GUJARAT TECHNOLOGICAL UNIVERSITY

Master of Engineering in Power Electronics
Subject Code: 3732907

Semester – III
POWER ELECTRONICS
Subject Name: Modulation Techniques for Power Electronic Converters

Type of Course: Engineering

Prerequisite: 3710713 - Power Electronics Converters and Applications
Knowledge of power semiconductor devices and converters at UG level

Rationale: Power electronic devices and converters are widely used in the domestic applications as well as industrial applications like electric drives, power systems, renewable energy-based power generation etc. Novel power converter topologies are being invented every year. The operation mainly depends on the modulation and control strategy used in the same. This course focuses on understanding various modulation techniques and control strategies for inverters and DC-DC converters using PWM for power electronics. It also gives an overview of design, analysis and control of these power electronic converters using PWM.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Content	Total Hours
1	**Introduction to Modulation Techniques:** • Modulation Techniques – Classification – Concept and Requirement w.r.t. Power Electronics – Applications • Pulse Modulation Methods – Types – Analog Over Analog Techniques: PAM, PWM, PPM	3
2	**Pulse Width Modulation:** • PWM Concept – Control and Analysis – Need for PWM – Voltage Control and Current Control PWM Techniques for Inverter • Types – Generation of Basic PWM – Typical Circuit to Generate PWM and its Block Diagram– Reference and Carrier – Modulation Index – Over Modulation	6
3	**Control Techniques for DC-DC Converters:** • Control Strategies for DC-DC Converters – Time Ratio Control (TRC): Constant Frequency Operation (PWM Control) and Variable Frequency Operation (Frequency Modulation Control) – Current Limit Control (CLC) – Analysis – Advantages and Disadvantages – Applications	6

4	**PWM Techniques for DC-AC converters (Inverters):** • Square Wave Modulation of Inverter – Time Domain and Frequency Domain Analysis of 1-Phase VSI – Harmonic Analysis of Voltage Waveform for 1 and 3 Phase Inverter – PWM Modulation • Modulation techniques for Single Phase and Three Phase VSI – Modulation of Current Source Inverters – Nature of Pole Voltage Waveforms Output by PWM Inverters – Harmonic Analysis – Trade Off Between Low Order and High Order Harmonics – Programmed Modulation Strategies • Single PWM, Multiple Pulse PWM, Quasi Square Modulation, End Pulse Modulation, Centre Pulse Modulation – Analysis of Pole Voltage Waveform with DC and Sinusoidal Modulating Signal • Sine PWM – Generation of 1 and 3 SPWM – Unipolar and Bipolar PWM – Their Harmonic Content and its Analysis – Third Harmonic Injection – Selective Harmonic Elimination Technique – Current Controlled PWM (CCPWM) – Trapezoidal PWM – Harmonic Content Analysis and Comparison of Various PWM Schemes	**12**
5	**PWM Techniques for Multi-Level Inverters (MLI):** • Bipolar and Unipolar PWM for Cascaded H-Bridge MLI – Carrier Based PWM Schemes – Phase Shifted Multicarrier Modulation – Level Shifted Multicarrier Modulation – Comparison of Phase Shifted and Level Shifted PWM – Staircase Modulation	**9**
6	**Space Vector Pulse Width Modulation (SVPWM)** • Space Vector Modulation Principle– Switching States – Space Vectors and Sectors – Dwell Time Calculation – Modulation Index – Switching Sequence – Spectrum Analysis – Even-Order Harmonic Elimination – Naturally Sampled SVM – Discontinuous SVPWM • SVPWM – Merits and Demerits – Comparison with Conventional PWM Techniques – Algorithm for Producing Sinusoidal Output Voltages Using SVPWM	**9**

Reference Books:

1. Mohan, Undeland and Robbins, “Power Electronics – Converters, Applications and Design”, John Willey & Sons Inc., 3rd Edition, 2003.
2. Muhammad H. Rashid, “Power Electronics - Circuits, Devices and Applications”, Prentice Hall of India, 3rd Edition, 2003.
3. Bin Wu, “High-Power Converters and AC Drives”, John Wiley & Sons, 2007
4. L. Umanand, “Power Electronics: Essentials & Applications”, Wiley India Pvt. Ltd, 2009
5. D. Grahame Holmes and Thomas A. Lipo, “Pulse Width Modulation for Power Converters: Principles and Practice”, Wiley IEEE Press, 2003.
6. Marian K. Kazimierczuk, “Pulse-Width Modulated DC-DC Power Converters”, John Wiley & Sons Inc, 2nd Edition, 2015.

7. Robert Ericksson and Dragan Maksimovic, "Fundamentals of Power Electronics", Springer (India) Pvt. Ltd., 2nd Edition, 2005.
8. Daniel M. Mitchell, "DC-DC Switching Regulator Analysis", McGraw-Hill, New York, 1988.

Course Outcomes:

After completion of this course, the student shall be able to do the following as specified below:

Sr. No.	CO statement	Marks % weightage
CO-1	Understand different modulation techniques and able to identify the techniques required for Power Electronics applications, Understand PWM and	20
CO-2	Explain the philosophy behind PWM inverters and concept of different PWMs for inverter, design controllers to generate different types of PWMs using relevant/available circuits and controller/processor, compare the quality of output voltage and its harmonic content produced by inverters using different PWM techniques, calculate output voltage magnitude from the inverter operating parameters and compare it using different PWM schemes, decide PWM scheme for a specific application	45
CO-3	Understand various control strategies for DC-DC converters, generate PWM for control of DC-DC converters,	20
CO-4	Explain different PWM schemes for Multi Level Inverters (MLI), compare the magnitude and quality of output voltage using these schemes, explain Space-Vector based PWM (SVPWM) technique	15

List of Open Source Software/learning website:

1) **NPTEL:** https://nptel.ac.in