# SEMESTER S4

# POWER ELECTRONICS AND DRIVES LAB

| Course Code | PCEEL408 | CIE Marks | 50 |
|---|---|---|---|
| Teaching Hours/Week (L: T:P: R) | 0:0:3:0 | ESE Marks | 50 |
| Credits | 2 | Exam Hours | 2 Hrs. 30 Min. |
| Prerequisites (if any) | PCEET403 | Course Type | Lab |

**Course Objectives:**

1. To motivate students to design and implement power electronic converters having high efficiency, small size, high reliability and low cost
2. To enable the students to select suitable power devices and passive components
3. To compare simulation results and hardware results and do iterative design

| Expt. No. | Experiments |
|---|---|
| | ***Suggestions:*** *Students are encouraged to do the simulations associated with the experiments before the corresponding lab session so that more emphasis can be given to the hardware part in the lab (Simulations can be done off-lab) and the simulation results need to be correlated with the hardware results. For experiments where the effects of device parasitics cannot be neglected and circuit-level simulations are needed, SPICE based simulation software such as LTSpice$^{TM}$, OrCAD$^{TM}$, PSpice$^{TM}$, Proteus$^{TM}$ etc. may be used. In other cases, software like MATLAB Simulink$^{TM}$, SciLab$^{TM}$, SEQUEL$^{TM}$, PSIM$^{TM}$,* <br> *PLECS$^{TM}$ etc. may be used if required.* |
| | **Preliminary work-1** ***(Mandatory)*** <br> (a) Testing and Troubleshooting- Power diodes, SCR, Power Transistors, MOSFETS, IGBTS, OP-Amps, MOSFET drivers etc – Use of Multimeter, DSO, and Data sheets <br> (b) Simulation of any Power Electronic circuit using a SPICE based software such as LTSpice, ORCAD, PSpice, and Proteus |

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| | **Preliminary work -2** ***(Mandatory)***<br>(a) PCB routing using any standard PCB layout software such as ORCAD, Proteus, KiCAD, Altium, Eagle etc. ensuring good PCB routing practices<br>(b) Soldering and desoldering Practice – Through-Hole/SMD (It is recommended to select any one of the experiments for the PCB practice) |
| 1 | **Static VI characteristics of Power Devices**<br>**Aim:** To simulate the static VI characteristics of (a) Power Diode (b) SCR (b) MOSFET (c) IGBT using any suitable simulation software and compare with datasheet values |
| 2 | **High frequency diode - Measurement of power loss and reverse recovery time Aim:** To measure the power losses & reverse recovery time of a high frequency diode, compare with theoretical estimate and to compare with a schottky diode of similar ratings (Hardware/Simulation). |
| 3 | **Single-Phase half-wave-controlled rectifier feeding R/RL load**<br>**Aim:** To simulate and set up a half-wave-controlled rectifier with line synchronized R and RC firing circuits and plot relevant waveforms such as voltage waveform across the load and thyristor, gate voltage and gate current for different firing angles. The need for line synchronization to be emphasized. (Any suitable simulation software may be used for the simulation) |
| 4 | **Single-Phase half-controlled(semi-converter)/fully-controlled rectifier feeding R/RL loads**<br>**Aim:** To simulate and set up any type of line synchronized Triggering circuit such as UJT firing, Ramp firing, Digital firing etc. for single-phase half-controlled/full controlled rectifier feeding R and RL loads and observe relevant waveforms. The need for line synchronization to be emphasized (Any suitable simulation software may be used for the simulation). |
| 5 | **Effect of source inductance in single-phase controlled rectifier feeding highly inductive loads**<br>**Aim:** To set up a single-phase full controlled rectifier with source inductance, for highly inductive loads, observe relevant waveforms and calculate the source power factor, line current THD and the average voltage lost due to the effect of source inductance (Simulation may be used to get more insights). |
| 6 | **Single-Phase half-controlled/fully-controlled Rectifier fed PMDC/Separately excited DC motor drive**<br>**Aim:** To simulate and set up a single-phase half-controlled/full controlled rectifier feeding a PMDC/SEDC motor (additional inductor may be included in the armature circuit to get continuous conduction) and observe relevant waveforms (Any suitable simulation |

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| | software may be used for the simulation) |
| 7 | **AC Voltage controller feeding R/RL loads**<br>**Aim:** To set up a single-phase AC voltage controller using TRIAC/SCR and to observe relevant waveforms such as voltage waveforms across the load (R/RL Load) & TRIAC/SCR, gate voltage, gate current etc. for different firing angles (Simulation may be used to get more insights). |
| 8 | **Isolated Gate Driver Circuit for Single-phase half-Bridge IGBT/MOSFET Inverter**<br>**Aim:** (a) To identify the gate current and voltage requirement to drive the MOSFET/IGBT in a half-bridge configuration for a certain switching frequency with galvanic isolation, to select suitable industry-standard IGBT/MOSFET driver ICs and to test the driver circuit both for floating and ground-referenced configurations, and to observe relevant waveforms<br>(b) To simulate and set up a circuit for dead-time generation for use with the half- bridge inverter |
| 9 | **Gate drive using Bootstrap technique**<br>**Aim:** To identify the gate current and voltage requirement to drive the MOSFET/IGBT with boot-strap technique for a certain switching frequency, understand the merits & pertinent limitations of the bootstrapping circuit and to explore dead-time and shutdown/over current protection options |
| 10 | **Single-phase half-bridge/full-bridge IGBT/MOSFET inverter feeding RL load**<br>**Aim:** To simulate and set up a single-phase half-bridge inverter with L/LC filter for square wave and sine-triangle PWM, observe relevant waveforms and obtain THD<br>(Any suitable simulation software may be used for the simulation) |
| 11 | **Inductor design and Fabrication**<br>**Aim:** To design and fabricate an inductor to be used in a high frequency switching application and measure the inductance value using time constant measurement/LCR meter<br>**Note:** The inductor may be designed taking into account the requirement in expt #12 |
| 12 | **Design and set-up a buck/ boost /buck-boost converter**<br>***(Mandatory Experiment)***<br>**Aim:** (a) Design, simulate and set up a buck/boost/buck-boost converter (continuous conduction mode) and observe relevant waveforms (b) Compare the measured quantities such as capacitor voltage ripple and inductor current ripple with the designed values (c) Calculate power loss in power devices and select heat sink (and snubbers) needed if any (d) Overall efficiency computation and measurement of temperature of the heatsink and passive components (e) Explore performance improvement opportunities |

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| | (Any suitable simulation software may be used for the simulation) |
| 13 | **Speed control of Permanent Magnet/Separately-Excited DC motor using chopper drive**<br>**Aim:** To simulate and set up a One-quadrant/Two-quadrant DC chopper to control the speed of a PMDC/SEDC motor for operation in continuous conduction and observe relevant waveforms (Any suitable simulation software may be used for the simulation) |
| 14 | **Three-phase IGBT/MOSFET inverter feeding RL Load**<br>**Aim:** To simulate and set up (Demo is sufficient) a three-phase inverter for (a) sine-triangle PWM (b) third-harmonic (or triple-n harmonic) injection PWM and observe relevant waveforms & THD. Influence of various parameters such as switching frequency, amplitude & frequency modulation indices, dead-time etc. on the performance may be studied (Any suitable simulation software may be used for the simulation). |
| 15 | **Stator Voltage control of Three-Phase Induction Motor**<br>**Aim:** To set up (Demo is sufficient) a three-phase induction motor drive using stator voltage control and observe relevant waveforms & THD (Simulation may be used to get more insights). |
| 16 | **Single phase unidirectional/bidirectional interface – boost PWM rectifier Aim:**<br>To set up (Demo is sufficient) a single-phase PWM rectifier with near unity power, observe relevant waveforms and obtain the line current THD/PF (Simulation may be used to get more insights). |
| 17 | **V/F control of Three-Phase Induction Motor**<br>**Aim:** To simulate and set up (Demo is sufficient) a three-phase induction motor drive using V/F control and observe relevant waveforms & THD for different speeds of operation (Any suitable simulation software may be used for the simulation). |

## Course Assessment Method

## (CIE: 50 marks, ESE: 50 marks)

**Continuous Internal Evaluation Marks (CIE):**

| Attendance | Preparation/Pre-Lab Work experiments, Viva and Timely completion of Lab Reports / Record (Continuous Assessment) | Internal Examination | Total |
|---|---|---|---|
| 5 | 25 | 20 | 50 |

**End Semester Examination Marks (ESE):**

| Procedure/ Preparatory work/Design/ Algorithm | Conduct of experiment/ Execution of work/ troubleshooting/ Programming | Result with valid inference/ Quality of Output | Viva voce | Record | Total |
|---|---|---|---|---|---|
| 10 | 15 | 10 | 10 | 5 | 50 |

- ***Submission of Record: Students shall be allowed for the end semester examination only upon submitting the duly certified record.***
- ***Endorsement by External Examiner:*** *The external examiner shall endorse the record*

## Course Outcomes (COs)

At the end of the course students should be able to:

| Course Outcome | | Bloom's Knowledge Level (KL) |
|---|---|---|
| **CO1** | Understand the operation of modern power semiconductor devices, its characteristics and Design & Select suitable gate driver circuits & heatsinks | **K5** |
| **CO2** | Understand the features of phase-controlled rectifiers, AC voltage Controllers & Switching Regulators and Analyse the operation | **K4** |
| **CO3** | Understand the features of different types of switch mode DC-AC Inverters and Analyse the operation | **K3** |
| **CO4** | Understand the need for improved efficiency, improved reliability, improved load & source waveforms and improved utility interface | **K3** |
| **CO5** | Understand the features of adjustable speed drives and Analyse the basic drive schemes for DC motors and Induction Motors | **K4** |

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

## CO- PO Mapping (Mapping of Course Outcomes with Program Outcomes)

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | | | | | | | | | |
| **CO2** | 3 | 1 | 3 | | | | | | | | | |
| **CO3** | 3 | 1 | 3 | | | | | | | | | |
| **CO4** | 3 | 1 | 3 | | | | | | | | | |
| **CO5** | 3 | 1 | 3 | | | | | | | | | |

*1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

| Text Books | | | | |
|---|---|---|---|---|
| **Sl. No** | **Title of the Book** | **Name of the Author/s** | **Name of the Publisher** | **Edition and Year** |
| 1 | Power Electronics- Essentials and Applications | L. Umanand | John Wiley | 2009 |
| 2 | Power Electronic Systems- Theory and Design | Jai P Agrawal | Pearson | 2006 |
| 3 | Power Electronics- Converters, Applications and Design, 3e (Indian Adaptation) | Ned Mohan, Undeland, Robbins | Wiley India | 2022 |
| 4 | Power electronics: principles and applications | Joseph Vithayathil | Tata McGraw Hill | 2010 |
| 5 | Power Electronics | D.W. Hart | McGraw Hill | 2010 |

| Reference Books | | | | |
|---|---|---|---|---|
| **Sl. No** | **Title of the Book** | **Name of the Author/s** | **Name of the Publisher** | **Edition and Year** |
| 1 | Elements of Power Electronics | Philip T Krein | Oxford | 2017 |
| 2 | Power Electronics- Devices, Circuits and Applications | Muhammad H. Rashid, | Pearson | 2014 |
| 3 | Power Electronics | Cyril W Lander | McGrawHill | 1993 |
| 4 | Power Electronics- A first course: Simulations and Laboratory Implementations | Ned Mohan, Siddharth Raju | Wiley | 2023 |
| 5 | Power Electronics Step by Step- Design, Modeling, Simulation and Control | Weidong Xiao | McGrawHill | 2021 |

| Video Links (NPTEL, SWAYAM…) | |
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| **Module No.** | **Link ID** |
| 1 | Lecture Series on Power Electronics **by Prof. G. Bhuvaneswari**, IIT Delhi https://www.youtube.com/watch?v=Z2CORFayCv0&list=PLp6ek2hDcoND7i5-DAD9mPmYF1Wg6ROdO&index=3 |
| 2 | NPTEL Lecture Series on Power Electronics by **Prof. L. Umanand**, IISc Bangalore https://www.youtube.com/watch?v=eLIdqiPMjBs&list=PLgMDNELGJ1CaXa4sX6QSrkhu-yP_Wu2EN&index=26 |
| 3 | NPTEL Lecture Series by **Prof. Shabari Nath**, IIT Guwahati https://www.youtube.com/watch?v=S_UXW2UzAi8&list=PLwdnzlV3ogoWVgA9fHBV36L_bxWZlpa7X&index=7 |

## Continuous Assessment (25 Marks)

### 1. Preparation and Pre-Lab Work (7 Marks)

- Pre-Lab Assignments: Assessment of pre-lab assignments or quizzes that test understanding of the upcoming experiment.
- Understanding of Theory: Evaluation based on students' preparation and understanding of the theoretical background related to the experiments.

### 2. Conduct of Experiments (7 Marks)

- Procedure and Execution: Adherence to correct procedures, accurate execution of experiments, and following safety protocols.
- Skill Proficiency: Proficiency in handling equipment, accuracy in observations, and troubleshooting skills during the experiments.
- Teamwork: Collaboration and participation in group experiments.

### 3. Lab Reports and Record Keeping (6 Marks)

- Quality of Reports: Clarity, completeness and accuracy of lab reports. Proper documentation of experiments, data analysis and conclusions.
- Timely Submission: Adhering to deadlines for submitting lab reports/rough record and maintaining a well-organized fair record.

4. **Viva Voce (5 Marks)**

- Oral Examination: Ability to explain the experiment, results and underlying principles during a viva voce session.

***Final Marks Averaging: The final marks for preparation, conduct of experiments, viva, and record are the average of all the specified experiments in the syllabus.***

## Evaluation Pattern for End Semester Examination (50 Marks)

1. **Procedure/Preliminary Work/Design/Algorithm (10 Marks)**
   - Procedure Understanding and Description: Clarity in explaining the procedure and understanding each step involved.
   - Preliminary Work and Planning: Thoroughness in planning and organizing materials/equipment.
   - Algorithm Development: Correctness and efficiency of the algorithm related to the experiment.
   - Creativity and logic in algorithm or experimental design.

2. **Conduct of Experiment/Execution of Work/Programming (15 Marks)**
   - Setup and Execution: Proper setup and accurate execution of the experiment or programming task.

3. **Result with Valid Inference/Quality of Output (10 Marks)**
   - Accuracy of Results: Precision and correctness of the obtained results.
   - Analysis and Interpretation: Validity of inferences drawn from the experiment or quality of program output.

4. **Viva Voce (10 Marks)**
   - Ability to explain the experiment, procedure results and answer related questions
   - Proficiency in answering questions related to theoretical and practical aspects of the subject.

5. **Record (5 Marks)**
   - Completeness, clarity, and accuracy of the lab record submitted