POWER ELECTRONICS

ENEE 302

Lecture : 3 **Year : III**
Tutorial : 1 **Part : I**
Practical : 3/2

Course Objectives:
The objective of this course is to provide concepts on various power electronic devices and their applications in power circuits. By the end of the course, students will be able to analyze and apply the operation and mathematical principles of different power electronic circuits.

1 Introduction (2 hours)

1.1 Concept of power electronics
1.2 Applications of power electronics
1.3 Advantages and disadvantages of power electronics converters
1.4 Introduction to power electronic system

2 Power Electronic Devices (6 hours)

2.1 Power diode
  2.1.1 Construction and operating characteristics
  2.1.2 Schockley diode equation
  2.1.3 Turn on transient and turn off transient
2.2 Thyristor
  2.2.1 Construction and operating characteristics
  2.2.2 Turn on characteristics
  2.2.3 Turn off process - natural commutation and forced commutation
  2.2.4 di/dt and dv/dt protections
  2.2.5 Thyristor firing circuits-with isolation transformer, pulse train generator, opto-coupler
  2.2.6 Advantages, disadvantages and applications of thyristors power diode
2.3 TRIAC
  2.3.1 Construction and operating characteristics
  2.3.2 Advantages, disadvantages and applications of thyristors
2.4 Gate turn off thyristor (GTO)
  2.4.1 Construction and operating characteristics
  2.4.2 Advantages, disadvantages and applications of GTO
2.5 Bi-polar junction transistor (BJT)
  2.5.1 Construction, operating characteristics and operation as a switch
  2.5.2 Base drive circuits

2.5.3 Advantages, disadvantages and applications of BJT

2.6 Metal oxide semi-conductor field effect transistor (MOSFET)

2.6.1 Construction, operating characteristics and operation as a switch

2.6.2 Advantages, disadvantages and applications of MOSFET

2.7 Insulated gate bipolar transistor (IGBT)

2.7.1 Construction, operating characteristics and operation as a switch

2.7.2 Advantages, disadvantages and applications of IGBT

3 Single Phase AC to DC Converters (10 hours)

3.1 Single phase half wave un-controlled rectifier with resistive load: Operating theory and waveforms, average and RMS values of output voltage, efficiency, ripple factor, Fourier analysis of output voltage

3.2 Single phase half wave un-controlled rectifier with inductive load: Operating theory and waveforms, average and RMS values of output voltage, load current equation

3.3 Single phase half wave rectifier with capacitor filter: Operating theory and waveforms, ripple factor

3.4 Single phase full wave un-controlled rectifier with center tap transformer: Operating theory and waveforms, average and RMS values of output voltage, efficiency, ripple factor, Fourier analysis of output voltage

3.5 Single phase full wave bridge rectifier with resistive load: Operating theory and waveforms, average and RMS values of output voltage.

3.6 Single phase full wave bridge rectifier with inductive load: Operating theory and waveforms, average and RMS values of output voltage, ripple factor, input current harmonics

3.7 Single phase half wave controlled rectifier with resistive load: Operating theory and waveforms, average and RMS values of output voltage, ripple factor, Fourier analysis of output voltage

3.8 Single phase full converter with resistive load: Operating theory and waveforms, average and RMS values of output voltage ripple factor, Fourier analysis of output voltage

3.9 Single phase full converter with highly inductive load: Operating theory and waveforms, average and RMS values of output voltage ripple factor, input current harmonics, Fourier analysis of output voltage and input ac current, input displacement factor, distortion factor, input harmonic factor, total harmonics distortion (THD), input power factor

3.10 Input power factor improvement: Extinction angle control, symmetrical angle control, multiple pulse width control

4 Three Phase AC to DC Converters (6 hours)

4.1 Three phase single way un-controlled rectifier with resistive load: Operating theory and waveforms, average and RMS values of output voltage, ripple factor, Fourier analysis of output voltage

4.2 First three phase un-controlled bridge rectifier with resistive load: Operating theory and waveforms, average and RMS values of output voltage, ripple factor, Fourier analysis of output voltage
4.3 Three phase single way controlled rectifier with resistive load: Operating theory and waveforms, average and RMS values of output voltage, ripple factor, Fourier analysis of output voltage
4.4 Three phase controlled bridge rectifier with resistive load: Operating theory and waveforms, average and RMS values of output voltage, ripple factor
4.5 Three phase full converter: Operating theory and waveforms, average and RMS values of output voltage
4.6 Twelve pulses of operation of three-phase full converter
4.7 Series connection of full converter

5 DC Chopper (6 hours)

5.1 Step down DC chopper with resistive load: Operating theory and waveforms, average and RMS values of output voltage, output power, effective input resistance, constant frequency mode of operation, variable frequency mode of operation
5.2 Step down dc chopper with DC motor load: Operating theory and waveforms, load current equation, average load current
5.3 Step up chopper with resistive load
5.4 Buck-boost converter
5.5 Bi-directional dc to dc converter: Operating principle, step-up and step-down operation, application in electric vehicle
5.6 Chopper classification: Type-A, Type-B, Type-C, Type-D, Type-E

6 Inverters (10 hours)

6.1 Single phase inverter with square wave AC output and resistive load
  6.1.1 Operating theory and waveforms, RMS value and AC motorload
  6.1.2 Fourier analysis of output voltage
6.2 Single phase inverter with square wave AC output and AC motor load
6.3 Three-phase inverter
  6.3.1 Three-phase inverter with 180^0 conduction mode with six-steps square wave output and resistive load
  6.3.2 Three-phase inverter with 120^0 conduction mode with six-steps square wave output and resistive load
  6.3.3 Fourier analysis of 3-phase inverter output voltage, positive, negative and zero sequence series
6.4 Pulse width modulated (PWM) inverter
  6.4.1 Single pulse width modulation
  6.4.2 Multiple pulse width modulation
  6.4.3 Sinusoidal pulse width modulation
6.5 Current source inverter

7 AC Voltage Controller (5 hours)

7.1 Single phase AC voltage controller with resistive load: Operating theory and waveforms, RMS values of output voltage, output power, Fourier analysis of output voltage waveform

7.2 Single phase AC voltage controller with R-L inductive load: Operating theory and waveforms, load current equation RMS values of output voltage and load current

7.3 Single phase AC voltage controller with induction motor load: Operating theory and waveforms, load current equation RMS values of output voltage and load current

7.4 Three phase AC voltage controller with resistive load: Operating theory and waveforms, RMS values

7.5 Cyclo-converter

7.5.1 Single phase step-down cyclo-converter

7.5.2 Three phase to single phase step-down cyclo-converter

7.5.3 Three phase to three phase step-down cyclo-converter

Tutorial (15 hours)

1. Numerical related to Schockley diode equation and turn off transient
2. Numerical related to di/dt and dv/dt protection of thyristor and thyristor firing circuits
3. Numerical related to single phase half wave and full-wave uncontrolled rectifier with resistive load and inductive load
4. Computer programming to calculate Fourier coefficients output voltage waveform of single phase full wave rectifier up to 36^{th} order and re-construction of wave-forms
5. Numerical related to single phase half wave and full-wave controlled rectifier with resistive load and inductive load
6. Numerical related to capacitor filter for single phase un-controlled rectifier
7. Numerical related to extinction angle control, symmetrical angle control, multiple pulse width control
8. Numerical related to three-phase un-controlled and controlled rectifier
9. Numerical related to DC chopper: Step up, step down and Buck-boost
10. Numerical related to single phase inverter with resistive load, ac motor load
11. Computer programming to calculate Fourier coefficients output voltage waveform of single phase inverter up to 36^{th} order and re-construction of wave-forms
12. Numerical related to Pulse Width Modulated Inverters
13. Numerical related to single phase AC voltage controller with resistive and inductive loads
14. Computer programming to calculate Fourier coefficients output voltage waveform of single phase AC voltage controller up to 36^{th} order and re-construction of wave-forms
15. Numerical related to cyclo-converter

Practical **(22.5 hours)**

1. Study of single phase half wave and full wave uncontrolled rectifier circuit and effect of capacitor filter
2. Study of single phase half-wave controlled rectifier and single phase full-wave controlled rectifier circuits
3. Study of three-phase single way un-controlled and controlled rectifier
4. Study of step down DC-DC chopper
5. Study of single phase AC voltage Controller
6. Study of three-phase inverter with resistive load
7. Simulation study of grid-connected 3-phase inverter with hysteresis band current control

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	2	4
2	6	6
3	10	12
4	6	8
5	6	10
6	10	12
7	5	8
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Rashid, M. H. (2017). Power electronics: Devices, circuits, and applications. Pearson India
2. Bimbhra, P. S. (2022). Power electronics. Khanna Publishing House
3. Gupta, B. R., & Singhal, V. (2010). Power electronics. S. K. Kataria & Sons.
4. Mohan, N., Undeland, T. M., & Robbins, W. P. (2017). Power electronics: Converters, applications, and design. John Wiley & Sons.