# GUJARAT TECHNOLOGICAL UNIVERSITY

**POWER ELECTRONICS (24)**
POWER ELECTRONIC CIRCUITS – II
**SUBJECT CODE:** 2162409
B.E. 6th SEMESTER

**Type of Course:** Engineering Science (Power Electronics)

**Prerequisite: 1) 2132404: Principles of Power Electronics**
**2) 2152407: Power Electronic Circuits - I**

**Rationale:** This subject focuses on the study of AC-AC Converters, Basics of Active Front-End Rectifiers, different types of Inverters (DC-AC Converters) and the analysis & basic applications of the same in Electrical Engineering.

**Teaching and Examination Scheme:**

| Teaching Scheme | | | Credits | Examination Marks | | | | | | Total Marks |
|---|---|---|---|---|---|---|---|---|---|---|
| L | T | P | C | Theory Marks | | | Practical Marks | | | |
| | | | | ESE (E) | PA (M) | | PA (V) | | PA (I) | |
| | | | | | PA | ALA | ESE | OEP | | |
| 4 | 0 | 2 | 6 | 70 | 20 | 10 | 20 | 10 | 20 | 150 |

**Content:**

| Sr. No. | Topic With Details | Teaching Hours | % Weigh tage |
|---|---|---|---|
| 1 | **AC-AC Converters:**<br>• Introduction – Classification – Performance Parameters – Applications<br>• AC Voltage Regulators – Principle of On-Off (ICC) Control – Principle of Phase Control – Single Phase Voltage Controllers with R & RL Load – Three Phase Voltage Controllers – Different Configurations | 8 | 10-20 |
| 2 | **Active Front-End (AFE) Rectifiers:**<br>• Review of Controlled Rectifiers – Their Main Drawbacks – AFE Rectifiers: Advantages and Applications | 4 | 5-10 |
| 3 | **DC-AC Converter (Inverter) Basics:**<br>• Introduction – Principle of Operation – Classification – Square Wave & Quasi-Square Wave Inverter – Dead Band & its Importance – Fourier Analysis and % THD – Performance Parameters: THD, $HF_n$, DF & LOH – Applications<br>• High and Low Side Switch Drivers for Inverter | 6 | 10-20 |
| 4 | **Inverter Control Techniques:**<br>• Different Methods of Inverter Control: Internal and External<br>• External Control Techniques – Input Side Control: Variation of DC by Uncontrolled Rectifier & Chopper, Variation of DC by Controlled Rectifier – Output Side Control: Varying Output AC Voltage by Using Transformer & AC Voltage Regulators<br>• Internal Control Techniques: Voltage Mode & Current Mode | 6 | 10-20 |
| 5 | **Pulse Width Modulation of Inverters:**<br>• Modulation Techniques – PWM: Review – Types – Single & Multiple PWM – Sinusoidal PWM – Sine Triangle PWM (Bipolar & Unipolar) – Stepped – Third/Triplen Harmonic Injection – Trapezoidal – Selective Harmonic Elimination | 10 | 20-30 |

| Sr. No. | Topic With Details | Teaching Hours | % Weigh tage |
|---|---|---|---|
| | • SVPWM – Switching States – Space vectors – Dwell Time – Modulation Index – Over-modulation<br>• Single Phase Half Bridge & Full Bridge Inverter on different loads – Three Phase Inverters: 120° and 180° Conduction Mode | | |
| 6 | **Resonant Pulse Inverters:**<br>• Resonant Pulse Inverters – Review of Resonance: Series & Parallel L-C Resonant Circuits – Principle of Operation of Resonant Converters – Classification – Advantages<br>• Series and Parallel Resonant Inverters – Class E Resonant Inverters – ZVS and ZCS Resonant Inverters | 8 | 10-20 |
| 7 | **Thyristor Based Force Commutated Inverters:**<br>• Voltage Source Inverters – Current Source Inverters – Series and Parallel Inverters – Load Commutated Inverters – McMurray Inverters – McMurray Bedford Inverters | 8 | 10-20 |
| 8 | **Multilevel Inverters:**<br>• Introduction – Concept – Classification – Advantages & Disadvantages - Applications<br>• Diode Clamped, Flying Capacitor & Cascaded H-Bridge: Principle of Operation, Features and Five Level Operation | 6 | 10-20 |

**Suggested Specification table with Marks (Theory):**

| **Distribution of Theory Marks (Revised Bloom's Taxonomy)** | | | | |
|---|---|---|---|---|
| **Remembrance R Level** | **Understanding U Level** | **Application A Level** | **Analyse N Level** | **Evaluate E Level** |
| 25% | 30% | 10% | 25% | 10% |

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

**Reference Books:**


1. Power Electronics: Circuits, Devices and Applications, Third edition by M. H. Rashid, PHI
2. Power Electronics by M.D. Singh & K B Khanchandani, TMH
3. High-Power Converters And AC Drives by Bin Wu, IEEE Press Wiley Interscience
4. Power Electronics by Barry Williams, CRC Press
5. Power Electronics Handbook by M H Rashid, Academic Press
6. Power Electronics by Dr. P. S. Bhimbra, Khanna publishers
7. Power Electronics Essentials and Applications by L Umanand, Wiley
8. Power Electronics by M. S. Jamil Asghar, PHI
9. Power Electronics: Converters, Applications and Design by Mohan, Undeland and Robbins, Wiley
10. Power Electronic Circuits by Issa Batarseh, Wiley
11. Integrated Power Electronic Converters and Digital Control by Ali Emadi, CRC Press
12. Power Electronics by Philips T. Krein, Oxford
13. Power Electronics by P C Sen, TMH
14. Principles of Power Electronics by Kassakian, Schlecht & Verghese
15. The Essence of Power Electronics by Ross, Prentice Hall
16. The Power Electronics Handbook by T L Skvarenina, CRC Press
17. Thyristor Engineering by M. S Berde, Khanna Publishers

**Course Outcome:**

After learning this course, the students should be able to:

1. Understand different AC-AC Converters.
2. Understand the basic concept of AFE and its advantages over conventional converters.
3. Understand the working principle of an inverter and its classification.
4. Able to select proper driver circuit for high & low side switches in an inverter.
5. Able to derive the % THD in the output voltage of an inverter using Fourier analysis.
6. Understand different inverter control techniques along with their advantages and drawbacks.
7. Understand and analyse different types of PWM along with its application and importance.
8. Understand the concept and basics of resonance, resonant inverters and multilevel inverters.
9. Understand and analyse different types of DC-AC converters along with their basic applications.

**List of Experiments (Laboratory Work):**

**Objectives:** The laboratory work is aimed at putting the theory learnt in class in practice and to show that the results are matched with theory closely. In this context, following are the core objectives for laboratory work of this subject.

- Study various AC-AC converters and study ICC & Phase Angle control technique.
- Study and design driving circuits for high and low side switches in inverters.
- Study and analyze half wave & full wave inverters in square wave and quasi-square wave operation, its THD analysis.
- Study different PWM techniques.
- To study different Inverters.

Directions for Laboratory work:

- ✓ The list of experiments is given as a sample.
- ✓ Minimum 10 experiments should be carried out.
- ✓ At least one experiment should be selected from each group.
- ✓ Similar laboratory work fulfilling the objectives can also be considered.
- ✓ Each experiment should be simulated before verifying practically.
- ✓ As far as possible, **printed manual should be preferred** so that students can concentrate in laboratory experiments and related study.

The sample list of experiments is given below.

**List of Experiments and Design Based (DP)/Open Ended Problems:**

There are four experiment groups: A, B, C and D. Total 10 experiments from Group A, B & C should be carried out (At least two experiments from each group). Over and above 10 performance experiments, self-study work may be given to students. This includes study of datasheets, protection & driver circuits for power semiconductor switches, practical applications of different power electronics converters, etc.

Group A (AC-AC Converters):

1. To study Integrated Cycle Control technique for AC-AC converter.
2. To study Phase Angle Control technique for AC-AC converter.

Group B (PWM Inverters):

3. To study and analyse square wave operation of inverter.
4. To study and analyse quasi-square wave operation of inverter.
5. To study and analyse Inverter operation with different types of PWM.
6. To study SVPWM for inverters.

Group C (Resonant Inverters):

7. To study the operation of LC resonant circuits.
8. To study Class E resonant inverter for electronic ballast.
9. To study ZVS and ZCS inverters.

Group D (Multilevel Inverters):

10. To study Diode Clamped Multilevel inverter.
11. To study Flying Capacitor Multilevel inverter.
12. To study Cascaded Multilevel inverter.

**Major Equipment:**

- GP PCB Board, Function Generator, AC & DC Power Supply, Oscilloscope, Power Electronics Trainer Kits, Multimeter, Power Supply, Various Kits for Experimental Setup, etc.
- Consumable Items: Various Power Semiconductor Switches, Various Control ICs, Various Ferrite Cores, Copper Wires for Inductors & Transformers, Soldering Iron, Desoldering Pump, Electronics Toolkit, etc.

**List of Open Source Software/learning website:**

Open Source Software:

- TINA-TI for circuit simulation (http://www.ti.com/tool/tina-ti)
- OSCAD for CAD application (http://www.oscad.in/downloads)
- Multisim for circuit simulation (http://www.ni.com/multisim)
- http://sourceforge.net/projects/ktechlab/
- http://www.cburch.com/logisim/

Web-based tools for design:

- www.st.com
- www.nxp.com
- www.irf.com
- www.infineon.com
- www.ti.com
- www.vishay.com
- www.linear.com
- http://india.ni.com
- http://www.cosmoferrites.com
- http://www.tdk.com
- http://en.tdk.eu
- http://www.tdk.com/design-tools.php
- http://www.smps.us/smpsdesign.html
- http://www.poweresim.com
- www.snubberdesign.com
- https://www.circuitlab.com/editor

Open source for Math Tools:

- http://maxima.sourceforge.net
- www.scilab.org
- www.sagemath.org
- www.gnu.org/software/octave/

Learning website:

- http://www.datasheetcatalog.com
- http://nptel.iitm.ac.in/courses.php
- http://ocw.mit.edu
- http://www.smpstech.com

- http://www.ni.com/white-paper/14676/en/
- http://www.irf.com/product/_/N~1nje1m
- http://www.allaboutcircuits.com/vol_3/chpt_3/4.html
- http://www.deltapowersolutions.com/en/tps/rectifiers.php
- http://www.electrical-engineering-portal.com

**ACTIVE LEARNING ASSIGNMENTS**: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.