# GUJARAT TECHNOLOGICAL UNIVERSITY

**Program Name: Bachelor of Engineering**
**Level: UG**
**Branch: Electrical Engineering**
**Subject Code: BE05009061**
**Subject Name: Advanced Power Electronics**

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| w.e.f .Academic Year: | 2024-25 |
| Semester: | 5 |
| Category of the Course: | Professional Elective Course - 1 |

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| **Prerequisite:** | Basic knowledge of Power Electronics, Analog and Digital Electronics |
| **Rationale:** | The syllabus of Advanced Power Electronics is designed to meet the increasing demand for efficient, high-performance power conversion systems used in industrial drives, renewable energy systems, and electric vehicle applications. It provides strong fundamentals in front-end converters to improve power quality, achieve unity power factor, and reduce harmonics in grid-connected systems. The inclusion of isolated and non-isolated DC–DC converter topologies strengthens students' design understanding for applications such as SMPS, battery energy storage, and EV powertrains. Multilevel inverter structures such as Neutral-Point Clamped (NPC) inverter, Flying Capacitor inverter, and Cascaded H-Bridge inverter expose learners to medium- and high-voltage high-power conversion technologies. Furthermore, advanced modulation techniques including Space Vector Pulse Width Modulation and Sinusoidal Pulse Width Modulation equip students with modern digital control strategies for reducing harmonic distortion, optimizing switching losses, and enhancing overall converter performance. |

**Course Outcomes:**

| Sr.No. | COstatement | Marks% weightage |
|---|---|---|
| CO-1 | Analyze and design front-end converters for power quality improvement. | 16 |
| CO-2 | Understand isolated and non-isolated DC DC converter topologies. | 22 |
| CO-3 | Explain multilevel inverter structures and applications | 22 |
| CO-4 | Implement advanced PWM control techniques | 22 |
| CO-5 | Evaluate converter performance for high-power applications | 18 |

**Teaching and Examination Scheme:**

| Teaching / Learning Scheme (in Hours per semester) | | | | | Total Credits | Assessment Pattern and Marks | | | | | Total Marks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Theory | | Tutorial / Practical | | | |
| L | T | P | PBL | Total no of hours per semester | | ESE (E) | PA / CA (M) | PA/CA (I) | PBL (I) | ESE (V) | |
| 45 | 0 | 30 | 15 | 90 | 3 | 70 | 30 | 20 | 30 | 50 | 200 |

**** Problem-Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.***

**Content:**

| Sr. No. | Content | Total Hrs |
|---|---|---|
| 1 | **Front-End Converters**<br>Introduction to front-end converters, classification of FECs, active front-end converters, PWM rectifiers, unity power factor operation, harmonic mitigation techniques, and applications in drives | 7 |
| 2 | **Isolated and Non-Isolated DC–DC Converters**<br>Non-isolated converters: Buck, Boost, Buck Boost converters, Isolated converters: Fly-back, Forward, Push–Pull, Half-Bridge, Full-Bridge converters. Comparison, and applications. | 10 |
| 3 | **Multilevel Inverters**<br>Introduction to multilevel converters, advantages and limitations, diode-clamped (NPC), flying capacitor, and cascaded H bridge inverters. Voltage balancing issues and applications in medium- and high voltage systems. | 10 |
| 4 | **Control Techniques for Multilevel Converters**<br>Control objectives, voltage and current control strategies, capacitor voltage balancing methods, carrier-based PWM techniques, nearest level modulation, and digital control concepts. | 10 |
| 5 | **Advanced PWM Techniques**<br>Sinusoidal PWM (SPWM), Space Vector PWM (SVPWM), Phase-Shifted Carrier PWM (PSC-PWM), Level-Shifted PWM (PD, POD, APOD), comparison based on THD, switching losses, and complexity. | 8 |
| | **TOTAL** | **45** |

**Suggested Specification table with Marks (Theory) : (For B.E.only)**

| Distribution ofTheory Marks | | | | | |
|---|---|---|---|---|---|
| R Level | U Level | A Level | N Level | E Level | C Level |
| **15** | **30** | **15** | **20** | **10** | **10** |

**R: Remembrance;U:Understanding;A:Application,N:AnalyzeandE:EvaluateC:Create and above Levels (Revised Bloom's Taxonomy)**

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

**The syllabus of *Advanced Power Electronics* directly contributes to**

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| **SDG 7** | **Affordable and Clean Energy** |
| **SDG 9** | **Industry, Innovation and Infrastructure** by equipping students with knowledge of efficient power conversion systems, renewable energy integration, and advanced inverter technologies that enhance energy sustainability and support modern industrial applications |
| **SDG 11** | **Sustainable Cities and Communities** |
| **SDG 13** | **Climate Action** through its emphasis on electric vehicle powertrains, harmonic mitigation, and high-performance converters that reduce environmental impact and foster resilient urban energy solutions. |

**Reference Books:**


1. Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Education, New Delhi
2. Ned Mohan, Tore M. Undeland and William P. Robbins, Power Electronics: Converters, Applications and Design, John Wiley & Sons, Inc., New York
3. L Umanand, Power Electronics, Essentials & Applications, Wiley India
4. Fang Lin Luo and Hong Ye, *Power Electronics: Advanced Conversion Technologies*, CRC Press / Taylor & Francis, Boca Raton, FL.
5. Dorin O. Neacsu, *Switching Power Converters: Medium and High Power*, CRC Press / Taylor & Francis, Boca Raton, FL.
6. Sergio A. González, Santiago A. Verne, and María I. Valla, *Multilevel Converters for Industrial Applications*, CRC Press / Taylor & Francis, Boca Raton, FL.
7. B. K. Bose, *Power Electronics and Motor Drives: Advances and Trends*, Academic Press (an imprint of Elsevier), Waltham, MA.
8. Research Papers on IEEE/IET/Science Direct etc


**List of Experiments:**

1. To Design and simulation of three-phase PWM rectifier for unity power factor operation.
2. To perform the harmonic analysis of front-end converters using FFT tool in MATLAB/Simulink.
3. To Study of Push–Pull, Half-Bridge, and Full-Bridge isolated converters.
4. To Simulate of Fly-back converter and transformer design considerations.
5. To Simulate of 3-level diode-clamped (NPC) inverter.
6. To Implementation of carrier-based PWM for multilevel inverter.
7. To study and simulate the CHB multilevel inverter with R-Load using LS-PWM technique
8. To study and compare the different multi-carrier based PWM Technique (PSC-PWM, LS-PWM, etc.)
9. To Study of switching frequency variation impact on inverter performance.
10. To Prepare Minor Project.

**Major Equipment:**

1. Power Electronics Trainer Kits (DC–DC Converter and Inverter Trainer Modules)
2. Three-Phase IGBT/MOSFET Based PWM Inverter Kit
3. Multilevel Inverter Trainer Kit (NPC / Cascaded H-Bridge)
4. Isolated DC–DC Converter Trainer (Flyback / Forward / Push–Pull)
5. Digital Storage Oscilloscope (DSO) – Minimum 100 MHz
6. MATLAB/Simulink Software with Simscape Electrical Toolbox

**List of Open Source Software**

1. Scilab (https://www.scilab.org/) – An open-source alternative to MATLAB
2. PSIM (Free Version) / OpenModelica (https://openmodelica.org/) – For modeling and simulating power electronics circuits

**List of learning website:**

1. MIT Open Course Ware (https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/)
2. Circuit Lab (Free with limited access) (https://www.circuitlab.com/) – Web-based circuit simulator
3. Virtual Labs by IITs (Government of India Initiative) (https://vlab.co.in/) – Simulations and experiments related to Power electronics.
4. Reputed Research Journal Website

**List of suggested activities for Problem-based Learning (PBL):**

| Sr. No. | PBL Category | Name of the activity | No. of hours | Evaluation Criteria |
|---|---|---|---|---|
| 1 | Industry / Research Laboratory Visit | Industry/Research laboratory Visit (Power converters/electronics/drives company) | Visit = 5hrs, Report preparation = 5hrs Total = 10hrs | Based on report submitted. Report should contain observations and calculations based on industry/ lab data. |
| 2 | Video Based Learning | Technical Video based learning related to the subject (MOOC/NPTEL Video) | Duration of video = 5hrs Report preparation = 5hrs Total = 10hrs | Report /presentation based on the video learning outcomes. |
| | | Self-learning on-line course | Minimum duration of the course should be 10hrs. | Examination based assessment at the end of course. Based on the certificate produced. |
| | | Annotated Video Explanation of Concept/Problem | 10hrs (Preparation + Recording + Submission) | Based on accuracy of explanation, clarity, and presentation style. |
| 3 | Assignment/ | Assignment writing. | 5 assignments of | Based on the |

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| | Technical Writing / Research Writing | Numerical based assignment is preferable. | 2hrs each. Total = 10hrs | assignment submitted. |
| | | Blog or Technical Article Writing | 10hrs (Research – 6hrs, Writing – 4hrs) | Based on originality, technical content, references cited, and clarity of communication. |
| 4 | Complex Problem-Solving targeting relevant SDGs. / Mini Project | Complex problem solving | Maximum 2 problem. Study of the problem and solution finding, Total = 10 hrs | Based on the depth of the solution submitted. |
| 5 | Research Paper Review / Analysis | Discussion on research paper based on relevant subject (SCOPUS Index/any reputed Journal) | 5 research paper = 20 hrs | Summarize research paper and evaluation critical parameters |
| 6 | Poster/ Chart/ Power point presentation | Poster/chart/power point preparation on technical topics | Duration = 6 hrs | Based on poster/chart preparation and presentation skills |
| 7 | Micro Project | Working/non-working model on technical topics | Working = 5hrs | Based on inter department/external evaluation |
| 8 | Group Discussion / Quiz / Simulation | Group Discussion on emerging/trending technicaltopics based on subject | Duration = 1 hrs each | Based on performance in group discussion, technical depth,knowledge etc. |
| | | Online Technical Quizzes/Simulations | Multiple quizzes summing up to 10hrs | Based on quiz scores and reflection report after each quiz. |
| 9 | Case Study Analysis / Seminar | Real world case studies-based learning | Duration of data collection/study = 5hrs Report preparation = 5hrs Total = 10hrs | Based on in-depth study, technical depth, data collected, fact finding, etc. |
| 10 | Other | Patent Search and Innovation Gap Identification | 10hrs (Search + Report) | Based on number of relevant patents analyzed and identification of innovation scope. |

**Note:**

1. In alignment with Outcome-Based Education (OBE) and NBA accreditation requirements, the subject Advanced Power Electronics incorporates;
   - Mini Project – 10 Marks
   - Micro Project – 5 Marks

These activities are incorporated as integral Project-Based Learning (PBL) components. These activities are designed to foster experiential learning, encourage innovation, and strengthen problem-solving skills by engaging students in practical applications of power converter design, simulation, and analysis. The inclusion of PBL ensures that learners develop higher-order cognitive abilities mapped to Bloom's taxonomy, while simultaneously enhancing teamwork, communication, and research competencies essential for professional engineering practice.

2. The hours allocated to specific activities should be proportionate to the total no. of PBL hours and marks.

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