## SEMESTER S4

## POWER ELECTRONICS AND DRIVES

| Course Code | PCEET403 | CIE Marks | 40 |
|---|---|---|---|
| Teaching Hours/Week (L: T:P: R) | 3:1:0:0 | ESE Marks | 60 |
| Credits | 4 | Exam Hours | 2 Hrs. 30 Min. |
| Prerequisites (if any) | PCEET303, PCEET304 | Course Type | Theory |

**Course Objectives:**

1. To give a strong foundation on power converters, power quality and electric drives
2. To enable the students to select suitable power devices and passive components for target applications
3. To motivate students to design and implement power electronic converters having high efficiency, small size, high reliability and low cost

## SYLLABUS

| Module No. | Syllabus Description | Contact Hours |
|---|---|---|
| 1 | Role of Power Electronics, Motivation, Objectives and Challenges, Power Electronics Vs Linear Electronics, Ideal and real switches- Static and dynamic Performance – Power losses- Temperature rise- Thermal Analogy- Use of Heat sinks- Need for high efficiency, small size, high reliability and low cost- Overview of Applications<br>Uncontrolled Switch: Power Diodes – Types- Characteristics (Static and Dynamic) –Effects of Reverse Recovery Transient- Ratings-Schottky Diodes – Features & Applications<br>Semi-controlled switch: SCR (Thyristor) – Symbol, Structure, Characteristics (Static and dynamic) – Turn-on and Turn-off phenomena – Ratings- Gate control of SCR – Gate pulse magnitude and duration requirements- Typical gate drive circuits – Gate synchronisation – Isolated gate drives | 11 |

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| | Fully-controlled switches: MOSFETS and IGBTs: Symbol, Structure, Characteristics (Static and Dynamic) -Device ratings -Gate drive requirements–Typical gate drive circuits<br>Modern power devices: Introduction to Wide Bandgap Devices – SiC MOSFET and GaN HEMT – Features and advantages<br>**Suggestions:** Reading and interpreting datasheets are to be encouraged [To be tested through assignments] –Possibility of simulation assignments/homework may be explored- Design of MOSFET/IGBT gate drives – need/requirement of isolation in certain circuits- Use of pulse transformers/opto-isolators – sample circuits [Design assignments may be given using popular driver ICs for MOSFETs/SCRs – not to be tested in ESE] | |
| **2** | Controlled Rectifiers (Single Phase) – Fully controlled and half-controlled rectifiers (semi-converter)with RL and RLE loads- Rectifier and inverter modes of operation- waveforms (continuous & discontinuous conduction)– Output voltage, Input line current, Real Power, Power factor and THD(Continuous conduction, ripple free current)- Effect of source inductance(Full converter in continuous conduction, ripple free current)<br>Controlled Rectifiers (3-Phase) - Fully controlled & Half-controlled bridge converter with RLE load (continuous conduction, ripple free current)– Waveforms- Output voltage equation<br>AC voltage controllers (ACVC) – 1-phase full-wave ACVC with R & RL loads – waveforms – RMS output voltage - applications<br>DC-DC Switching Regulators- Buck, Boost & Buck-Boost– Operation with Continuous conduction Waveforms– Effect of non-idealities such as capacitor ESR and inductor resistance (qualitative treatment only)- Design of filter inductance and capacitance- Selection of power devices | **12** |
| **3** | Switch mode DC-AC Voltage Source Inverters (VSI)- Single phase Half-Bridge and Full-Bridge configurations- Sinusoidal Pulse Width Modulation (PWM) - Control of Fundamental output voltage- Harmonic spectrum- Bipolar and Unipolar PWM- Linear, Over Modulation and Square wave modes -Merits and demerits- Need for blanking time (dead-time)<br>Three-Phase Pulse Width Modulated VSI - Fundamental Output voltage- Linear, Over Modulation and Square wave modes – Third harmonic Injection PWM<br>Single phase current regulated VSI –Tolerance band current control- Fixed | **11** |

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|---|---|---|
| | frequency operation - Single phase current source Inverters (IGBT based)- Comparison<br>Need for improved utility interface- Generation of current harmonics- Power factor- Harmonics and IEEE 519 standard- Active shaping of the input line current- Single-phase front end boost converter(circuit diagram, operation, block diagram of the control scheme) | |
| **4** | Introduction to Electric Drives– Advantages of adjustable speed electric drives –Block diagram, Types of loads – Classification of load torque- Motor torque-load combination: characteristics and dynamic equation- Steady state stability<br>DC Drives- Chopper control of Separately Excited DC drives (SEDC) –One quadrant, Two quadrant and four quadrant Chopper fed drives(Continuous conduction only)- Motoring and Regenerative braking – Speed-Torque characteristics – Speed control- Controlled rectifier fed separately excited DC motor drive- Single phase and three phase (Continuous conduction only)- Speed-Torque characteristics- Speed control –Dual converter drives (single phase) - Circulating current Type and Non-circulating current - Static four-quadrant operation with SEDC<br>Three-phase VSI fed induction motor drives: Stator Voltage control - V/F speed control– Speed-Torque characteristics- Speed control – operation below and above base speed – Braking: dynamic and regenerative | **10** |

## Course Assessment Method

## (CIE: 40 marks, ESE: 60 marks)

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

| Attendance | Assignment/ Microproject | Internal Examination-1 (Written) | Internal Examination- 2 (Written ) | Total |
|---|---|---|---|---|
| **5** | **15** | **10** | **10** | **40** |

**End Semester Examination Marks (ESE)**

*In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions*

| Part A | Part B | Total |
|---|---|---|
| • 2 Questions from each module.<br>• Total of 8 Questions, each carrying 3 marks<br><br>**(8x3 =24marks)** | • Each question carries 9 marks.<br>• Two questions will be given from each module, out of which 1 question should be answered.<br>• Each question can have a maximum of 3 sub divisions.<br>**(4x9 = 36 marks)** | **60** |

## 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 select suitable gate driver circuits & heatsinks | **K3** |
| **CO2** | Understand the features of phase-controlled rectifiers, AC voltage Controllers &Switching Regulators and analyse the operation | **K3** |
| **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 | **K2** |
| **CO5** | Understand the features of adjustable speed drives and analyse the Basic drive schemes for DC motors and Induction Motors | **K3** |

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

## CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | | | | | | | | | 2 |
| **CO2** | 3 | 1 | 3 | | | | | | | | | 2 |
| **CO3** | 3 | 1 | 3 | | | | | | | | | 2 |
| **CO4** | 3 | 1 | 3 | | | | | | | | | 2 |
| **CO5** | 3 | 1 | 3 | | | | | | | | | 2 |

Note: *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- Converters, Applications and Design, 3ed(Indian Adaptation) by Mohan, Undeland, Robbins, Wiley India, 2022 | Ned Mohan, Undeland, Robbins | Wiley-India | 2022 |
| 2 | Power Electronics- Principles and Applications | Joseph Vithayathil | Tata McgrawHill | 2010 |
| 3 | Power Electronics | Cyril W Lander | McGrawHill | 1993 |
| 4 | Power Electronics – Circuits, Devices and Applications | Muhammad H. Rashid | Pearson Education | 2014 |
| 5 | Power Electronics | D.W. Hart | McGrawHill | 2010 |
| 6 | Power Electronics – Essentials & Applications | L. Umanand | Wiley-India | 2009 |
| 7 | Fundamentals of Electric Drives | G K Dubey | Narosa | 2001 |

| 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 Handbook-5e | Muhammad H. Rashid | Butterworth | 2024 |

| Video Links (NPTEL, SWAYAM…) | |
|---|---|
| **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.ShabariNath**, IIT Guwahati https://www.youtube.com/watch?v=S_UXW2UzAi8&list=PLwdnzlV3ogoWVgA9fHBV36L_bxWZlpa7X&index=7 |