioning of electrical equipment
  - ⇨ Transformer and motor testing
  - ⇨ Study of protection systems and switchgear
  - ⇨ PLC/SCADA/HMI programming and operation
  - ⇨ Industrial automation practices
  - ⇨ Electrical panel design and maintenance
  - ⇨ Power quality analysis and load studies
  - ⇨ Use of simulation software such as MATLAB, ETAP, PSCAD, AutoCAD Electrical, LabVIEW, or equivalent
  - ⇨ Renewable energy system analysis and monitoring
  - ⇨ Electrical measurements and instrumentation
  - ⇨ Preventive and predictive maintenance activities
  - ⇨ Use of updated version control systems
  - ⇨ Documentation practices
- **Phase III – Project Execution**
  - ⇨ Module development
  - ⇨ Testing and validation
  - ⇨ Performance optimization
  - ⇨ Client interaction (if applicable)
  - ⇨ Team collaboration
- **Phase IV – Documentation and Presentation**
  - ⇨ Preparation of internship report
  - ⇨ Preparation of technical drawings/charts/results
  - ⇨ Preparation of project demonstration
  - ⇨ Presentation of work carried out
  - ⇨ Viva voce and technical discussion

Deliverables

- Internship Joining Report
- Weekly Logbook
- Mid-term Progress Report
- Supervisor Feedback (Initial and Final)
- Internship Completion Certificate
- Final Internship Report
- Presentation/PPT of work carried out

- Attendance Record (if applicable)

Internship Structure

The internship may be carried out in any one of the following domains:

- Power Generation, Transmission and Distribution
- Electrical Machines and Drives
- Industrial Automation and Control Systems
- PLC, SCADA and HMI Systems
- Power Electronics Applications
- Renewable Energy Systems
- Solar and Wind Energy Systems
- Smart Grid and Energy Management Systems
- Electrical Maintenance and Testing
- Electrical Design and Consultancy
- Protection and Switchgear Systems
- Electric Vehicles and Charging Infrastructure
- Industrial Instrumentation
- Embedded Systems and IoT Applications in Electrical Engineering
- Energy Auditing and Energy Conservation
- High Voltage Engineering
- Research and Development
- Entrepreneurship and Startup Projects
- Government/NGO Technical Projects

Nature of Internship

Students shall undergo internship/training in one of the following:

- Registered industries and companies
- Power generation and distribution companies
- Manufacturing industries
- Government organizations and PSUs
- Research institutions and laboratories
- Renewable energy industries
- Automation and electrical consultancy firms
- Recognized industry-academic collaborative projects
- Startups related to Electrical Engineering

Internships may be conducted in offline, online, or hybrid mode, subject to proper approval and verification.

Guidelines for Internship Report Writing

1. **Preliminary Pages**
   - Cover Page
   - Certificate from Organization
   - Certificate from Department
   - Acknowledgement
   - Abstract
   - Table of Contents
2. **Chapter 1 – Organization Profile**
   - Company overview
   - Vision and mission

- Products/services
- Organizational structure

3. **Chapter 2 – Problem Statement and Objectives**
   - Project title
   - Need of project
   - Objectives
   - Scope
4. **Chapter 3 – Technologies and Methodology**
   - Electrical equipment used
   - Software tools used
   - Testing instruments and devices
   - Industrial standards followed
   - Methodology adopted
   - System/block diagrams
   - Circuit diagrams and layouts
5. **Chapter 4 – Work Carried Out**
   - Tasks completed
   - Industrial activities performed
   - Testing and analysis results
   - Performance observations
   - Data collection and interpretation
   - Challenges faced
   - Solutions implemented
   - Photographs/screenshots/results
6. **Chapter 5 – Learning Outcomes**
   - Technical learning
   - Practical exposure gained
   - Industrial safety awareness
   - Professional skills acquired
   - Teamwork and communication skills
   - Future scope and improvements
7. **Chapter 6 – Conclusion**
   - Summary of work
   - Achievements
   - Outcomes attained
   - Suggestions and recommendations
8. **References:**
   - **IEEE format references preferred**
   - **Manuals, datasheets, standards, journals, and websites used**
9. **Additional details (If available)**
   - Appendices
   - Certificates
   - Circuit diagrams
   - Technical drawings
   - Additional photographs/screenshots
   - Code snippets/programs

Internship Evaluation Rubrics

The internship is evaluated for 100 marks using a well-defined rubric aligned with program outcomes. The "Presentation" component (30 marks) serves as the Semester End Examination (SEE), while the remaining 70 marks are assigned as Continuous Evaluation by the faculty/industry mentor.

Evaluation of Industrial Training/Internship (Continuous and SEE)

Institute Marks: 100 (Continuous Evaluation - 70, SEE - 30)

Sr No.	Criteria	Marks	Type	Performance Levels
1	Relevance	10	Continuous	8–10: High; 5–7: Moderate; <5: Poor
2	Justification	10	Continuous	8–10: Strong; 5–7: Basic; <5: Weak
3	Attendance	5	Continuous	5: ≥90%; 4: 80–89%; 3: 70–79%; 2: 60–69%; 1: <60%
4	Engagement	10	Continuous	8–10: Proactive; 5–7: Average; <5: Disengaged
5	Progress	5	Continuous	5: Exceeds; 3–4: Meets; <3: Incomplete
6	Practical	10	Continuous	8–10: Excellent; 5–7: Adequate; <5: Poor
7	Behavior	5	Continuous	5: Professional; 3–4: Acceptable; <3: Unprofessional
8	Feedback	5	Continuous	5: Seeks & applies; 3–4: Limited; <3: Resistant
9	Clarity	5	Continuous	5: Excellent; 3–4: Understandable; <3: Unclear
10	Growth	5	Continuous	5: Significant; 3–4: Moderate; <3: No growth
11	Presentation (SEE)	30	SEE	25–30: Excellent; 18–24: Good; 12–17: Satisfactory; <12: Poor
	Total	**100**		

Learning Resources

1. Reference Books

[R1]. W. J. King and James G. Skakoon , The Unwritten Laws of Engineering, ASME Press

[R2]. Stuart Walesh, Engineering Your Future: The Professional Practice of Engineering

[R3]. Eliyahu M. Goldratt, The Goal: A Process of Ongoing Improvement

[R4]. AICTE Internship policy: AICTE Internship Policy: Guidelines & Procedures

[R5]. AICTE Internship Portal: https://internship.aicte-india.org

2. Online resources

[M1]. NPTEL Courses on Power Systems

[M2]. NPTEL Courses on Industrial Automation

[M3]. NPTEL Courses on Renewable Energy Systems

[M4]. SWAYAM Courses on Electrical Engineering Applications

[M5]. MATLAB and ETAP tutorials

[M6]. PLC and SCADA training modules

Savitribai Phule Pune University, Pune

Maharashtra, India

Task Force for Curriculum Design and Development

Overall Coordination and Compilation

Dr. A. N. Sarwade, Member, Board of Studies- Electrical Engineering

Core Committee members

Dr. S. A. Deokar	BOS Chairman (Electrical Engineering)
Dr. B. E. Kushare	Former BOS chairman (Electrical Engineering)
Dr. M. G. Unde	Former BOS chairman (Electrical Engineering)

Team Members for Course Design

Electrical Machines-II	
Dr. M. G. Unde	Former BOS chairman (Electrical Engineering)
Prof. U. B. Sarode	PVGCOET, Technology and Management, Pune
Prof. S. M. Chaudhari	AISSMS College of Engineering, Pune
Prof. S. V. Chakor	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Prof. G. G. Gadhave	Sharadchandra Pawar College of Engineering and Tech, Someshwarnagar

Power Electronics	
Dr. D. M. Sonje	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Prof. Reddy M. V.	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Dr. M. H. Nerkar	Dr. Vithalrao Vikhe Patil College of Engineering, Ahilyanagar
Prof. P. R. Khatri	PVGCOET, Technology and Management, Pune
Dr. H. R. Kulkarni	K.V.N. Naik Institute of Engineering Education & Research, Nasik

Electrical Installation Design & Condition Based Maintenance	
Dr. M. G. Unde	TSSM'S Bhivarabai College of Engineering & Research, Narhe
Dr. V. S. Bugade	Marathwada Mitra Mandal's College of Engineering, Pune
Prof. Rahul Nikam	MET Institute of Engineering, Nasik
Dr. Mrs. K. D. Vidhate	Dr. Vithalrao Vikhe Patil College of Engineering, Ahilyanagar
Dr. L.S. Godse	AISSMS College of Engineering, Pune

Microcontroller and Embedded System	
Dr. D. P. Kadam	MET Institute of Engineering, Nasik
Dr. Swati Thete	Jawahar Education Society's Institute of Tech, Mgmt, & Research, Nashik
Dr. R. S. Tidke	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Prof. R. A. Ranjekar	PVGCOET, Technology and Management, Pune
Prof. S. P. Koparkar	R. H. Sapat College of Engineering, Management Studies & Research, Nasik

Renewable Energy systems	
Dr. M. S. Thakare	PVGCOET, Technology and Management, Pune
Prof. Somnath Hadpe	Matoshri College of Engineering & Research centre Nasik
Prof. H. B. Wagh	R. H. Sapat College of Engineering, Management Studies & Research, Nasik

Computer aided design of Electric Machines	
Dr. M. G. Unde	TSSM'S Bhivarabai College of Engineering & Research, Narhe
Dr. H. S. Avchat	HSBPVT's, GOI facutly of Engineering, Kashti
Dr. Bhawalkar M P	PVGCOET, Technology and Management, Pune
Prof. Neelam Jadhav	SVPM College of Engineering, Malegaon

AI Applications in Electrical Engineering	
Dr. S. A. Deokar	Sharadchandra Pawar College of Engineering and Tech, Someshwarnagar
Dr. Rahul Agrawal	Guru Govind Singh College of Engineering and research, Nasik
Dr. Kazi K. N.	S B Patil college of Engineering, Indapur
Dr. Sanjay Kanade	TSSM'S Bhivarabai College of Engineering & Research, Narhe

Open Elective	
Dr. A. N. Sarwade	Sinhgad College of Engineering, Pune
Prof. S. S. Patil	NBN School of Engineering, Pune

Technical Seminar	
Dr. N. R. Kulkarni	Modern College of Engineering, Pune
Prof. Chinmay Deshpande	Zeal College of Engineering and Research, Pune

Power System Engineering-II	
Prof Ponkshe V. S.	AISSMS College of Engineering, Pune
Prof. O. S. Pawaskar	PVGCOET, Technology and Management, Pune
Dr. S. G. Khadilkar	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Prof. T.P. Pandhi	MET Institute of Engineering, Nasik
Dr. Swati Thete	Jawahar Education Society's Institute of Tech, Mgmt, & Research, Nashik

Control System Engineering	
Dr. A. R. Laware	Dr. Vithalrao Vikhe Patil College of Engineering, Ahilyanagar
Dr. D. M. Sonje	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Dr. Apte A. A.	AISSMS College of Engineering, Pune
Dr. R. S. Tidke	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Dr. T. T. Waghmare	Government college of Engineering, Avsari

Electric Vehicles-I	
Dr. M. S. Thakare	PVGCOET, Technology and Management, Pune
Prof. Reddy M. V.	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Dr. Utkarsha Mohite	MET Institute of Engineering, Nasik
Prof. S. H. Yamalla	PVGCOET, Technology and Management, Pune
Dr. T. T. Waghmare	Government college of Engineering, Avsari

PLC and Scada	
Dr. S. N. Chaphekar	Modern College of Engineering, Pune
Prof. Swaraj Kadam	DY Patil college of Engineering, Pimpari
Dr. Shilpa Joshi	Modern College of Engineering, Pune
Dr. U. S. Thakar	PVGCOET, Technology and Management, Pune
Prof. Chaitanya Deshpande	Zeal College of Engineering and Research, Pune

Energy Storage & Grid Interconnected Renewable Energy Systems	
Dr. S. A. Deokar	Sharadchandra Pawar College of Engineering and Tech, Someshwarnagar
Dr. Archana Thosar	College of Engineering, Pune
Dr. A. R. Laware	Dr. Vithalrao Vikhe Patil College of Engineering, Ahilyanagar
Dr. S. N. Chaphekar	Modern College of Engineering, Pune

Illumination Engineering	
Prof. S. M. Chaudhari	AISSMS College of Engineering, Pune
Prof. Kavita Shrivastava	ALARD College of Engineering and Management, Pune
Dr. Sanjay Kanade	TSSM'S Bhivarabai College of Engineering & Research, Narhe

Energy Management	

Dr. Bhawalkar M P	PVGCOET, Technology and Management, Pune
Prof. Somnath Hadpe	Matoshri College of Engineering & Research centre Nasik
Dr. R. S. Tidke	R. H. Sapat College of Engineering, Management Studies & Research, Nasik
Dr. H. R. Kulkarni	K.V.N. Naik Institute of Engineering Education & Research, Nasik
Digital Signal Processing	
Prof. R. A. Ranjekar	PVGCOET, Technology and Management, Pune
Prof. Ekta Mishra	ASM's Nextgen Technical Campus, Talegaon Dabhade
Prof. S. B. Joshi	Modern College of Engineering, Pune
Evolutionary Algorithms in Electrical Engineering	
Dr. A. A. Kalage	Sinhgad Institute of Technology, Lonavala
Dr. Rahul Agrawal	Guru Govind Singh College of Engineering and research, Nasik
Dr. Datey S. D.	Sinhgad Institute of Technology, Lonavala
Dr. S.L. Mhetre	Sinhgad Institute of Technology, Lonavala
Solar Technology and maintenance	
Dr. M. S. Thakare	PVGCOET, Technology and Management, Pune
Dr. V. S. Bugade	Marathwada Mitra Mandal's College of Engineering, Pune
Prof. A. P. Kinge	TSSM'S Bhivarabai College of Engineering & Research, Narhe
Prof. S.K. Awaze	Dr. Vithalrao Vikhe Patil College of Engineering, Ahilyanagar
Prof. Ekta Mishra	ASM's Nextgen Technical Campus, Talegaon Dabhade
Internship/OJT	
Dr. S. N. Chaphekar	Modern College of Engineering, Pune
Dr. A. R. Laware	Dr. Vithalrao Vikhe Patil College of Engineering, Ahilyanagar

Chairman

Dr. Sanjay. A. Deokar
Board of Studies, Electrical Engineering
Savitribai Phule Pune University, Pune

Dean

Dr. Raosaheb Latpate
Science and Technology
Savitribai Phule Pune University, Pune

***