GUJARAT TECHNOLOGICAL UNIVERSITY

Master of Engineering (Electrical Engineering)
Subject Code: 3720735
Semester – II
Subject Name: PWM for Power Converters

Type of course: Program Elective

Prerequisite: Power Electronics Converters and Applications (3710713)

Rationale: Pulse Width Modulated Converter are being widely used in numerous applications due to its ability to synthesize the fundamental voltage and current with hard switching of the converter. Number of PWM methods have been developed over the years and each having its own significance for the application. The subject aims at developing a generalized analytic approach towards the PWM method. Once the common threads of PWM are identified, the selection of a PWM strategy for any converter topology becomes immediately obvious.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	Overview of PWM Converters Review of power electronic converters for dc-ac and ac-dc power conversion, Purpose of pulse-width modulation, Review of Fourier series, fundamental and harmonic voltages; machine model for harmonic voltages; undesirable effects of harmonic voltages- line current distortion, increased losses, pulsating torque in motor drives; control of fundamental voltage; mitigation of harmonics and their adverse effects	**4**
2	PWM Techniques Pulsewidth modulation (PWM) at low switching frequency: Square wave operation of voltage source inverter, PWM with a few switching angles per quarter cycle, equal voltage contours, selective harmonic elimination, THD optimized PWM, off-line PWM Triangle-comparison based PWM : Average pole voltages, sinusoidal modulation, third harmonic injection, continuous PWM, bus-clamping or discontinuous PWM Space vector based PWM : Space vector concept and transformation, per-phase methods from a space vector perspective, space vector based modulation, conventional space vector PWM, bus-clamping PWM, advanced PWM, triangle comparison approach versus space vector approach to PWM	**10**
3	Performance Analysis Analysis of line current ripple: Synchronously revolving reference frame; error between reference voltage and applied voltage; integral of voltage error; evaluation of line current	

	ripple; hybrid PWM for reduced line current ripple Analysis of dc link current: Relation between line-side currents and dc link current; dc link current and inverter state; rms dc current ripple over a carrier cycle; rms current rating of dc capacitors Analysis of torque ripple: Evaluation of harmonic torques and rms torque ripple, hybrid PWM for reduced torque ripple Analysis for inverter's loss: Simplifying assumptions in evaluation of inverter loss, dependence of inverter loss on line power factor, influence of PWM techniques on switching loss, design of PWM for low inverter loss. Effect of inverter dead-time effect: Requirement of dead-time, effect of dead-time on line voltages, dependence on power factor and modulation method, compensation of dead-time effect.	**14**
4	Overmodulation Per-phase and space vector approaches to over-modulation, average voltages in a synchronously revolving d-q reference frame, low-frequency harmonic distortion	**4**
5	PWM for multilevel inverter Extensions of sine-triangle PWM to multilevel inverters, voltage space vectors, space vector based PWM, analysis of line current ripple and torque ripple	**4**
6	Applications Active power filtering, Reactive power compensation, Constant Volt Per hertz drives, PWM Rectifier etc.	**5**

Reference Books:

1. D. G. Holmes, T. A. Lipo, 'Pulse Width Modulation For Power Converters: Principles and Practice', John Wiley and Sons., 2003.
2. NPTEL Lecture series by Prof. G. Narayanan, Department of Electrical Engineering, IISC Bangalore on the web-course . http://www.digimat.in/nptel/courses/video/108108035/
3. Bin Wu, "High Power Converters and AC Drives", John Willey & sons, Inc., 2006.
4. Euzeli Cipriano dos Santos Jr. and Edison Roberto Cabral Da Silva "Advanced Power Electronics Converters - PWM Converters Processing AC Voltages", Willey – IEEE Press, 2014.
5. Recent Literature

Course Outcomes:

After learning the course the students will be able to:

Sr. No.	CO statement	Marks % weightage
CO-1	Explain the need of PWM	10
CO-2	Compare various PWM techniques on different aspects.	24
CO-3	Analyze parameters like losses, torque ripple, current ripple etc. for	30

	different PWM approaches.	
CO-4	Design the PWM techniques for over-modulation region.	12
CO-5	Develop suitable Pulse Width Modulation method for power converter used for different applications	24

List of Experiments:

Lab experiments shall be based on the course content. A list provided here is to indicate the type of experiments that can be included.

1. Analyze the fundamental and sideband harmonics of output voltage with PWM with different carrier ratio.
2. Compare conventional sine PWM and third harmonic injected PWM.
3. Develop Space Vector PWM method for two-level inverter.
4. Evaluate the effect of zero placement on output of inverter.
5. Analyze operation of three level NPC inverter with various carrier based PWM techniques
6. Simulate the operation of Cascaded H-Bridge MLI for various carrier based PWM techniques
7. Simulate the operation of three level NPC inverter with various SVPWM
8. Model the converter for analysing the losses
9. Study of parameters like torque/current ripple
10. Designing hybrid PWM for minimizing the current ripple

Major Equipment:

Simulation software like MATLAB, PSIM, Scilab and Power Electronic Converters and probes, scope and meters as demanded by the course.

List of Open Source Software/learning website:

1. http://www.digimat.in/nptel/courses/video/108108035/
2. http://nptel.ac.in/courses/108108077/
3. https://www.semikron.com/service-support/semisel-simulation.html